BACHELOR THESIS - ME184841

IMPLEMENTATION OF MAINTENANCE METHOD ON STEAM TURBINE USING RELIABILITY-CENTRED MAINTENANCE (RCM)

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DOUBLE DEGREE PROGRAM
DEPARTMENT OF MARINE ENGINEERING
FACULTY OF MARINE TECHNOLOGY
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TUGAS AKHIR - ME184841

IMPLEMENTASI METODE PERAWATAN PADA TURBIN UAP MENGGUNAKAN RELIABILITY-CENTRED MAINTENANCE (RCM)

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2020

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APPROVAL FORM

IMPLEMENTATION OF MAINTENANCE METHOD ON STEAM TURBINE USING RELIABILITY-CENTERED MAINTENANCE (RCM)

BACHELOR THESIS

Submitted to fulfill one of the requirements to obtain
Bachelor Engineering Degree

on

Digital Marine Operational and Maintenance (DMOM)
Bachelor Program Department of Marine Engineering
Faculty of Marine Technology
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July, 24th 2020

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APPROVAL FORM

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APPROVAL FORM

IMPLEMENTATION OF MAINTENANCE METHOD ON STEAM TURBINE USING RELIABILITY-CENTRED MAINTENANCE (RCM)

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Submitted to fulfill one of the requirements to obtain
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on

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Department	: Marine Engineering

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Surabaya, July 2020

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IMPLEMENTATION OF MAINTENANCE METHOD ON STEAM TURBINE USING RELIABILITY-CENTRED MAINTENANCE (RCM)

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ABSTRACT

Thermal power plant contributes the most electricity generated in Indonesia. As the main source of electricity generator, thermal power plant is needed to be always available due to provide electricity at all time. The unavailability of thermal power plant has so many disadvantages such as financial losses, production losses or unavailability of any important activity that needs electricity. Steam turbine is the most critical component in thermal power plant. Failure on steam turbine will cause the unavailability of thermal power plant. While, the most reason of the unavailability of thermal power plant is caused by a failure on steam turbine. Beside, failure on steam turbine can also cause a catastrophic incident which causes a financial loss, injury, or even death. Therefore, a proper maintenance on steam turbine is necessary to be implemented due to prevent all those consequences. Reliability-Centred Maintenance (RCM) is the best maintenance method to be implemented on the steam turbine because it focuses on keeping its reliability. With a good reliability of steam turbine, an availability of the thermal power plant can be achieved. After analyzing 4 equipment using Reliability-Centred Maintenance (RCM), it is obtained the best maintenance task for those equipment. High Pressure Turbine (MAA) and Intermediate Pressure Turbine (MAB) are recommended to have 30 scheduled on-condition tasks, 19 scheduled restoration tasks, 40 scheduled discard task, and 13 failure finding tasks. For maintenance interval, it is recommended to has 33 daily, 22 weekly, 3 monthly, and 44 annually. Low Pressure Turbine 1 (MAC10) and Low Pressure Turbine 2 (MAC20) are recommended to have 20 scheduled on-condition tasks, 11 scheduled restoration tasks, 14 scheduled discard task, and 13 failure finding tasks. For the maintenance interval, it is recommended to has 23 daily, 14 weekly, 3 monthly, and 18 annually. Those maintenance data then will be summarized into a work package based on the equipment, interval, and executor.

Keyword: Maintenance, Reliability, Reliability-Centred Maintenance (RCM), Steam Turbine

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IMPLEMENTASI METODE PERAWATAN PADA TURBIN UAP MENGGUNAKAN *RELIABILITY-CENTRED MAINTENANCE* (RCM)

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ABSTRAK

Pembangkit listrik tenaga panas merupakan kontributor listrik paling tinggi di Indonesia. Sebagai sumber utama penghasil listrik, pembangkit listrik tenaga panas harus selalu dapat bekerja dengan baik setiap saat. Kegagalan pada pembangkit listrik tenaga uap dapat menyebabkan banyak kerugian dalam hal finansial, produksi, atau hal penting lainnya yang memerlukan sumber listrik. Turbin uap ialah salah satu komponen paling kritis pada pembangkit listrik tenaga panas. Kegagalan pada turbin uap akan memperlambat proses produksi pada pembangkit listrik. Sedangkan, alasan terbanyak dari lambatnya proses produksi pada pembangkit listrik tenaga uap disebabkan oleh kegagalan pada turbin uap itu sendiri. Selain itu, kegagalan pada turbin uap juga dapat mengakibatkan bencana alam yang dapat mengakibatkan kerugian finansial, cedera, hingga kematian. Maka dari itu, perawatan yang tepat pada turbin uap sangatlah penting untuk diimplementasikan agar dapat mencegah segala konsekuensi tersebut. *Reliability-Centred Maintenance (RCM)* ialah metode perawatan yang terbaik untuk diimplementasikan pada turbin uap karena metode tersebut fokus pada penjagaan keandalan dari sebuah peralatan. Dengan metode keandalan yang baik, maka tingkat ketersediaan pembangkit listrik tenaga panas juga akan meningkat. Setelah menganalisa 4 peralatan menggunakan *Reliability-centred Maintenance (RCM)*, didapatkan pekerjaan perawatan yang terbaik untuk peralatan tersebut. *High Pressure Turbine (MAA)* dan *Intermediate Pressure Turbine (MAB)* direkomendasikan untuk dilakukannya 30 *Scheduled On-Condition Tasks*, 19 *Scheduled Restoration Tasks*, 40 *Scheduled Discard Tasks*, dan 13 *Failure Finding Tasks*. Untuk interval perawatan, direkomendasikan untuk mendapatkan 33 harian, 22 mingguan, 3 bulanan, dan 18 tahunan. Pada *Low Pressure Turbine 1 (MAC10)* dan *Low Pressure Turbine 2 (MAC20)* direkomendasikan untuk dilakukannya 20 *Scheduled On-Condition Tasks*, 11 *Scheduled Restoration Tasks*, 14 *Scheduled Discard Tasks*, dan 13 *Failure Finding Tasks*. Untuk interval perawatan, direkomendasikan untuk mendapatkan 23 harian, 14 mingguan, 3 bulanan, dan 18 tahunan. Data perawatan tersebut selanjutnya dirangkum kedalam *Work Package* berdasaran peralatan, waktu, dan pelaku.

Kata Kunci: Perawatan, Keandalan, *Reliability-Centred Maintenance (RCM)*, Turbin Uap

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PREFACE

Praise to the Almighty God who has given the author blessing and grace to finish this bachelor thesis punctually.

The author hopes this research could be useful for everyone who has need of, whether for academic purpose or applicative purpose. This bachelor thesis also could not be finished without any help and support from others. Therefore, the author would like to say thank to these people who had already helped and supported:

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The author realizes that there are mistakes and limitations in this research. Hence, the author apologizes for all those imperfections. Any criticisms and suggestions would be welcomed and appreciated.

Surabaya, July 2020

Muhamad Noval Fahmy

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CHAPTER I
INTRODUCTION

1.1 Background

Each year energy demand in Indonesia increases along with the increase of the citizen and the growth of economics. The increase of Indonesian citizenship is assumed approximately 1.3% each year whereas the growth of economic in Indonesia is assumed to be increased approximately 6.1% each year (Septyani, 2015). Those data shows that the growth of citizenship and economic in Indonesia will increase and it leads to increasing of electrical-energy demand in Indonesia. The electrical- energy demand is estimated to increase approximately 6% each year (MEMR, 2016)

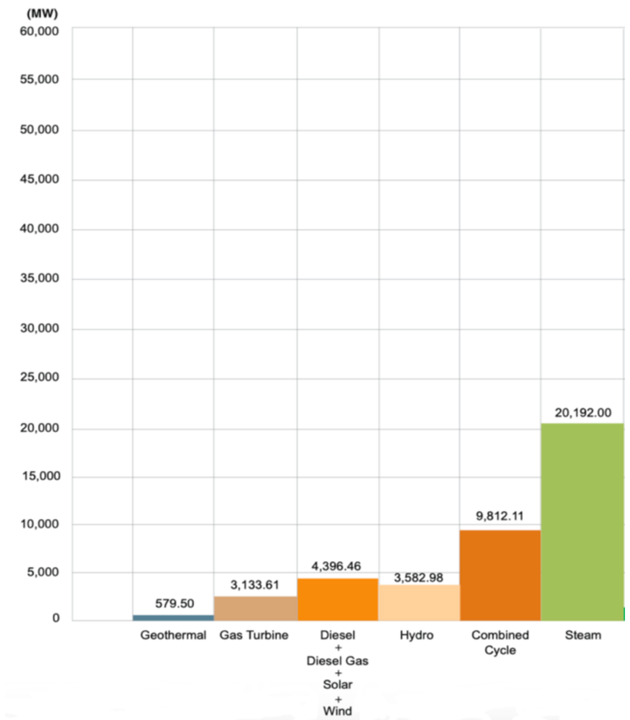

Figure 1.1 Indonesia's Power Plant in 2017 (PT. PLN, 2019)

Based on the statistic report from PT. PLN, the source of electrical energy in Indonesia from the generating plant or power plant in 2017 is divided into 6 types; Steam Turbine 20,192.00 MW (48.43%), Combine Cycle 9,812.11 MW (23.53%), Diesel 4,383.42 MW (10.51%), Hydro 3,582.98 MW (8.59%), Gas Turbine 3,133.61 MW (7.52%), Geothermal 579.50 MW (1.39%), Solar Cell and Wind 12.54 MW (0.03%).

From the data above it is known that the main source of electricity in Indonesia is from the steam power plant or coal-fired power plant. Indonesia has a lot of steam power plant spread all over the country. Some of them is located in Paiton, Probolinggo. In Probolinggo, there are 9 units of power plant operated by 3 different companies. They are PT. PJB, PT. POMI, and PT. YTL Jawa Timur. PT. YTL Jawa Timur is a multinational company which take a part in a field of operation and maintenance on some steam power plants. The steam power plant which they operate is a 1220 MW steam power plant owned by PT. Jawa Power.

As the main source of electricity, power plants require to be available and reliable in any time. Therefore, each component in it must be maintained well. If the power plants go shutdown, the consequences could lead to production losses due to damaged equipment, production downtime, and severe injuries and even death. (Awosope, 2014)

If there is one equipment that occurs a failure, it might cause the subsystem or even the whole system to fail. The reliability of the subsystem or the whole system in the power plant relies on the reliability of each component (Jiang.. et all, 2018). Therefore, proper maintenance strategy is required due to reduce those consequences to happen in the future.

1.2 Problem Statements

Based on the background described, the problem statements that can be solved in this thesis are

1. How to determine an appropriate maintenance task on the steam turbine in coal-fired power plant?
2. How to determine an appropriate schedule of maintenance task on the steam turbine in coal-fired power plant?

1.3 Objectives

Based on the problem described, the objectives of this thesis are

1. To determine an appropriate maintenance task on the steam turbine in coal-fired power plant
2. To determine an appropriate schedule of maintenance task on the steam turbine in coal-fired power plant

1.4 Scope and Limitation

This scope and limitation in this thesis are

1. The Reliability-centred Maintenance method used for the guideline is based on the John Moubray
2. The object focused on this research is in Steam Power Plant Unit 5
3. The final cost after using this method is not calculated

1.5 Benefits

The expected benefits from this thesis are

1. Provide an information regarding the implementation of RCM method based on John Moubray

2. Provide an insight to the company regarding the maintenance activities by implementing RCM method on the steam turbine
3. As an evaluation to the company that already applies RCM method

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CHAPTER II
LITERATURE STUDY

2.1 Problem Overview

One factor that can decrease the efficiency of the power plant is the forced outage or unplanned downtime. Forced outage could loss up to millions of USD and at least 5% of the total power generation availability. For power plant industry, the hidden cost of the downtime could represent 5-10% of the annual revenue and potentially 30-40 % of annual profits (David, 2001).

One The main cause responsible to the forced outage of the thermal power plant is turbine trip. It is also supported by (Energy and Environmental Analysis, 2004) that the forced outage in thermal power plant is often caused by steam turbine

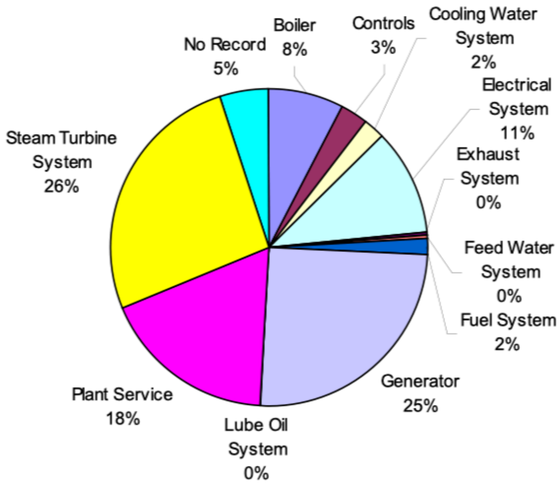


Figure 2.1 Forced Outage Cause (Energy and Environmental Analysis, 2004)

From the figure shown above, it represents that the steam turbine is one of the most critical components that must be aware. The material characteristic of turbine could gradually degrade and loss its durability which lead to fully loss of machine life (Rusin, 2006).

Currently, Unit Steam Turbines is already 20 years old and according to the cumulative turbine failure (August, 1999), in the age of 21, it is assumed that the steam turbine will have high potency of failure that causes forced outage.

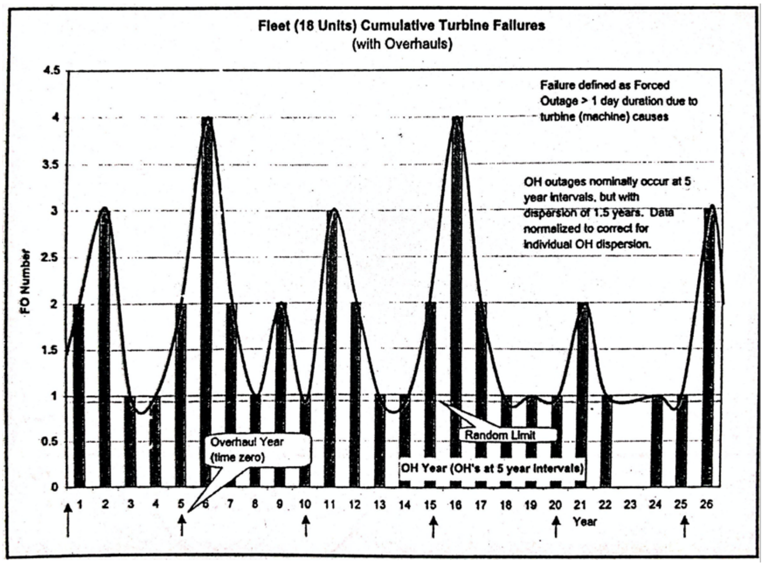


Figure 2.2 Cumulative Turbine Failure (August, 1999)

Based on maintenance operator in Unit 5, These days the steam turbines often occur these failure:

- High bearing vibration,
- Lube oil spill to the exhauster
- Turbine control valve / stop valve passing problem
- Crack in HP turbine outer casing
- Corrosion / erosion in LP turbine final blade

The failure of turbine component has financial consequences related to the costs of purchasing new equipment, costs of replacement, costs of start-up losses, costs of profit loss involved in stand-by, costs of penalty fees for failure in energy supply (Rusin, 2006)

Besides that, turbine failure can also cause a catastrophic incident that can cause death and great loss of money. There are many catastrophic incidents caused by steam turbine failure, which are Nagasaki Power Plant (1970), Kainan Thermal Power Station (1972), Eskom Duvha Power Plant (2011), Ironbridge Power station (2014), and Sherco Power Plant (2014). The further information about these incident is as shown in **Table 2.1**

Table 2.1 Catastrophic Incident Caused by Turbine

Power Plant	Date & Place	Failure	Consequence	Disadvantage
Nagasaki Power Plant (Japan)	October, 1970	Crack in turbine rotor	Cause a brittle fracture on the rotor which cause the broken fragments scatter in all direction	• Turbine is damaged • 4 people death • 61 people injured
Kainan Thermal Power Plant (Japan)	June, 1972	The bearing housing fails to secure the bearing stand and vibration-absorbing pad	Cause a deformation on the bearing, bearing housing, and bolts then the shaft is damaged and cause the broken fragments to scatter	• Turbine is damaged • No people death

Eskom Duvha Power Plant (South Africa)	February, 2011	Mechanical shutoff valve fails to stop the overspeed turbine while conducting overspeed trip test	Cause the turbine blade to detached from the rotor then the broken fragments scatter in all direction	• Equipment are burned • Turbine is damaged • Structure of building is damaged • 1 year repairing time • No people death
Ironbridge Power Plant (England)	February, 2014	Blade flutter and half speed impacting occurs in the turbine blade	Cause the turbine blade to detached from the rotor then the broken fragments scatter in all direction and fire as well	• Equipment are burned • Turbine is damaged • Structure of building is damaged • No people death
Sherco Power Plant (USA)	November, 2014	Corrosion crack on the turbine blade	Cause the turbine blade to detached from the rotor then the broken fragments scatter in all direction and fire as well	• Equipment are burned • Turbine is damaged • 22 months repairing time • $200 million repairing cost • No people death

From all those consequences, it is necessary to implement a best maintenance strategy in order to increase the reliability of steam turbine and prevent more forced outages or even catastrophic incident in the future. Based on the journal from (Brodov.. et all, 2017) he stated that proper maintenance and increasing turbine reliability can reduce turbine failure and its consequences.

RCM is one of the best-known and most used method to preserve the operational efficiency of the power plant (Dong.. et all, 2008). It can help preventing the failure of each component lead to undesired technical and economic losses (Sabouhi.. et all, 2016).

Therefore, RCM is exactly the right method to increase the reliability effectively and efficiently on a steam turbine because steam turbine is one of critical equipment in steam power plant that needs high reliability to operate commercially in a long term.

2.2 Thermal Power Plant

Thermal power plant is an industrial facility which generates electricity in mass scale by converting heat energy into electrical energy. The source of the electricity we get is partially generated from the thermal power plant. Thermal power plant itself is divided into 5 types based on its energy source; steam power plant, diesel power plant, gas turbine power plant, nuclear power plant, and hydro-electric power plant.

2.3 Steam Power Plant

Steam power plant is a thermal power plant which generates electricity by burning coal into steam. Steam converted is used to move turbine rotor connected with the generator. In steam power plant there are 3 main equipment; boiler, turbine, and generator.

a) Boiler

Boiler is an enclosed vessel used as a place for boiling water until it becomes high-pressured steam. In industrial boiler there are 2 types of boiler; water-tube boiler and fire-tube boiler. Fire-tube boiler is a boiler which the hot gas or fire is inside the tube and the water surrounds it. Otherwise, water-tube boiler is boiler which the water is inside the tube and the hot gas or fire surrounds it. Simply, the difference of those types is the location of the hot gas or fire and the water.

b) Steam Turbine

Steam turbine is a rotating device which rotate a shaft by converting thermal energy from pressured steam into mechanical energy. The common turbine has 4 main part: the rotor which carries the blade or buckets; the stator which consists of cylinder and casing; the nozzle which flows the steam; and the frame which is as a place supporting the rotor and stator.

c) Generator

Generator is a device used to generate electricity by converting mechanical energy into electrical energy. The mechanical energy from the turbine shaft makes the coiled wires in the generator to spin inside a magnetic field which can cause an electric current to flow through the wire.

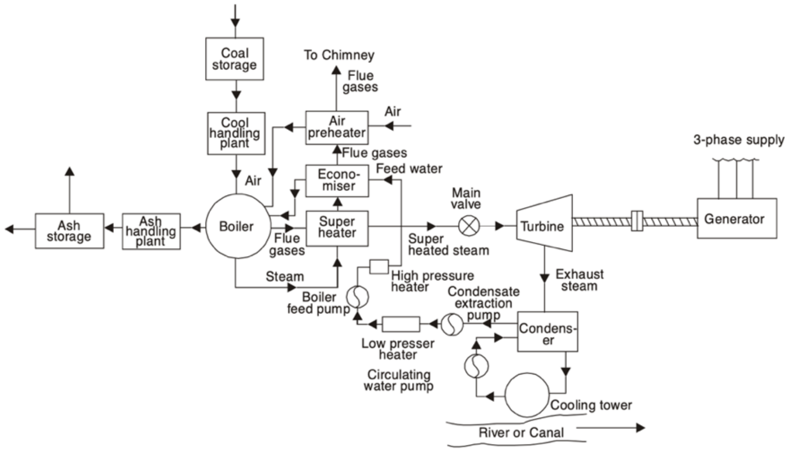


Figure 2.3 Steam Power Plant (Raja, 2006)

2.4 Steam Turbine

The work principle of steam turbine is first the thermal energy of the steam is converted into kinetic energy by expanding the steam in stationary nozzles, or in moving blades. Then the thermal energy is converted into mechanical energy when the steam passes through the moving blades, where the momentum of the steam jet is changed in direction or in magnitude. In steam power plant, there are 2 types of turbine; impulse turbine and reaction turbine. Impulse turbine is a type of turbine which the superheated steam is flowed by fixed nozzle in a high-speed velocity making the steam rotate the turbine shaft. Whereas, the reaction turbine is a type of turbine which the superheated steam is flowed from the fixed stator blade to the shaped rotor blade causing a reaction of rotation in the turbine shaft.

2.4.1 Efficiency Losses

Productivity of the power plant depends on the efficiency of the steam turbine. If the steam turbine losses its efficiency, it will affect the productivity of power plant. In further consequences, efficiency losses in steam turbine can cause a failure. There are several reasons of efficiency losses in steam turbine which are often categorized into 4 types (Albert, 2000):

a) **Leakage Loss**
The leakage loss in steam turbine is frequently caused by a big clearances between the rotating and stationary components. The big clearances increased are caused by rubbing between components, erosion, or other object damage.

b) **Friction Loss**
The friction loss in steam turbine is frequently caused when the boundary layer is thinner and there it appears even small projections. Projections

are caused by contaminants in steam which deposit in the surface of the partitions and also are caused when unfamiliar particles collide against partition surfaces.

c) Aerodynamic Loss

The aerodynamic loss will occur if there is a change in nozzle or bucket profiles which automatically change the entrance and/or exit steam angels. The most usual reason of off-angle losses are because of the erosion of the nozzle trailing edges and bad-quality of repairs.

d) Changing of Flow Passage Area Loss

Losses due to the changing of flow passage area can be occurred because if the flow passage area of a stage changes, the initial pressure into that stage must change in order to pass a constant steam flow. The change in the initial pressure will change the amount of available energy which affects the efficiency of that stage.

2.4.2 Failure Mechanism

Every equipment indeed has its own failure mechanism. In steam turbine itself, there are several failure mechanisms that must be considered. Those failure mechanisms can be categorized into 4 types, such as

a) Corrosion

Corrosion can be defined as a degradation of material caused by electrochemical reaction. In steam turbine failure mechanism, corrosion is usually caused by chemical reaction of corrosive element in steam. Corrosion also can cause extensive pitting on turbine equipment.

b) Erosion

Erosion can be defined as a degradation of material caused by natural forces such as wind or water. In steam turbine failure mechanism, erosion is usually caused by debris and water droplet in steam. Erosion also can cause thinning on turbine equipment.

c) Fatigue

Fatigue can be defined as a degradation of material caused by failure in holing the cyclic load. In steam turbine failure mechanism, fatigue is usually caused by vibration, aging, and water induction incident. Fatigue also can cause crack on turbine equipment.

d) Stress Corrosion Cracking

Stress corrosion cracking can be defined as a degradation of material in a crack form growing in a corrosive environment. In steam turbine mechanism, stress corrosion cracking is usually caused by the combination of corrosive elements and high stresses in high-loaded location. Stress corrosion cracking also can cause crack on turbine equipment

2.4.3 General Problem

The general problems frequently faced in the steam turbine are rotor vibration, bearing problem, and blade problem. Further information about the cause and consequences of those several problems is as shown in **Table 2.2**

Table 2.2 Common Problem in Steam Turbine (J. Jung, 1994)

Problems	Cause	Consequences
Rotor Vibration	• Weight unbalance • Bearing misalignment • Resonance • Bearing malfunction • Unbalanced electromagnetic forces in generator	• Rubbing and impact damage to turbine seals, blades or bearings • Fatigue damage of turbine blades, coupling bolts, steam or oil lines
Bearing Problem	• Improper lubrication • Excessive bearing load • High vibration levels	• Melting of babbit lining • Fatigue cracking of the babbit lining
Blade Problem	• Stress corrosion cracking and fatigue cracking • Nozzle impulse effect • Stall flutter • Rotor vibration	• Long moving blades can pierce the casing and become turbine missiles • Very high vibration can destroy generator bearings, seals, and oil lines • Broken blade can shear off or bend some of other blades

In solving the steam turbine problems, there are 2 terms used; repairs and overhauls. Repair generally solves minor problems by fixing the problem or replacing one or more components such as seals, bearings, and governor directly in field. Whereas, overhaul is conducted when the steam turbine can no longer be repaired in the field and it requires major work such as blade replacement due to erosion, bearing journals repair, and leaking split-lines repair. (Perez.. et all, 2016)

2.4.4 Steam Turbine Reliability

Every component has its expected lifetimes. The steam turbine itself also has an expected lifetimes in average which is approximately between 5.71 and 7.42 years. The expected lifetimes of steam turbine also depends on the failure modes related to it. Improving the lifetimes of the steam turbine can be done by maximizing its reliability. To maximize the reliability, we need to maximize the mean times between overhauls and maximize the mean time between repairs of the components by optimizing design standards, operating procedures, repair standards, frequent inspection, and good maintenance strategy (Perez.. et all, 2016)

2.5 Maintenance

Maintenance is a concept which monitors and maintains the equipment by planning, arranging, and checking to ensure the function of the equipment in the uptime and minimalize the downtime caused by failure or reparation. The main purpose of maintenance is to ensure that all equipment is operating properly at full efficiency at all times. In order to increase the reliability of an equipment, a proper maintenance is needed.

2.6 Evolution of Maintenance

a) The First Generation

In the 1930s, the downtime is not concerned well as a priority because the industry in those days was not sophisticatedly mechanized. Most equipment in those days was simple and over-designed (Moubray, 1997)

b) The Second Generation

In the 1950s, industry began to rely on mechanization because of the wartime pressures which increased the demand for goods of all kinds while the industrial manpower dropped sharply. Machines in this time were more numerous and complex. Because of those dependence grew, people started to focus on the downtime and led to the idea of preventive maintenance (Moubray 1997)

c) The Third Generation

In the 1970s, automation started to spread around the world because of its high-quality standards and high production capabilities. The more complex of the system, the more potency of failure. Even though failure can cause safety and environmental issues, the dependency on physical assets is still growing in accordance to their cost to operate and to own as well. Facing those problems, the industry started to keep working efficiently to secure the maximum return of investment (Moubray 1997)

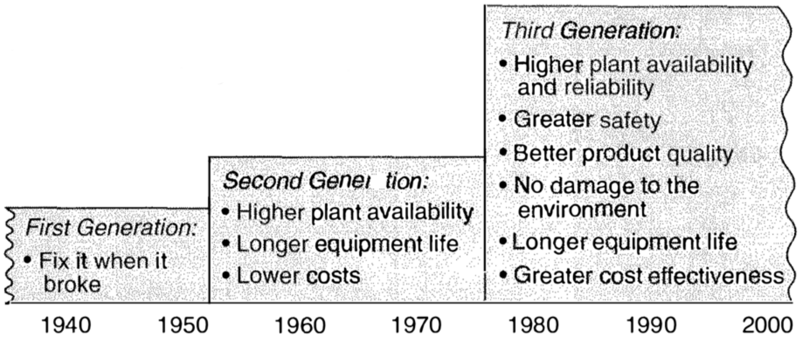


Figure 2.4 Evolution of Maintenance (Moubray 1997)

2.7 Types of Maintenance Strategy

Commonly, maintenance is divided into 2 types; unplanned maintenance and planned maintenance. Unplanned maintenance consists of breakdown maintenance. Whereas, planned maintenance is divided into 4 types; pro-active maintenance, preventive maintenance, preventive maintenance, predictive maintenance, and corrective maintenance (Rani, Baharum, Akbar, & Nawawi, 2014)

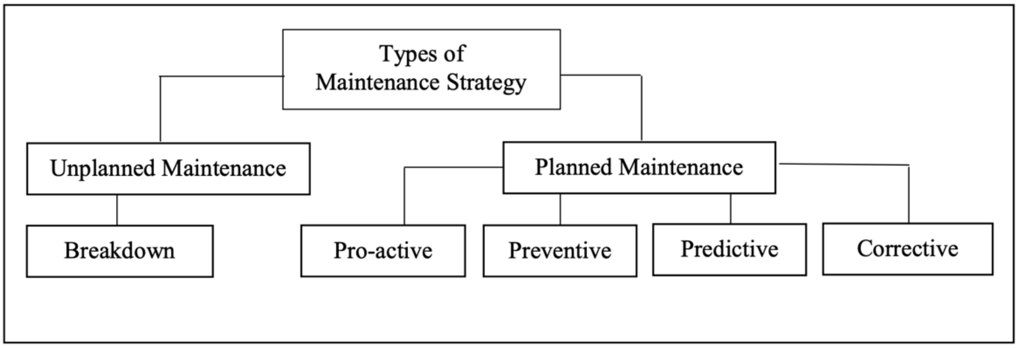


Figure 2.5 Types of Maintenance Strategy (Rani et al., 2014)

2.7.1 Unplanned Maintenance

Unplanned maintenance is also called reactive maintenance or emergency maintenance. It is often regarding with an unexpected case and leads to high maintenance cost. (Rani, Baharum, Akbar, & Nawawi, 2014)

2.7.2 Planned Maintenance

Planned maintenance is a maintenance which is already planned in order to correct the lower performance than the expected or failure for managerial decision (Pinto & Xavier, 2007)

a. **Pro-active Maintenance**
Proactive maintenance is one type of maintenance which detect the failure from the source of the failure. It can extend the life of equipment so it can enhance production capacity. Proactive maintenance is not similar to preventive or predictive maintenance. proactive maintenance is designed to extend the useful age of the equipment to wear-out stage by implementing a top level of mastery regarding the operating precision (Hisham, 2003)

b. **Preventive Maintenance**
Preventive maintenance is one type of maintenance which assess the efficiency of equipment at regular time intervals, so the lifetime of the equipment can be extended. It is designed to solve the disadvantages of corrective maintenance by reducing the probability of a failure occurrence and avoiding a sudden failure. Preventive maintenance is also better than the corrective maintenance because it can reduce maintenance cost of major damage, minimize downtime and improve safety of asset (Horner et al., 1997)

c. **Predictive Maintenance**
Predictive maintenance is one type of maintenance strategy which depends on the problem detected. It is slightly similar to condition-based or condition monitoring maintenance which measures the condition of the equipment using some supporting tools
(Hisham, 2003)

d. **Corrective Maintenance**
Corrective maintenance is the simplest maintenance strategy, which involves just the repair or replacement of an element that has failed in its function. Corrective maintenance can be extremely expensive because the failure of an item can cause a large amount of consequential damage to other elements in the building and failure of an item can occur at a time that is inconvenient to both the user and the maintaining authority (Horner et al., 1997)

2.8 Reliability-Centred Maintenance

Reliability-Centred Maintenance (RCM) is a process used to determine the maintenance requirements of any physical asset in its operating context. RCM provides a framework which enables applicants to respond to these challenges, quickly and simply (Moubray, 1997). RCM will choose the right maintenance activities such as preventive maintenance or corrective maintenance for the right equipment at the right time to reach the most cost-efficient solution (Bertling, 2005)

2.8.1 RCM Seven Basic Questions

RCM process has seven questions to the asset or system applied (Moubray, 1997)

1. **What are the functions and associated performance standards of the asset in its present operating context (system function)?**

In this step, to make it possible to apply a process used to determine what must be done to ensure that any physical asset continuous to do whatever its users want it to do in its present operating contentwe need to do these things:

- Determine what its users want it to do
- Ensure that it is capable of doing what its users want to start with

This is the first step in the RCM process. There are two categories of functions, which are:

- Primary function, which sum up why the asset is created in the first place
- Secondary function, which recognize that every asset can do more than fulfil its primary function.

2. **In what ways does it fail to fulfil its functions (functional failure)?**
The only cause which stops any asset performing the expected standard is some kind of failure. In this stage, The RCM process does these two things:
   - First, by identifying what circumstances amount to a failed state
   - Second, by asking what events can cause the asset to get into a failed state

   In the world of RCM, failed states are generally called as a functional failures because it occurs when the asset is unable to perform its standard function to be accepted by the user.
3. **What cause each functional failure (failure modes)?**
After the functional failure of each asset has been identified, then the next step is to identify the all reason of possible events which can cause each failed state. The function of identifying each failed state is to ensure that time and effort are not wasted trying to treat symptoms instead of causes. There are three parameters in determining the failure modes, which are:
   - When capability falls below desired performance
   - When desired performance rises above initial capability
   - When the asset is not capable of doing what is wanted from the outset
4. **What happens when each failure occurs (failure effect)?**
The next step in the RCM process is listing failure effects based on each failure mode occur. The list should include all information needed, such as:
   - What evidence (if any) that the failure has occurred
   - In what ways (if any) it poses a threat to safety or the environment
   - In what ways (if any) it affects production or operations
   - What physical damage (if any) is caused by the failure
   - What must be done to repair the failure
5. **In what way does each failure matter (failure consequences)?**
Each failure can affect the organization differently in each case. They may affect operation, product quality, customer service, safety, or the environment. Those consequences will take time and cost to repair. A great strength of RCM is it recognizes that the consequences of failure are more important than their technical characteristics which then it can avoid or at least reduce those consequences. The consequences in the RCM process are divided into 4 types

- Hidden failure consequences, which it has no direct impact but they possibly can cause serious or even catastrophic consequences.
- Safety and environmental consequences, which it can cause injury or death (safety consequences) and can lead to a breach of any corporate, regional, national, or international environmental standard.
- Operational consequences, which it can affect production in term of output, product quality, customer service, or operating costs in addition to the direct cost of repair.
- Non-operational consequences, which it doesn't affect safety production but only the direct costs of repair.

6. **What can be done to predict or prevent each failure (proactive task)?**
The best way to increase the availability of plant is to do some proactive maintenances. In RCM, maintenance is divided into 3 types:
    - Scheduled restoration tasks
    - Scheduled discard tasks
    - Scheduled on-condition tasks

    Scheduled restoration tasks and scheduled discard tasks are remanufacturing or overhauling the asset without paying attention to the condition at that time. While, the scheduled on-condition tasks are paying attention to the asset's condition to detect the potential failure. On-condition maintenance includes predictive maintenance, condition-based maintenance, and condition monitoring. RCM enables the user to freely select the desired maintenance based on its consideration.
7. **What should be done if a suitable proactive task cannot be found (default action)?**
Default action in the RCM is divided into 3 types:
    - Failure finding, which consists of checking the hidden function occasionally to consider the asset is failed or not.
    - Redesign, which consists of making any one-off change such as modification of the asset and one-off change to the procedure.
    - No scheduled maintenance, which consists of doing no prevention to the failure mode which it allows the failure to occur and then do the repair. This type of default action is also called run-to-failure.

2.8.2 Logic Tree Analysis

Logic tree analysis is an analysis concept that helps determining the conclusion by using deductive logic. In RCM method, logic tree analysis is used to determine the proposed maintenance task based on the FMEA analysis. There are four main proposed maintenance tasks in RCM logic tree analysis, such as scheduled on-condition task, scheduled restoration task, scheduled discard task and failure finding task. Those four maintenance tasks are determined by two parameters which are technically feasible and worth doing. Technically feasible means that the maintenance task proposed is more beneficial and feasible in technical way. While, worth doing means that the maintenance task proposed is more beneficial in consequences so it will be worth to be done. Based on John Moubray (Moubray 1997), There are several points required in technically feasible parameter of each proposed maintenance task

1. **Scheduled On-Condition Task**

This proposed maintenance task is technically feasible when

- It is possible to define a clear potential failure condition
- The P-F interval is reasonably consistent
- It is practical to monitor the item intervals less than the P-F interval
- The net P-F interval is long enough to be of some use (in other words, long enough for action to be taken to reduce or eliminate the consequences of the functional failure)

2. **Scheduled Restoration Task**

This proposed maintenance task is technically feasible when

- There is an identifiable age at which the item shows a rapid increase in the conditional probability of failure
- Most of the items survive to that age (all of the items if the failure has safety or environmental consequences)
- They restore the original resistance to failure of the item

3. **Scheduled Discard Task**

This proposed maintenance task is technically feasible when

- There is identifiable age at which the item shows a rapid increase in the conditional probability of failure
- Most of the items survive to that age (all of the items if the failure has safety or environmental consequences)

4. **Failure Finding Task**

This proposed maintenance task is technically feasible when

- It is possible to do the task
- The task does not increase the risk of multiple failure
- It is practical to do the task at the required interval

2.8.3 Six Pattern of Failure

It is believed that the proactive maintenance is must to be done on a routine basis. However, the electrical and mechanical asset of this era is much more complex due to its development. This fact leads people to develop the patterns of failure as show in **Figure 2.6** (Moubray, 1997)

Figure 2.6 Six Pattern of Failure (Moubray, 1997)

a) **Pattern A**
Pattern A is commonly known as the bathtup curve. It starts with high potency of failure then followed by constant failure and end with increasing probability of failure.

b) **Pattern B**
Pattern B starts with a constant failure then followed by increasing probability of failure.

c) **Pattern C**
Pattern C starts with a slow-increasing probability of failure but the wear-out age is identifiable.

d) **Pattern D**
Pattern D starts with low probability of failure then followed by a constant probability of failure.

e) **Pattern E**
Pattern E starts and ends with constant probability of failure (random failure).

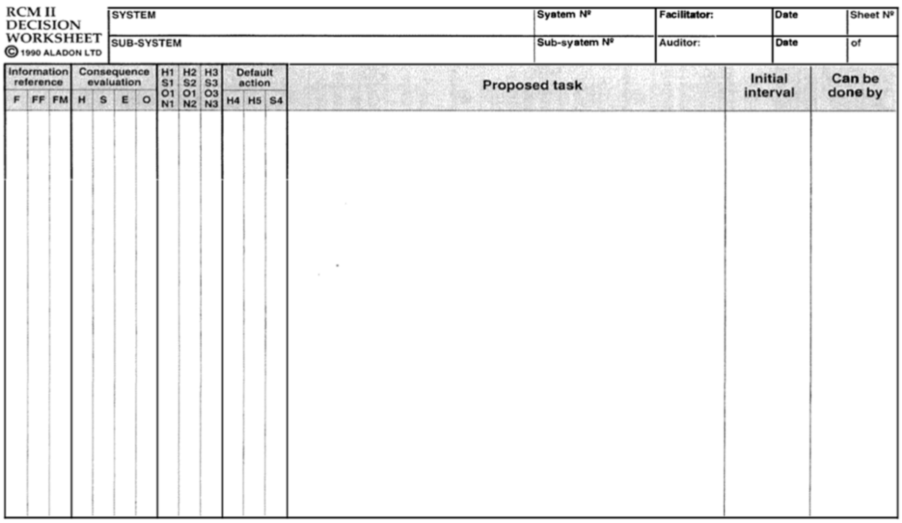
f) **Pattern F**
Pattern F starts with high probability of failure then followed by constant or slowly increasing probability of failure.

2.8.4 RCM Decision Worksheet

Based on John Moubray (Moubray 1997), RCM decision worksheet consists of a table which records:

- What routine maintenance (if any) to be done, how often it is to be done and by whom
- Which failures are serious enough to warrant redesign
- Cases where a deliberate decision has been made to let failures happen

The RCM decision worksheet based on John Moubray book is shown as **Figure 2.7**



RCM II DECISION WORKSHEET
© 1990 ALADON LTD

SYSTEM	Syatem Nº	Facilitator:	Date	Sheet Nº
SUB-SYSTEM	Sub-syatem Nº	Auditor:	Date	of

Information reference			Consequence evaluation				H1 S1 O1 N1	H2 S2 O1 N2	H3 S3 O3 N3	Default action			Proposed task	Initial interval	Can be done by
F	FF	FM	H	S	E	O				H4	H5	S4			

Figure 2.7 RCM Decision Worksheet (Moubray, 1997)

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CHAPTER III
METHODOLOGY

3.1 Research Methodology

This section shows the step of conducting this research. The step will be shown as the flowchart below in **Figure 3.1**

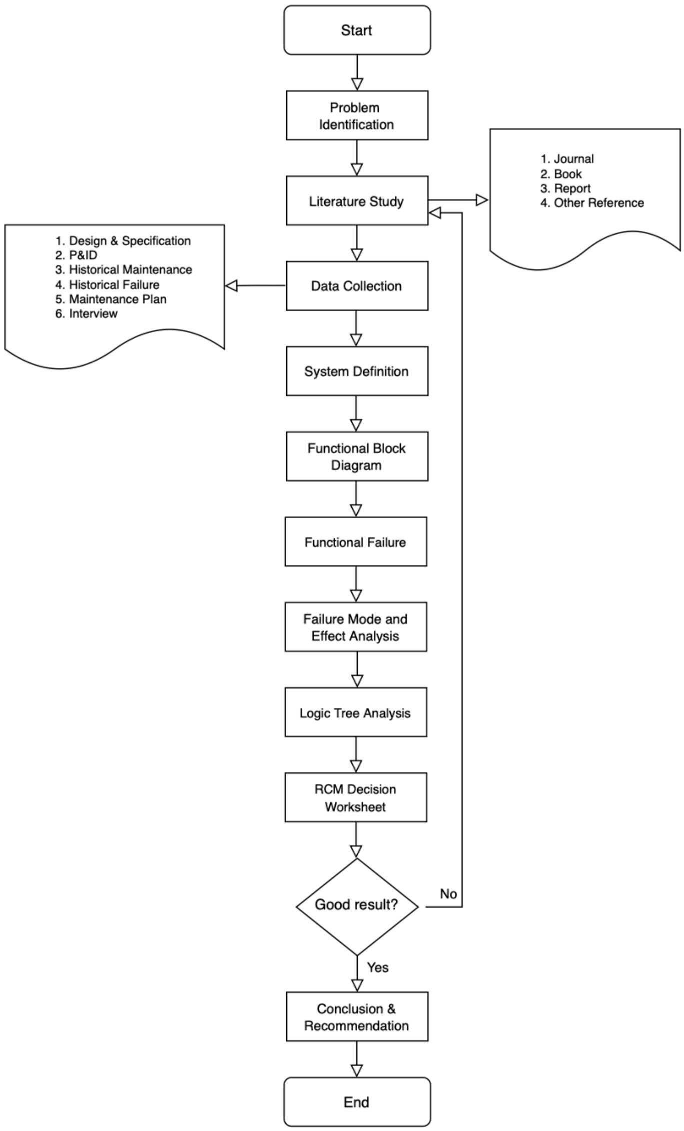

Figure 3.1 Flowchart of The Methodology

3.2 Problem Identification

This section contains the main problem of this thesis. The main problem comes from the existing condition compared to the required condition (Study Case). The problem that will be solved by implementing RCM method is Unit 5 Steam Turbine.

3.3 Literature Study

This section contains an act of studying all the supporting knowledge as a basis in order to solve the problem scientifically based on journals, books, reports, and other references.

3.4 Data Collection

This section contains an act of collecting data required in order to solve the problem. The data that will be collected are

- Design & Specification
- PID & PFD
- Historical Maintenance
- Historical Failure
- Maintenance Plan
- Interview

3.5 System Definition

This section contains an act of determining the definition and limitation of this thesis. This research focuses on the steam turbine in unit 5 consists of high pressure turbine, intermediate pressure turbine, and low pressure turbine. The function of this step is to help specifying the object that will be researched more clearly.

3.6 Functional Block Diagram

This section contains an act of determining the flow, function, and relationship between each equipment. Function block diagram in this thesis is following the guideline from Anthony Smith's book (Smith, 2003). Functional block diagram consists of the equipment, flow, and standard performance related to its function. The function of this step is to help clarifying the function and knowing the relationship of each equipment.

3.7 Functional Failure

This section contains of an act of determining the specific function and the failure of each equipment. There are two types of function in each equipment which are primary function and secondary function. In determining those functions, standard performance must be included. Then, to determine the functional failure, it should be followed by total failure and partial failure in order. Total failure means when the equipment cannot do its function totally. While, partial failure means when the equipment cannot do its function in accordance with its standard performance.

3.8 Failure Mode and Effect Analysis

This section contains an act of determining the failure mode and its effect. Failure mode means any possible condition that can cause functional failure. Then, failure effect can be obtained from each failure mode. Failure effect should contain these five elements which are hidden or evident event, safety or environmental consequences, operational consequences, physical damage occurred, and repair action that must be done.

3.9 Logic Tree Analysis

This section contains an act of determining the supportive data in order to select the maintenance task and schedule. Logic tree analysis consists of question about "feasibility" and "worth doing" of maintenance task on each failure mode. The outputs of this analysis are the category of maintenance task, such as scheduled on-condition task, scheduled restoration task, scheduled discard task, or default task. Then, those analysis will be put into RCM Decision Worksheet.

3.10 Maintenance Task & Schedule

This section contains an act of selecting the proposed maintenance task and schedule based on logic tree analysis conducted in RCM Decision Worksheet. Those analysis then will be summarized again on work packages based on the equipment, interval, and executor. The work packages created can be a guideline for the executor while doing the maintenance task.

3.11 Conclusion & Recommendation

This section contains an act of summarizing a conclusion and giving a recommendation based on the RCM analysis implemented. The conclusion consists of important point of this thesis and the recommendation consists of proposed action that should be taken against the problem existed.

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CHAPTER 4
DATA ANALYSIS AND DISCUSSION

4.1 Data Collection

All the data collected are based on the interview with the engineer and operator and also the manual book, logsheet, and another related documents from document control room.

- ⇒ Data collected from document control room
  - Specification
  - P&ID
  - Historical Operation
  - Historical Failure
  - Historical Maintenance
- ⇒ Data collected from interview
  - Turbine General Knowledge
  - Turbine Documentation
  - Turbine Troubleshooting
  - Failure Consequences
  - Primary and Secondary Function

4.2 System Definition

After getting the data required, it is important to determine the system in order to make the works specifically clearer because RCM method is a comprehensive method that needs specific information about what equipment included or not. In system boundaries definition consists of the system name, ID, major equipment included, and primary physical boundary. The example of system in turbine unit 5 are

- Name : Steam Turbine Unit 5
- ID : 117844
- Major Equipment Included : High Pressure Turbine, Intermediate Pressure Turbine, Low Pressure Turbine
- Primary Physical Boundary : Start with HP inlet nozzle until LP exhaust.

The further information about functional hierarchy, asset register and PFD are shown in the **Appendix 1, 2, and 3.**

4.3 Functional Block Diagram

In the RCM process, making the functional block diagram is necessary. Functional block diagram can help clarifying the function and its relation of each component. Therefore, the component affected by failure will be known from this diagram. The functional block diagram in this research is based on the book from Anthony Smith. The figure of functional block diagram is shown in **Appendix 4.**

4.4 Functional Failure

As we know that every component has its own function. Functional failure in this thesis is selected by analyzing each possible failure of the component function specifically. Possible failure analyzed is based on the standard performance of each component. In this thesis, HPT governor, IPT governor, HP turbine, IP turbine, and LP turbine are analyzed to have 6 functional failures and 30 in total. The example of functional failure in this thesis is shown in **Table 4.1** and the complete table is shown in **Appendix 5.**

Table 4.1 Functional Failure

<table>
<tr><td colspan="5">Equipment: 610 MW Low-Pressure Turbine (MAC 10)</td></tr>
<tr><td colspan="3">Function</td><td colspan="2">Functional Failure</td></tr>
<tr><td>Item No.</td><td>Functional Statement</td><td>Function Type</td><td>Item No.</td><td>Functional Failure</td></tr>
<tr><td rowspan="3">1</td><td rowspan="3">To produce rotational speed of shaft at 3000 rpm in 50 Hz</td><td rowspan="3">Primary</td><td>1.1</td><td>Rotational speed is not produced</td></tr>
<tr><td>1.2</td><td>Rotational speed is more than 3000 rpm</td></tr>
<tr><td>1.3</td><td>Rotational speed is less than 3000 rpm</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">To prevent overspeed rotation from more than 3300 rpm</td><td rowspan="3">Secondary</td><td>2.1</td><td>Inactive of overspeed protection</td></tr>
<tr><td>2.2</td><td>Overspeed protection activates at safe rpm (3000 rpm)</td></tr>
<tr><td>2.3</td><td>Overspeed protection activates more than 3300 rpm</td></tr>
</table>

4.5 Failure Mode and Effect Analysis

The data collected in this research is further analyzed on FMEA table. FMEA is method that helps analyzing the failure of system or component and its effect. This research uses FMEA table based on RCM book by John Moubray which consists of function, functional failure, failure mode and failure effect. The table of FMEA is shown in **Appendix 6, 7, 8, and 9.**

4.5.1 Function

As what has been analyzed, all those primary and secondary functions are put in the FMEA table. The function is required to be specific which includes the verb, object and standard performance. In this research, the author finds 2 functions of each High Pressure Turbine, Intermediate Pressure Turbine, Low Pressure Turbine and governor.

4.5.2 Functional Failure

The author defines the functional failure of each equipment based on the function itself. There are 2 types of functional failure which are total failure and partial failure. The author puts the total failure in the first order of functional failure and the rest is partial failure. The author defines the total failure is when the equipment cannot do its desired function totally while the partial failure is when the equipment cannot do its desired function such as in below standard performance or above the standard performance.

4.5.3 Failure Mode

The author finds 218 failure modes in this research based on the journal, manual book, and also the interview with the engineer. All the failure modes analyzed are mostly because of damage mechanism of each component such as corrosion, erosion, bending, crack and followed by some other electrical failure such as short circuit, misdetection and etc.

4.5.4 Failure Effect

One failure mode must be followed by one failure effect. The failure effect analyzed in this research consists of 5 important information to help evaluating the consequences of the failure. Those 5 important information are the evidence of the failure, safety or environmental effect, production effect, physical damage occurred, and the action needed in order to fix the failure.

4.6 Failure Consequences

There are 4 consequences analyzed which are hidden or evident functions, safety consequences, environmental consequences, and operational consequences. The author finds all failure modes analyzed are mostly evident and its consequences are mostly operational consequences. The example of the failure consequences are shown in the **Figure 4.1**

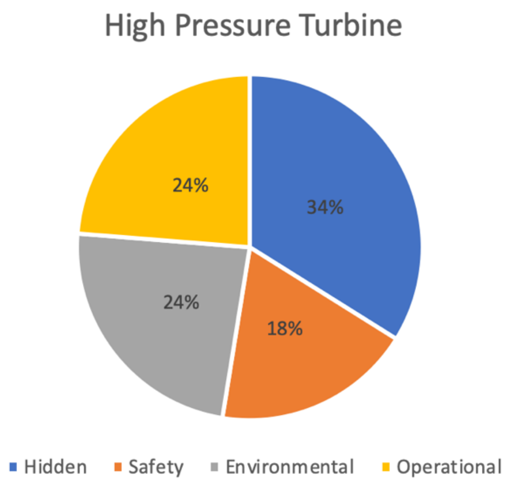

Figure 4.1 Failure Consequences of High Pressure Turbine

Failure consequences reaches further analysis of effect like how much the failure matters to others. Further analysis means the failure consequences consists of the hidden or evident function, safety consequences, environmental consequences, and operational consequences. This information is important to be analyzed in order to help selecting the proposed task in each failure mode combined with the Logic Tree Analysis method.

4.7 Logic Tree Analysis

After analyzing specifically about the failure and its effect, logic tree analysis is necessary in order to help choosing the proper maintenance task of each failure mode. Generally, There are 4 types of maintenance task in this research which are Scheduled On-Condition Task, Scheduled Restoration Task, Scheduled Discard Task, and Default Task. The example of proposed maintenance task that has been analyzed is shown in the **Figure 4.2**

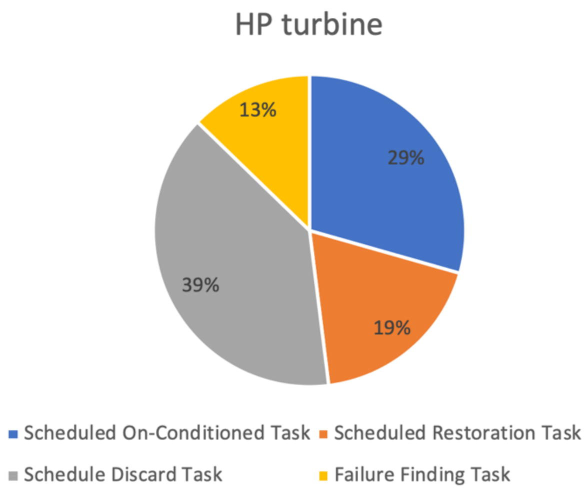

Figure 4.2 Proposed Maintenance Task of High Pressure Turbine

Logic tree analysis used in this research is based on John Moubray's book. Those analysis then, are put in into the RCM Decision Worksheet as shown in the **Appendix 9.**

4.8 Work Packages

In order to make all maintenance tasks analyzed in RCM Decision Worksheet more applicative, creating work packages is a necessary step. The author categorizes the maintenance tasks based on the equipment itself, interval, and executor. The equipment included are high pressure turbine (MAA), intermediate pressure turbine (MAB), low pressure turbine 1 (MAC10), and low pressure turbine 2 (MAC20). The interval of the maintenance is categorized into daily, weekly, monthly, and annually. The executor is divided into mechanic, electrician, and operator. The example of work package is shown in the **Table 4.2** and the complete work packages are shown in **Appendix 10.**

Table 4.2 Work Package of High Pressure Turbine

Maintenance Schedule	
HIGH PRESSURE TURBINE	
Interval	Done by
DAILY	OPERATOR
These are lists of recommended action that can reduce potential failure of steam turbine: 1. Monitor hydraulic supply power, servo valve, solenoid valve, control valve actuator, control valve and seal 2. Monitor the electrical flow within those equipment 3. Conduct visual inspection on seal. Ensure there is no leakage 4. Check water and steam purity. Ensure it is not contaminated 5. Monitor operational speed of turbine. Ensure it is not overspeed 6. Monitor lubricating system. Ensure it is flowed with no obstacles and not contaminated 7. Monitor temperature and pressure of turbine. Ensure the temperature is at range of operational design 8. Conduct inspection if there is abnormalities 9. Repair or replace if it is needed	

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CHAPTER V
CONCLUSION & SUGGESTION

5.1 Conclusion

RCM analysis can cover the potential failure more specific and detail on unit 5 steam turbine. The existing maintenance on unit 5 steam turbine is only using corrective maintenance and time-based maintenance while those maintenance activities are already included in the RCM analysis with the addition of preventive maintenance. After analyzing 4 equipment using Reliability-Centred Maintenance (RCM), it is obtained the best maintenance task for those equipment. High Pressure Turbine (MAA) and Intermediate Pressure Turbine (MAB) are recommended to have 30 scheduled on-condition tasks, 19 scheduled restoration tasks, 40 scheduled discard task, and 13 failure finding tasks. For maintenance interval, it is recommended to has 33 daily, 22 weekly, 3 monthly, and 44 annually. Low Pressure Turbine 1 (MAC10) and Low Pressure Turbine 2 (MAC20) are recommended to have 20 scheduled on-condition tasks, 11 scheduled restoration tasks, 14 scheduled discard task, and 13 failure finding tasks. For the maintenance interval, it is recommended to has 23 daily, 14 weekly, 3 monthly, and 18 annually. Those maintenance data then will be summarized into a work package based on the equipment, interval, and executor.

5.2 Suggestion

Here are the suggestion in order to improve the implementation of RCM method on steam turbine:

1. More complete data could help improving the research to get the best result
2. More discussion with the engineer could help improving the research to get the best result
3. Further analysis into the smaller parts of the equipment could help improving the research to get the best result
4. Including the cost of maintenance could help improving the research to get the best result

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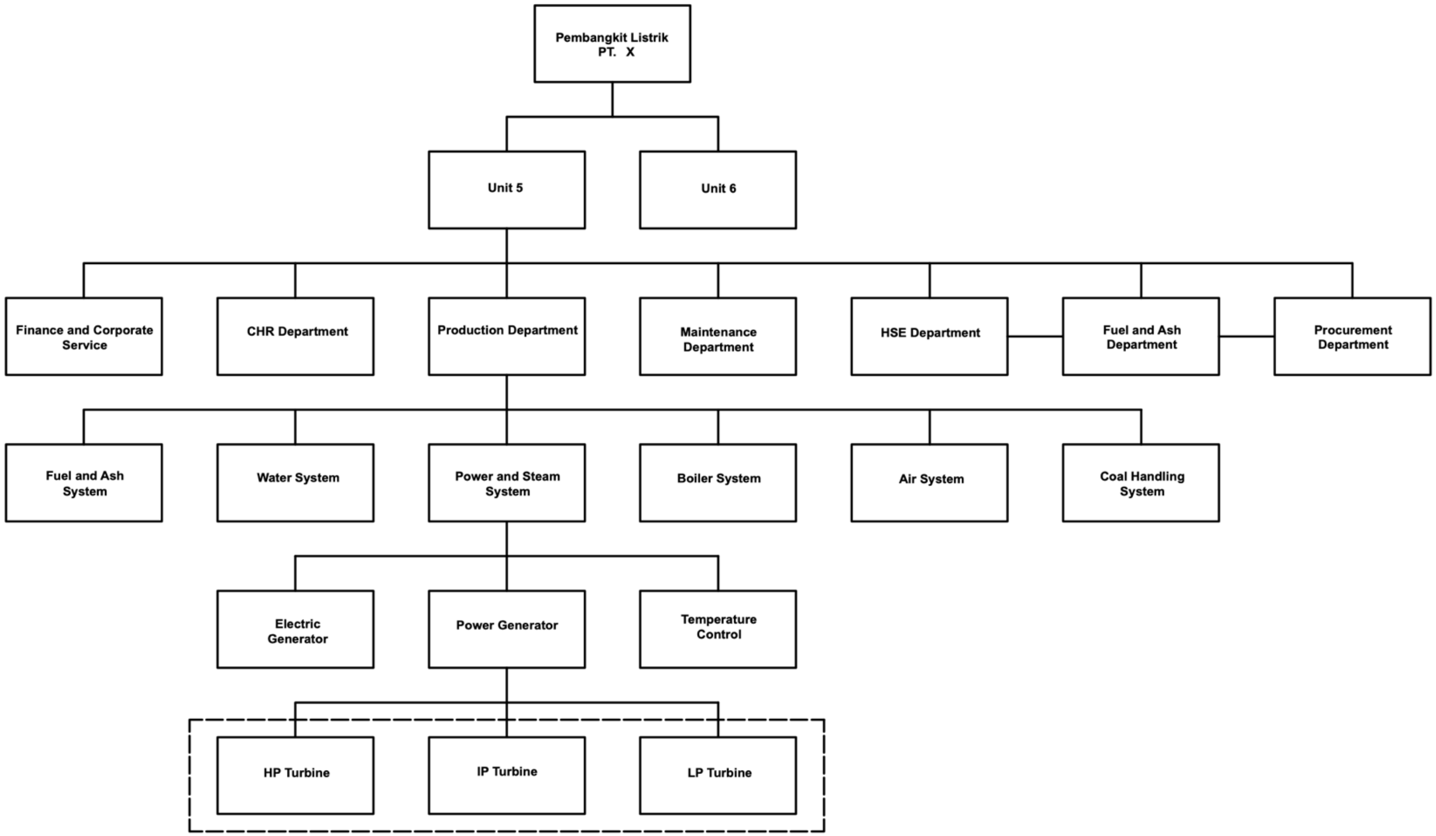
ATTACHMENT

ATTACHMENT 01
FUNCTIONAL HIERARCHY

FUNCTIONAL HIERARCHY



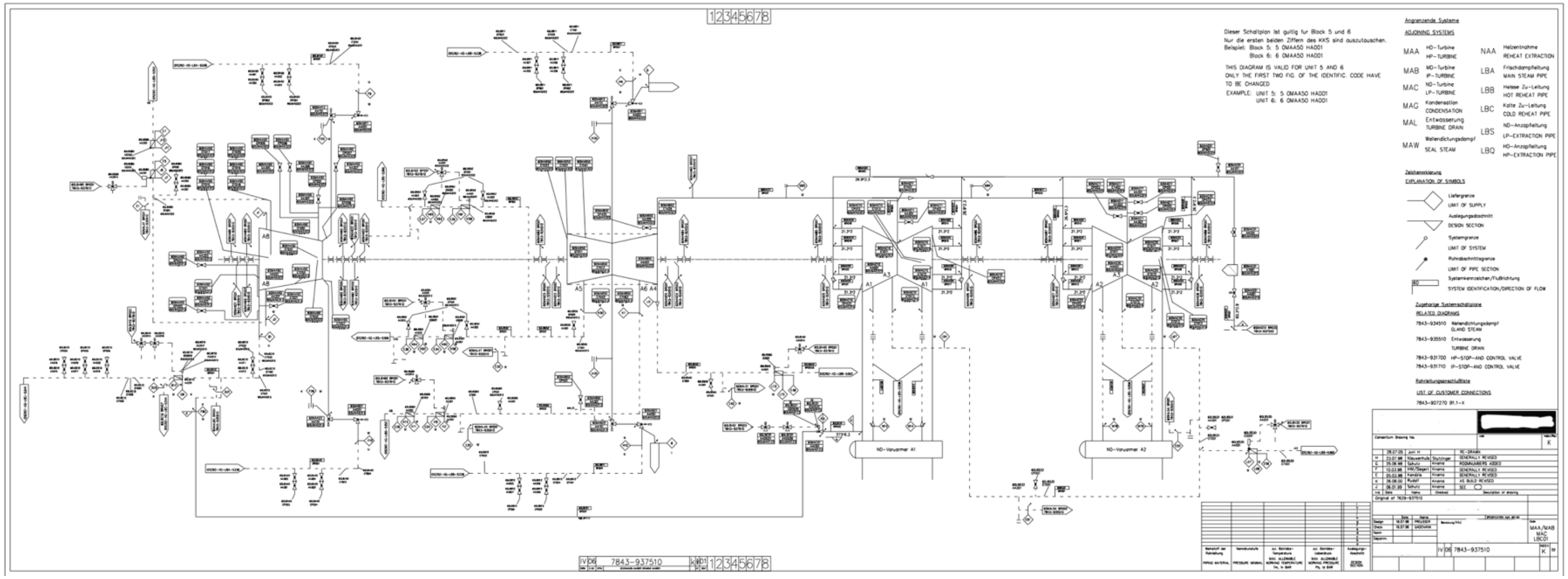
ATTACHMENT 02
ASSET REGISTER

ASSET REGISTER

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	
Plant	Operating Unit	Operating Area	System	Subsystem	Equipment	Component	Component Item	Equipment Tag Number
Pembangkit Listrik PT. X								
	Unit 5							
		Production Department						
			Power and Steam					
				Power Generator				
					Turbine			
						HP Turbine		MAA
							Rotor	
							Stator	
							Bearing	
							Shaft	
							Casing	
						IP Turbine		MAB
							Rotor	
							Stator	
							Bearing	
							Shaft	
							Casing	
						LP Turbine		MAC10
							Rotor	
							Stator	
							Bearing	
							Shaft	
							Casing	
						LP Turbine		MAC20
							Rotor	
							Stator	
							Bearing	
							Shaft	
							Casing	

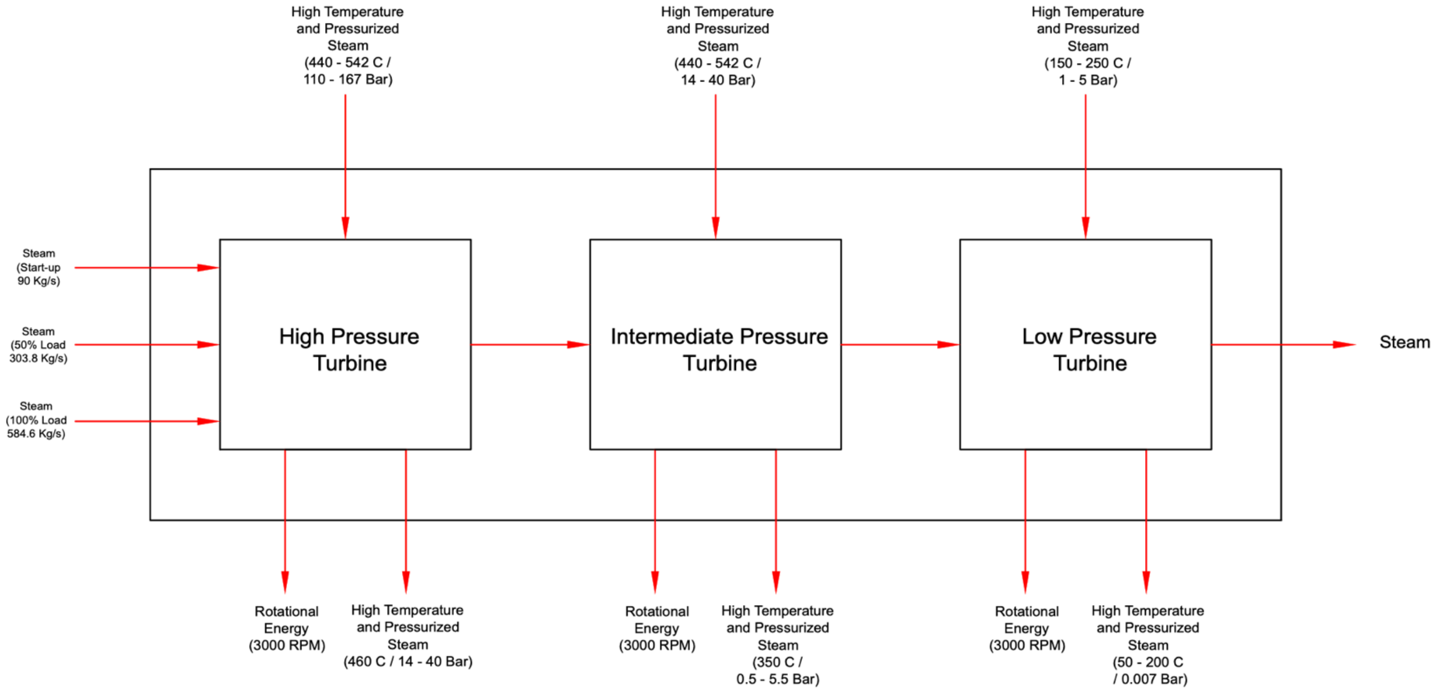
ATTACHMENT 03
PFD

PFD



ATTACHMENT 04
FUNCTIONAL BLOCK DIAGRAM

FUNCTIONAL BLOCK DIAGRAM



ATTACHMENT 04
FUNCTIONAL FAILURE

FUNCTIONAL FAILURE

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<tr><td colspan="2">SUB - SYSTEM</td><td>SUB - SYSTEM Nº</td><td colspan="2">Auditor</td><td>Date</td><td>of</td></tr>
<tr><td colspan="9">Equipment: 610 MW High-Pressure Turbine (MAA)</td></tr>
<tr><td colspan="3">Function</td><td colspan="6">Functional Failure</td></tr>
<tr><td>Item No.</td><td>Functional Statement</td><td>Function Type</td><td>Item No.</td><td colspan="5">Functional Failure</td></tr>
<tr><td rowspan="3">1</td><td rowspan="3">To produce rotational speed of shaft at 3000 rpm in 50 Hz</td><td rowspan="3">Primary</td><td>1.1</td><td colspan="5">Rotational speed is not produced</td></tr>
<tr><td>1.2</td><td colspan="5">Rotational speed is more than 3000 rpm</td></tr>
<tr><td>1.3</td><td colspan="5">Rotational speed is less than 3000 rpm</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">To control the steam flow rate at between 303.8 - 584 kg/s by adjusting control valve in load condition</td><td rowspan="3">Secondary</td><td>2.1</td><td colspan="5">Steam is not injected</td></tr>
<tr><td>2.2</td><td colspan="5">Steam is injected more than 584 kg/s</td></tr>
<tr><td>2.3</td><td colspan="5">Steam is injected less than 303.8 kg/s</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">To control the steam flow rate at between 90 kg/s by adjusting control valve in load condition</td><td rowspan="3">Secondary</td><td>3.1</td><td colspan="5">Steam is not injected</td></tr>
<tr><td>3.2</td><td colspan="5">Steam is injected more than 90 kg/s</td></tr>
<tr><td>3.3</td><td colspan="5">Steam is injected less than 90 kg/s</td></tr>
<tr><td rowspan="3">4</td><td rowspan="3">To prevent overspeed rotation from more than 3300 rpm</td><td rowspan="3">Secondary</td><td>4.1</td><td colspan="5">Inactive of overspeed protection</td></tr>
<tr><td>4.2</td><td colspan="5">Overspeed protection activates at safe rpm (3000 rpm)</td></tr>
<tr><td>4.3</td><td colspan="5">Overspeed protection activates more than 3300 rpm</td></tr>
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<tr><td colspan="9">Equipment: 610 MW Intermediate-Pressure Turbine (MAA)</td></tr>
<tr><td colspan="3">Function</td><td colspan="6">Functional Failure</td></tr>
<tr><td>Item No.</td><td>Functional Statement</td><td>Function Type</td><td>Item No.</td><td colspan="5">Functional Failure</td></tr>
<tr><td rowspan="3">1</td><td rowspan="3">To produce rotational speed of shaft at 3000 rpm in 50 Hz</td><td rowspan="3">Primary</td><td>1.1</td><td colspan="5">Rotational speed is not produced</td></tr>
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<tr><td rowspan="3">1</td><td rowspan="3">To produce rotational speed of shaft at 3000 rpm in 50 Hz</td><td rowspan="3">Primary</td><td>1.1</td><td>Rotational speed is not produced</td></tr>
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<tr><td rowspan="3">2</td><td rowspan="3">To prevent overspeed rotation from more than 3300 rpm</td><td rowspan="3">Secondary</td><td>2.1</td><td>Inactive of overspeed protection</td></tr>
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<tr><td>SUB - SYSTEM</td><td>SUB - SYSTEM Nº</td><td>Auditor</td><td>Date</td><td>of</td></tr>
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ATTACHMENT 05
FMEA HPT (MAA)

RCM II INFORMATION WORKSHEET © 1996 ALADON LTD	SYSTEM Steam Turbine SUB - SYSTEM High Pressure Turbine	SYSTEM Nº 117844 SUB - SYSTEM Nº MAA	Facilitator Auditor	Date Date	Sheet Nº of	FORM 01

FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	A	Rotational speed is not produced	1	Stuck steam in governor due to wear out	1	This failure can easily be noticed by the operator from the situation on site or in the control room. Wear out of governor system can cause the steam stuck and not enter the turbine. Steam which is not entered absolutely stops the production which means huge loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of governor must be replaced
				2	Stuck steam in governor due to short circuit	2	This failure can easily be noticed by the operator from the situation on site or in the control room. Short circuit of governor can cause the steam stuck and not enter the turbine. Steam which is not entered absolutely stops the production which means huge loss of cost and productivity. Also, short circuit can cause a small fire in the governor system which can affect the component nearby. Short circuit of governor can be replaced
				3	Erosion on seal due to contaminated steam	3	This failure can easily be noticed on site or in the control room since the steam is visible. Contaminated steam can damage the seal component which results in erosion. Erosion on seal will cause thinning and hole which results in steam leakage. The worst case is steam leakage makes no steam rotates the turbine.

							No rotational energy from the turbine means no operation at all which also directly affects to financial and operational consequences. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on seal due to contaminated steam must be repaired.
				4	Erosion on seal due to contaminated steam	4	This failure can easily be noticed on site or in the control room since the steam is visible. Contaminated steam can damage the seal component which results in erosion. Erosion on seal will cause thinning and hole which results in steam leakage. The worst case is steam leakage makes no steam rotates the turbine. No rotational energy from the turbine means no operation at all which also directly affects to financial and operational consequences. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on seal due to contaminated steam must be repaired.
				5	Crack on seal due to wear out	5	This failure can easily be noticed on the control room. Build-up deposit can make control valve stuck and fails to be opened which means no steam is flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on control valve must be repaired
				6	Control valve fails to open due to build-up deposit	6	This failure can easily be noticed on the control room. Build-up deposit can make control valve stuck and fails to be opened which means no steam is flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial

							and operational consequences. Build-up deposit on control valve must be repaired

RCM II	SYSTEM	SYSTEM Nº	Facilitator	Date	Sheet Nº	FORM 01
INFORMATION	Steam Turbine	117844				
WORKSHEET	SUB - SYSTEM	SUB - SYSTEM Nº	Auditor	Date	of	
© 1996 ALADON LTD	High Pressure Turbine	MAA				

FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	B	Rotational speed is more than 3000 rpm	1	Erosion on valve due to contaminated steam	1	Contaminated steam can damage the valve components which results erosion. Erosion on valve can cause thinning and hole which the steam will leak from it. Less energy from the steam that will be absorbed by the rotor means less energy produced. Less energy produced results in loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on valve due to contaminated steam must be repaired
				2	Crack on valve due to wear out	2	Crack on valve can cause the steam flow rate exceeds from the required rate which can damage the turbine component. Turbine component which is damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Crack on valve due to wear out must be replaced

				3	Corrosion on valve due to contaminated steam	3	Contaminated steam can damage the valve and cause corrosion. corrosion on valve can cause the steam flow rate exceeds from the required rate which can damage the turbine component. Turbine component which is damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Corrosion on valve due to contaminated steam must be repaired
				4	Corrosion on valve due to wear out	4	Corrosion on valve can cause the steam flow rate exceeds from the required rate which can damage the turbine component. Turbine component which is damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Corrosion on valve due to wear out must be replaced
				5	Broken speed sensor due to wear out	5	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. If the speed sensor fails to detect the actual speed on turbine, it will also make the control valve does not close or open precisely as required. If the control valve opens wider than what is required, it can cause the turbine the turbine overspeed. If there is no action taken or the safety device also fails to work, the turbine components will be damaged. The worst-case scenario is the turbine components damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine

							can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Broken speed sensor due to wear out must be replaced
				6	Broken speed sensor due to short circuit	6	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. Short circuit can damage the speed sensor or even cause small fire nearby. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve opens wider than what is required, it can cause the turbine the turbine overspeed. If there is no action taken or the safety device also fails to work, the turbine components will be damaged. The worst-case scenario is the turbine components damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Broken speed sensor due to short circuit must be replaced

RCM II INFORMATION WORKSHEET © 1996 ALADON LTD	SYSTEM Steam Turbine	SYSTEM Nº 117844	Facilitator	Date	Sheet Nº	FORM 01
	SUB - SYSTEM High Pressure Turbine	SUB - SYSTEM Nº MAA	Auditor	Date	of	

FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	C	Rotational speed is less than 3000 rpm	1	Erosion on seal due to contaminated steam	1	Contaminated steam can damage the seal components which results erosion. Erosion on seal can cause thinning and hole which the steam will leak from it. Less energy from the steam that will be absorbed by the rotor means less energy produced. Less energy produced results in loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on seal due to contaminated steam must be repaired
				2	Crack on seal due to wear out	2	Crack on seal can cause the steam fully or partially leaks outside the turbine. Partial steam which leaks outside the turbine causes the rotor doesn't absorb the energy from the steam efficiently and results less energy produced. Less energy produced means loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Crack on seal due to wear out must be replaced
				3	Corrosion on seal due to contaminated steam	3	Contaminated steam can damage the seal components which results corrosion. Corrosion on seal can cause extensive pitting which the steam will leak from it. Less energy from the

							steam that will be absorbed by the rotor means less energy produced. Less energy produced results in loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Corrosion on seal due to contaminated steam must be repaired
				4	Corrosion on seal due to wear out	4	Corrosion on seal can cause extensive pitting which the steam will fully or partially leaks outside the turbine. Partial steam which leaks outside the turbine causes the rotor doesn't absorb the energy from the steam efficiently and results less energy produced. Less energy produced means loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Corrosion on seal due to wear out must be replaced
				5	Erosion on rotor due to contaminated steam	5	Contaminated steam can damage the rotor components which results erosion. Erosion on rotor can cause thinning which reduces efficiency of the turbine. Besides, thinning of rotor can also trigger initial crack. Cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Erosion on rotor due to contaminated steam must be repaired
				6	Crack on rotor due to wear out	6	Crack on rotor can cause fracture which reduces efficiency of the turbine. Besides, cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause

							an explosion if it meets the hydrogen from generator. Crack on rotor due to contaminated steam must be repaired
				7	Corrosion on rotor due to contaminated steam	7	Contaminated steam can damage the rotor components which results corrosion. Corrosion on rotor can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Corrosion on rotor due to contaminated steam must be repaired
				8	Corrosion on rotor due to wear out	8	Corrosion on rotor can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on rotor due to contaminated steam must be repaired
				9	Erosion on stator due to contaminated steam	9	Contaminated steam can damage the stator components which results erosion. Erosion on stator can cause thinning which reduces efficiency of the turbine. Besides, thinning of stator can also trigger initial crack. Cracked stator can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can

							cause an explosion if it meets the hydrogen from generator. Erosion on stator due to contaminated steam must be repaired
				10	Crack on stator due to wear out	10	Crack on stator can cause fracture which reduces efficiency of the turbine. Besides, cracked stator can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on stator due to contaminated steam must be repaired
				11	Corrosion on stator due to contaminated steam	11	Contaminated steam can damage the stator components which results corrosion. Corrosion on stator can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked stator can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Corrosion on stator due to contaminated steam must be repaired
				12	Corrosion on stator due to wear out	12	Corrosion on stator can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of stator can also trigger initial crack. Cracked stator can damage the whole turbine casing and widespread to the turbine room The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can

							cause an explosion if it meets the hydrogen from generator. Crack on stator due to contaminated steam must be repaired
				13	Erosion on shaft due to contaminated steam	13	Contaminated steam can damage the shaft which results erosion. Erosion on shaft can cause thinning which reduces efficiency of the turbine. Besides, thinning of shaft can also trigger initial crack. Cracked shaft can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Erosion on shaft due to contaminated steam must be repaired
				14	Crack on shaft due to wear out	14	Crack on shaft can cause fracture which reduces efficiency of the turbine. Besides, cracked shaft can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on shaft due to contaminated steam must be repaired
				15	Corrosion on shaft due to contaminated steam	15	Contaminated steam can damage the shaft components which results corrosion. Corrosion on shaft can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked shaft can damage the whole turbine casing and

							widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Corrosion on shaft due to contaminated steam must be repaired
				16	Corrosion on shaft due to wear out	16	Corrosion on shaft can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of shaft can also trigger initial crack. Cracked shaft can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on shaft due to contaminated steam must be repaired
				17	Rotor bending due to thermal shock	17	Rotor bending can be caused by thermal shock of uneven cooling. Rotor bending can reduce the rotational speed of turbine since it makes the rotation not smooth. Also rotor bending has a high possibility to crack. The worst case consequences is when the rotor starts to crack and the its pieces damage the turbine casing and also people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Rotor bending due to thermal shock must be repaired
				18	Stator bending due to thermal shock	18	Stator bending can be caused by thermal shock of uneven cooling. Stator bending can affect the energy from the steam which reduce rotational speed of turbine. Also stator bending has a high possibility to crack. The worst case consequences is when the stator starts to crack and the its pieces damage the

							turbine casing and also people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Stator bending due to thermal shock must be repaired
				19	Shaft bending due to thermal shock	19	Shaft bending can be caused by thermal shock of uneven cooling. Shaft bending can reduce the rotational speed of turbine since it makes the rotation not smooth. Also shaft bending has a high possibility to crack. The worst case consequences is when the shaft starts to crack and the its pieces damage the turbine casing and also people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Shaft bending due to thermal shock must be repaired
				20	Crack on rotor due to wear out of oil pump	20	Wear out of pump can cause oil to be stuck and not flowed to the rotor. Loss of lubrication can make the temperature around the rotor become hotter and also reduce rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to wear out of oil pump must be replaced
				21	Crack on bearing due to wear out of oil pump	21	Wear out of pump can cause oil to be stuck and not flowed to the bearing. Loss of lubrication can make the temperature around the bearing become hotter and also reduce bearing

							lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to wear out of oil pump must be replaced
				22	Crack on rotor due to short circuit of oil pump	22	Short circuit of electrical component on oil pump can cause oil to be stuck and not flowed to the rotor. Loss of lubrication can make the temperature around the rotor become hotter and also reduce rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to short circuit of oil pump must be replaced
				23	Crack on bearing due to short circuit of oil pump	23	Short circuit of electrical component on oil pump can cause oil to be stuck and not flowed to the bearing. Loss of lubrication can make the temperature around the bearing become hotter and also reduce rotor lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to short circuit of oil pump must be replaced
				24		24	

					Crack on rotor due to wear out of oil pipe		Wear out of oil pipe can cause leakage of oil. Loss of lubrication can make the temperature around the rotor become hotter and also reduce rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to wear out of oil pipe must be replaced
				25	Crack on bearing due to wear out of oil pipe	25	Wear out of pump can cause leakage of oil. Loss of lubrication can make the temperature around the bearing become hotter and also reduce bearing lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to wear out of oil pipe must be replaced
				26	Crack on rotor due to contaminated oil	26	Contaminated oil can cause the lubrication on the rotor less effective which results in increased temperature and also reduction of rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to contaminated oil must be replaced

				27	Crack on bearing due to contaminated oil	27	Contaminated oil can cause the lubrication on the bearing less effective which results in increased temperature and also reduction of bearing lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to contaminated oil must be replaced
				28	Speed sensor fails to detect actual rotational speed due to wear out	28	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. If the speed sensor fails to detect the actual speed on turbine, it will also make the control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of speed sensor must be replaced
				29	Speed sensor fails to detect actual rotational speed due to high temperature of turbine exceeding its operational design	29	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. High temperature exceeding the operational design can damage the speed sensor. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Broken speed sensor due to high temperature must be replaced

				30	Speed sensor fails to detect actual rotational speed due to high pressure of turbine exceeding its operational design	30	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. High pressure exceeding the operational design can damage the speed sensor. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Broken speed sensor due to high pressure must be replaced
				31	Speed sensor fails to detect actual rotational speed due to short circuit	31	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. Short circuit can damage the speed sensor or even cause small fire nearby. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. Also, fire created by short circuit can damage the component nearby. Broken speed sensor due to short circuit must be replaced

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
2	To control the steam flow rate at between 303.8 - 584 kg/s by adjusting control valve in load condition	A	Steam is not injected	1	Broken hydraulic power supply due to wear out	1	This failure mode can easily be noticed on the control room. Wear out of hydraulic power supply can cause the whole governor system stop working which results in closed control valve. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of hydraulic power supply must be replaced
				2	Broken hydraulic power supply due to short circuit	2	This failure mode can easily be noticed on the control room. Short circuit of hydraulic power supply can cause the whole governor system stop working which results in closed control valve. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Wear out of hydraulic power supply must be replaced

				3	Hydraulic servo valve fails to open the control valve due to wear out	3	This failure mode can easily be noticed on the control room. Wear out of hydraulic servomotor can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of hydraulic servomotor must be replaced
				4	Hydraulic servo valve fails to open the control valve due to short circuit	4	This failure mode can easily be noticed on the control room. Short circuit of hydraulic servomotor can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Short circuit of hydraulic servomotor must be replaced
				5	Broken selenoid valve due to wear out	5	This failure mode can easily be noticed on the control room. Wear out of selenoid valve can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of selenoid valve must be replaced

				6	Broken selenoid valve due to short circuit	6	This failure mode can easily be noticed on the control room. Short circuit of selenoid valve can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Short circuit of selenoid valve must be replaced
				7	Broken control valve actuator due to wear out	7	This failure mode can easily be noticed on the control room. Wear out of control valve actuator can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of control valve actuator must be replaced
				8	Broken control valve actuator due to short circuit	8	This failure mode can easily be noticed on the control room. Short circuit of control valve actuator can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Short circuit of control valve actuator must be replaced

				9	Stop valve wrong in receiving the actual signal which results in closing due to wear out	9	This failure mode can easily be noticed on the control room. Wear out of stop valve can be wrong in receiving the actual needs of steam. It results in closing the stop valve and no steam is flowed. No steam flowed means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of stop valve must be replaced
				10	Control valve fails to open due to built-up deposit	10	This failure mode can easily be noticed on the control room. Build-up deposit can make control valve stuck and fails to be opened which means no steam is flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on control valve must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
2	To control the steam flow rate at between 303.8 - 584 kg/s by adjusting control valve in load condition	B	Steam is injected more than 584 kg/s	1	Speed sensor fails to control actual needs of steam due to wear out	1	This failure mode can easily be noticed on the control room. Wear out of speed sensor can cause a wrong detection of actual needs of steam. It can inject exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of hydraulic servomotor must be replaced
				2	Servo valve fails to receive the actual needs of steam flow rate due to wear out	2	This failure mode can easily be noticed on the control room. Wear out of servo valve can be wrong in receiving the actual needs of steam. It results injecting exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of servo valve must be replaced

				3	Selenoid valve fails to receive the actual needs of steam flow rate due to wear out	3	This failure mode can easily be noticed on the control room. Wear out of selenoid valve can be wrong in receiving the actual needs of steam. It results injecting exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of selenoid valve must be replaced
				4	Control valve actuator fails to receive actual needs of steam flow rate due to wear out	4	This failure mode can easily be noticed on the control room. Wear out of control valve actuator can be wrong in receiving the actual needs of steam. It results injecting exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of control valve actuator must be replaced
				5	Control valve is difficult to be controlled due to built-up deposit	5	This failure mode can easily be noticed on the control room. Build-up deposit can make control valve difficult to be controlled which possibly make the steam is injected more than the required flow rate. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. . Build-up deposit on control valve must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
2	To control the steam flow rate at between 303.8 - 584 kg/s by adjusting control valve in load condition	C	Steam is injected less than 303.8 kg/s	1	Servo valve fails to receive the actual needs of steam flow rate due to wear out	1	This failure mode can easily be noticed on the control room. Wear out of servo valve can cause a wrong detection of actual needs of steam. It can inject less amount of steam than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of servo valve must be replaced
				2	Selenoid valve fails to receive the actual needs of steam flow rate due to wear out	2	This failure mode can easily be noticed on the control room. Wear out of selenoid valve can cause a wrong detection of actual needs of steam. It can inject less amount of steam than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of selenoid valve must be replaced

				3	Control valve actuator fails to receive the actual needs of steam flow rate due to wear out	3	This failure mode can easily be noticed on the control room. Wear out of control valve actuator can cause a wrong detection of actual needs of steam. It can inject less amount of steam than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of control valve actuator must be replaced
				4	Control valve is difficult to be controlled due to built-up deposit	4	This failure mode can easily be noticed on the control room. Build-up deposit can make control valve difficult to be controlled which possibly make the steam is injected less than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on control valve must be repaired
				5	Steam leakage due to seal wear out	5	This failure mode can easily be noticed on the control room. Wear out of seal can cause steam leakage which means less steam will be injected to the turbine. Steam leaked also can harm people nearby since it is high pressure and temperature. Wear out of seal must be replaced
				6	Steam leakage due to erosion on seal caused by contaminated steam	6	Contaminated steam can damage the seal components which results erosion. Erosion on seal will cause the steam leaks outside of the turbine which means less steam will be injected

							to the turbine. Steam leaked also can harm people nearby since it is high pressure and temperature. Erosion seal caused by unfunctional filter must be repaired
				7	Nozzle is hard to inject the steam as required due to built-up deposit	7	This failure mode can easily be noticed on the control room. Build-up deposit can cover the nozzle which exactly reduces the amount of steam injected. The more deposit the nozzle has, the less steam nozzle will inject. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on nozzle must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
3	To control the steam flow rate at between 90 kg/s by adjusting control valve in load condition	A	Steam is not injected	1	Broken hydraulic power supply due to wear out	1	This failure mode can easily be noticed on the control room. Wear out of hydraulic power supply can cause the whole governor system stop working which results in closed control valve. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of hydraulic power supply must be replaced
				2	Broken hydraulic power supply due to short circuit	2	This failure mode can easily be noticed on the control room. Short circuit of hydraulic power supply can cause the whole governor system stop working which results in closed control valve. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Wear out of hydraulic power supply must be replaced

				3	Hydraulic servo valve fails to open the control valve due to wear out	3	This failure mode can easily be noticed on the control room. Wear out of hydraulic servomotor can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of hydraulic servomotor must be replaced
				4	Hydraulic servo valve fails to open the control valve due to short circuit	4	This failure mode can easily be noticed on the control room. Short circuit of hydraulic servomotor can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Short circuit of hydraulic servomotor must be replaced
				5	Broken selenoid valve due to wear out	5	This failure mode can easily be noticed on the control room. Wear out of selenoid valve can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of selenoid valve must be replaced

				6	Broken selenoid valve due to short circuit	6	This failure mode can easily be noticed on the control room. Short circuit of selenoid valve can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Short circuit of selenoid valve must be replaced
				7	Broken control valve actuator due to wear out	7	This failure mode can easily be noticed on the control room. Wear out of control valve actuator can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of control valve actuator must be replaced
				8	Broken control valve actuator due to short circuit	8	This failure mode can easily be noticed on the control room. Short circuit of control valve actuator can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Short circuit of control valve actuator must be replaced

				9	Stop valve wrong in receiving the actual signal which results in closing due to wear out	9	This failure mode can easily be noticed on the control room. Wear out of stop valve can be wrong in receiving the actual needs of steam. It results in closing the stop valve and no steam is flowed. No steam flowed means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of stop valve must be replaced
				11	Control valve fails to open due to built-up deposit	11	This failure mode can easily be noticed on the control room. Build-up deposit can make control valve stuck and fails to be opened which means no steam is flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on control valve must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
3	To control the steam flow rate at between 90 kg/s by adjusting control valve in load condition	B	Steam is injected more than 90 kg/s	1	Speed sensor fails to control actual needs of steam due to wear out	1	This failure mode can easily be noticed on the control room. Wear out of speed sensor can cause a wrong detection of actual needs of steam. It can inject exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of hydraulic servomotor must be replaced
				2	Servo valve fails to receive the actual needs of steam flow rate due to wear out	2	This failure mode can easily be noticed on the control room. Wear out of servo valve can be wrong in receiving the actual needs of steam. It results injecting exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of servo valve must be replaced

				3	Selenoid valve fails to receive the actual needs of steam flow rate due to wear out	3	This failure mode can easily be noticed on the control room. Wear out of selenoid valve can be wrong in receiving the actual needs of steam. It results injecting exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of selenoid valve must be replaced
				4	Control valve actuator fails to receive actual needs of steam flow rate due to wear out	4	This failure mode can easily be noticed on the control room. Wear out of control valve actuator can be wrong in receiving the actual needs of steam. It results injecting exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of control valve actuator must be replaced
				5	Control valve is difficult to be controlled due to built-up deposit	5	This failure mode can easily be noticed on the control room. Build-up deposit can make control valve difficult to be controlled which possibly make the steam is injected more than the required flow rate. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. . Build-up deposit on control valve must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
3	To control the steam flow rate at between 90 kg/s by adjusting control valve in load condition	C	Steam is injected less than 90 kg/s	1	Servo valve fails to receive the actual needs of steam flow rate due to wear out	1	This failure mode can easily be noticed on the control room. Wear out of servo valve can cause a wrong detection of actual needs of steam. It can inject less amount of steam than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of servo valve must be replaced
				2	Selenoid valve fails to receive the actual needs of steam flow rate due to wear out	2	This failure mode can easily be noticed on the control room. Wear out of selenoid valve can cause a wrong detection of actual needs of steam. It can inject less amount of steam than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of selenoid valve must be replaced
				3		3	

					Control valve actuator fails to receive the actual needs of steam flow rate due to wear out		This failure mode can easily be noticed on the control room. Wear out of control valve actuator can cause a wrong detection of actual needs of steam. It can inject less amount of steam than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of control valve actuator must be replaced
				4	Control valve is difficult to be controlled due to built-up deposit	4	This failure mode can easily be noticed on the control room. Build-up deposit can make control valve difficult to be controlled which possibly make the steam is injected less than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on control valve must be repaired
				5	Steam leakage due to seal wear out	5	This failure mode can easily be noticed on the control room. Wear out of seal can cause steam leakage which means less steam will be injected to the turbine. Steam leaked also can harm people nearby since it is high pressure and temperature. Wear out of seal must be replaced
				6	Steam leakage due to abassive seal caused by unfunctional filter	6	This failure mode can easily be noticed on the control room. Unfunctional filter can cause the steam contaminated. Contaminated steam can damage the seal components which results abrassion. Abrassive seal will cause the steam leaks outside of the turbine which means less steam will be injected

							to the turbine. Steam leaked also can harm people nearby since it is high pressure and temperature. Abrassive seal caused by unfunctional filter must be repaired
				7	Nozzle is hard to inject the steam as required due to built-up deposit	7	This failure mode can easily be noticed on the control room. Build-up deposit can cover the nozzle which exactly reduces the amount of steam injected. The more deposit the nozzle has, the less steam nozzle will inject. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on nozzle must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
4	To prevent overspeed rotation from more than 3300 rpm	A	Inactive of overspeed protection	1	Magnetic speed sensor fails to detect the rotational speed and transmit the signal to signal processing unit due to wear out	1	The failure is difficult to be detected in normal condition. Wear out of magnetic speed sensor will cause the trip signal not to be transmitted to the signal processing unit which in the end it will keep the turbine rotating exceedingly from the operational design. If there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of agnetic speed sensor must be replaced
				2	Magnetic speed sensor fails to detect the rotational speed and transmit the signal to signal processing unit due to short circuit	2	The failure is difficult to be detected in normal condition. Short circuit of speed sensor will cause the trip signal not to be transmitted to the signal processing unit which in the end it will keep the turbine rotating exceedingly from the operational design. Also, short circuit of speed sensor has a possibility to make a fire which can burn the component nearby. And the worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from

							generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Short circuit of speed sensor must be replaced
				3	Signal processing unit fails to process and transmit the signal to trip unit due to wear out	3	The failure is difficult to be detected in normal condition. Wear out of signal processing unit will cause the trip signal not to be transmitted to the trip unit which in the end it will keep the turbine rotating exceedingly from the operational design. If there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of signal processing system must be replaced
				4	Signal processing unit fails to process and transmit the signal to trip unit due to short circuit	4	The failure is difficult to be detected in normal condition. Short circuit of signal processing unit will cause the trip signal not to be transmitted to the trip unit which in the end it will keep the turbine rotating exceedingly from the operational design. Also, short circuit of signal processing unit has a possibility to make a fire which can burn the component nearby. And the worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Short circuit of signal processing unit must be replaced

				5	Trip unit fails to open oil dump valve due to wear out	5	The failure is difficult to be detected in normal condition. Wear out of trip unit will cause the oil dump valve remain closed. Closed oil dump valve will cause the pressure of oil remain high or not reduced. Oil pressure not reduced will keep the emergency stop valve to remain close and then the turbine will keep rotating exceedingly the operational design. If there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of trip unit must be replaced
				6	Trip unit fails to open oil dump valve due to short circuit	6	The failure is difficult to be detected in normal condition. Short circuit of trip unit will cause the oil dump valve remain closed. Closed oil dump valve will cause the pressure of oil remain high or not reduced. Oil pressure not reduced will keep the emergency stop valve to remain close which can turn the turbine to keep rotating exceedingly the operational design. Also, short circuit of trip unit has possibility to make a fire which can burn the component nearby. The worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of trip unit must be replaced

				7	Oil dump valve fails to open due to a build-up deposits	7	The failure is difficult to be detected in normal condition. Deposits on oil dump valve stem can cause the valve stuck and remain closed. Closed oil dump valve will cause the pressure of oil remain high or not reduced. Oil pressure not reduced will keep the emergency stop valve remaining closed which can turn the turbine to keep rotating exceedingly the operational design. The worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Build-up deposit on oil dump valve must be repaired
				8	Emergency stop valve fails to close due to a build-up deposits on its stem	8	The failure is difficult to be detected in normal condition. Deposits on emergency stop valve stem can cause the valve stuck and remain open. If the emeregency stop valve fails to be opened while in overspeed situation, it will cause the turbine to keep rotating exceedingly the operational design. The worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Build-up deposit on emergency stop valve must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
4	To prevent overspeed rotation from more than 3300 rpm	B	Overspeed protection activates at safe rpm (3000 rpm)	1	Magnetic speed sensor fails to detect actual rotational speed due to wear out	1	This failure can be easily detected in control room or even on site. Wear out of magnetic speed sensor can possibly misread the actual rpm of the turbine. If speed sensor wrongly detects that the rpm is above the operational design, speed sensor will send a trip signal to signal processing unit which can cause the overspeed protection active in the end. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of magnetic speed must be replaced.
				2	Signal processing unit is wrong in reading the signal from speed sensor due to wear out	2	This failure can be easily detected in control room or even on site. Wear out of signal processing unit can possibly misinterpret the actual signal from the speed sensor. If the signal processing unit misinterpret the signal from speed sensor as a trip signal, that trip signal will be sent to trip unit which can cause the overspeed protection active in the end. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of signal processing unit must be replaced.
				3		3	

					Trip unit is wrong in reading the signal from signal processing unit due to wear out		This failure can be easily detected in control room or even on site. Wear out of trip unit can possibly misinterpret the actual signal from the signal processing unit. If the trip unit misinterpret the signal from signal processing unit as a trip signal, trip unit will open the oil dump valve which can cause the overspeed protection active . There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of trip must be replaced.	

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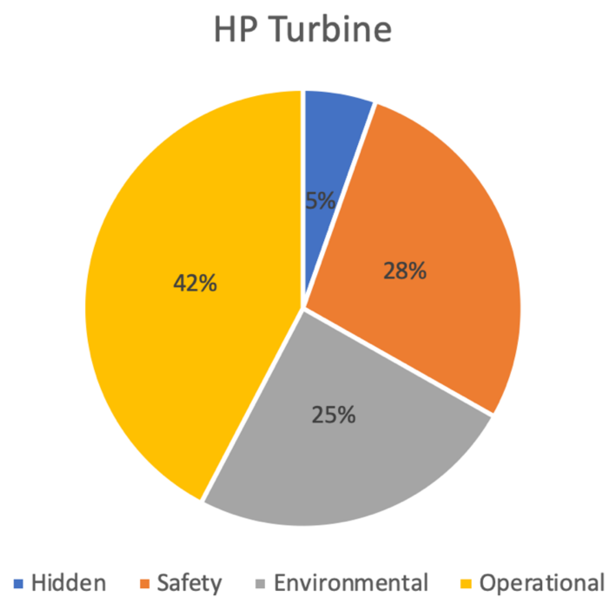
FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
4	To prevent overspeed rotation from more than 3300 rpm	C	Overspeed protection activates more than 3300 rpm	1	Magnetic speed sensor detects the rotational speed late due to wear out	1	The consequences of this failure is easy to be detected from the control room. Wear out of magnetic speed sensor will cause a late transmission of trip signal which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of magnetic speed sensor must be replaced
				2	Signal processing unit processes and transmits the trip signal to trip unit late due to wear out	2	The consequences of this failure is easy to be detected from the control room. Wear out of signal processing unit will cause a late transmission of trip signal which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has

							operational consequences which the operation will be stopped due to reparation. Wear out of signal processing unit must be replaced
				3	Trip unit opens the oil dump valve late due to wear out	3	The consequences of this failure is easy to be detected from the control room. Wear out of trip unit will cause the oil dump valve to be opened late which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of trip unit must be replaced
				4	Oil dump valve is opened late due to a build-up deposits	4	The consequences of this failure can be detected from the control room. A build-up deposit can make the oil dump valve take longer time to be opened which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped

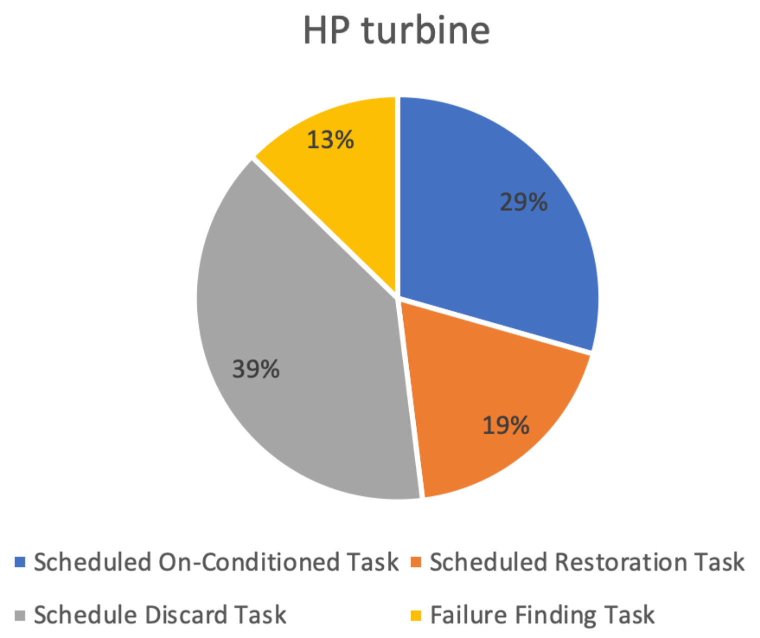
							due to reparation. A build-up deposit on oil dump valve must be repaired
				5	Emergency stop valve is closed late due to a build-up deposits	5	The consequences of this failure can be detected from the control room. A build-up deposit can make the emergency stop valve take longer time to be closed. The worst case consequences is when the overspeed condition cause a damage to the turbine component before the emergency stop valve is closed. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. A build-up deposit on emergency stop valve must be repaired

Hidden	Safety	Environment	Operation

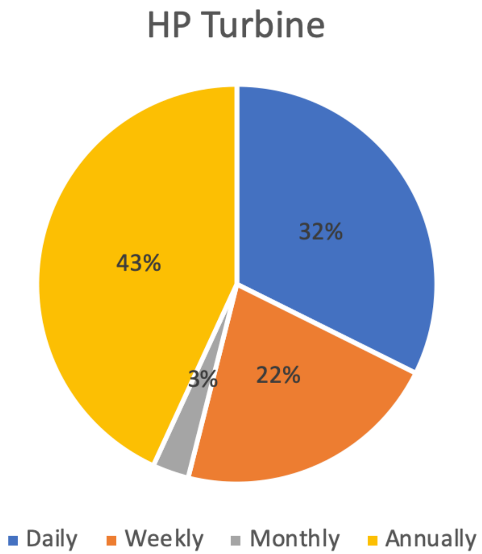
13	67	59	102


HP Turbine
5%
28%
25%
42%
Hidden
Safety
Environmental
Operational

Scheduled On-Condition Task	Scheduled Restoration Task	Scheduled Discard Task	Failure Finding Task
30	19	40	13



Daily	Weekly	Monthly	Annually
33	22	3	44



ATTACHMENT 06
FMEA IPT (MAB)

RCM II INFORMATION WORKSHEET © 1996 ALADON LTD	SYSTEM Steam Turbine SUB - SYSTEM Intermediate Pressure Turbine	SYSTEM Nº 117844 SUB - SYSTEM Nº MAB	Facilitator Auditor	Date Date	Sheet Nº of	FORM 01

FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	A	Rotational speed is not produced	1	Stuck steam in governor due to wear out	1	This failure can easily be noticed by the operator from the situation on site or in the control room. Wear out of governor system can cause the steam stuck and not enter the turbine. Steam which is not entered absolutely stops the production which means huge loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of governor must be replaced
				2	Stuck steam in governor due to short circuit	2	This failure can easily be noticed by the operator from the situation on site or in the control room. Short circuit of governor can cause the steam stuck and not enter the turbine. Steam which is not entered absolutely stops the production which means huge loss of cost and productivity. Also, short circuit can cause a small fire in the governor system which can affect the component nearby. Short circuit of governor can be replaced
				3	Erosion on seal due to contaminated steam	3	This failure can easily be noticed on site or in the control room since the steam is visible. Contaminated steam can damage the seal component which results in erosion. Erosion on seal will cause thinning and hole which results in steam leakage. The worst case is steam leakage makes no steam rotates the turbine.

							No rotational energy from the turbine means no operation at all which also directly affects to financial and operational consequences. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on seal due to contaminated steam must be repaired.
				4	Erosion on seal due to contaminated steam	4	This failure can easily be noticed on site or in the control room since the steam is visible. Contaminated steam can damage the seal component which results in erosion. Erosion on seal will cause thinning and hole which results in steam leakage. The worst case is steam leakage makes no steam rotates the turbine. No rotational energy from the turbine means no operation at all which also directly affects to financial and operational consequences. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on seal due to contaminated steam must be repaired.
				5	Crack on seal due to wear out	5	This failure can easily be noticed on the control room. Build-up deposit can make control valve stuck and fails to be opened which means no steam is flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on control valve must be repaired
				6	Control valve fails to open due to build-up deposit	6	This failure can easily be noticed on the control room. Build-up deposit can make control valve stuck and fails to be opened which means no steam is flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial

							and operational consequences. Build-up deposit on control valve must be repaired

RCM II INFORMATION WORKSHEET © 1996 ALADON LTD	SYSTEM Steam Turbine SUB - SYSTEM Intermediate Pressure Turbine	SYSTEM NΩ 117844 SUB - SYSTEM NΩ MAB	Facilitator Auditor	Date Date	Sheet NΩ of	FORM 01

FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	B	Rotational speed is more than 3000 rpm	1	Erosion on valve due to contaminated steam	1	Contaminated steam can damage the valve components which results erosion. Erosion on valve can cause thinning and hole which the steam will leak from it. Less energy from the steam that will be absorbed by the rotor means less energy produced. Less energy produced results in loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on valve due to contaminated steam must be repaired
				2	Crack on valve due to wear out	2	Crack on valve can cause the steam flow rate exceeds from the required rate which can damage the turbine component. Turbine component which is damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Crack on valve due to wear out must be replaced

				3	Corrosion on valve due to contaminated steam	3	Contaminated steam can damage the valve and cause corrosion. corrosion on valve can cause the steam flow rate exceeds from the required rate which can damage the turbine component. Turbine component which is damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Corrosion on valve due to contaminated steam must be repaired
				4	Corrosion on valve due to wear out	4	Corrosion on valve can cause the steam flow rate exceeds from the required rate which can damage the turbine component. Turbine component which is damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Corrosion on valve due to wear out must be replaced
				5	Broken speed sensor due to wear out	5	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. If the speed sensor fails to detect the actual speed on turbine, it will also make the control valve does not close or open precisely as required. If the control valve opens wider than what is required, it can cause the turbine the turbine overspeed. If there is no action taken or the safety device also fails to work, the turbine components will be damaged. The worst-case scenario is the turbine components damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine

							can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Broken speed sensor due to wear out must be replaced
				6	Broken speed sensor due to short circuit	6	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. Short circuit can damage the speed sensor or even cause small fire nearby. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve opens wider than what is required, it can cause the turbine the turbine overspeed. If there is no action taken or the safety device also fails to work, the turbine components will be damaged. The worst-case scenario is the turbine components damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Broken speed sensor due to short circuit must be replaced

RCM II INFORMATION WORKSHEET © 1996 ALADON LTD	SYSTEM: Steam Turbine	SYSTEM Nº: 117844	Facilitator	Date	Sheet Nº	FORM 01
	SUB - SYSTEM: Intermediate Pressure Turbine	SUB - SYSTEM Nº: MAB	Auditor	Date	of	

FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	C	Rotational speed is less than 3000 rpm	1	Erosion on seal due to contaminated steam	1	Contaminated steam can damage the seal components which results erosion. Erosion on seal can cause thinning and hole which the steam will leak from it. Less energy from the steam that will be absorbed by the rotor means less energy produced. Less energy produced results in loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on seal due to contaminated steam must be repaired
				2	Crack on seal due to wear out	2	Crack on seal can cause the steam fully or partially leaks outside the turbine. Partial steam which leaks outside the turbine causes the rotor doesn't absorb the energy from the steam efficiently and results less energy produced. Less energy produced means loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Crack on seal due to wear out must be replaced
				3	Corrosion on seal due to contaminated steam	3	Contaminated steam can damage the seal components which results corrosion. Corrosion on seal can cause extensive pitting which the steam will leak from it. Less energy from the

							steam that will be absorbed by the rotor means less energy produced. Less energy produced results in loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Corrosion on seal due to contaminated steam must be repaired
				4	Corrosion on seal due to wear out	4	Corrosion on seal can cause extensive pitting which the steam will fully or partially leaks outside the turbine. Partial steam which leaks outside the turbine causes the rotor doesn't absorb the energy from the steam efficiently and results less energy produced. Less energy produced means loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Corrosion on seal due to wear out must be replaced
				5	Erosion on rotor due to contaminated steam	5	Contaminated steam can damage the rotor components which results erosion. Erosion on rotor can cause thinning which reduces efficiency of the turbine. Besides, thinning of rotor can also trigger initial crack. Cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Erosion on rotor due to contaminated steam must be repaired
				6	Crack on rotor due to wear out	6	Crack on rotor can cause fracture which reduces efficiency of the turbine. Besides, cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause

							an explosion if it meets the hydrogen from generator. Crack on rotor due to contaminated steam must be repaired
				7	Corrosion on rotor due to contaminated steam	7	Contaminated steam can damage the rotor components which results corrosion. Corrosion on rotor can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Corrosion on rotor due to contaminated steam must be repaired
				8	Corrosion on rotor due to wear out	8	Corrosion on rotor can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on rotor due to contaminated steam must be repaired
				9	Erosion on stator due to contaminated steam	9	Contaminated steam can damage the stator components which results erosion. Erosion on stator can cause thinning which reduces efficiency of the turbine. Besides, thinning of stator can also trigger initial crack. Cracked stator can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can

							cause an explosion if it meets the hydrogen from generator. Erosion on stator due to contaminated steam must be repaired
				10	Crack on stator due to wear out	10	Crack on stator can cause fracture which reduces efficiency of the turbine. Besides, cracked stator can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on stator due to contaminated steam must be repaired
				11	Corrosion on stator due to contaminated steam	11	Contaminated steam can damage the stator components which results corrosion. Corrosion on stator can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked stator can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Corrosion on stator due to contaminated steam must be repaired
				12	Corrosion on stator due to wear out	12	Corrosion on stator can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of stator can also trigger initial crack. Cracked stator can damage the whole turbine casing and widespread to the turbine room The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can

							cause an explosion if it meets the hydrogen from generator. Crack on stator due to contaminated steam must be repaired
				13	Erosion on shaft due to contaminated steam	13	Contaminated steam can damage the shaft which results erosion. Erosion on shaft can cause thinning which reduces efficiency of the turbine. Besides, thinning of shaft can also trigger initial crack. Cracked shaft can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Erosion on shaft due to contaminated steam must be repaired
				14	Crack on shaft due to wear out	14	Crack on shaft can cause fracture which reduces efficiency of the turbine. Besides, cracked shaft can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on shaft due to contaminated steam must be repaired
				15	Corrosion on shaft due to contaminated steam	15	Contaminated steam can damage the shaft components which results corrosion. Corrosion on shaft can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked shaft can damage the whole turbine casing and

							widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Corrosion on shaft due to contaminated steam must be repaired
				16	Corrosion on shaft due to wear out	16	Corrosion on shaft can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of shaft can also trigger initial crack. Cracked shaft can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on shaft due to contaminated steam must be repaired
				17	Rotor bending due to thermal shock	17	Rotor bending can be caused by thermal shock of uneven cooling. Rotor bending can reduce the rotational speed of turbine since it makes the rotation not smooth. Also rotor bending has a high possibility to crack. The worst case consequences is when the rotor starts to crack and the its pieces damage the turbine casing and also people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Rotor bending due to thermal shock must be repaired
				18	Stator bending due to thermal shock	18	Stator bending can be caused by thermal shock of uneven cooling. Stator bending can affect the energy from the steam which reduce rotational speed of turbine. Also stator bending has a high possibility to crack. The worst case consequences is when the stator starts to crack and the its pieces damage the

							turbine casing and also people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Stator bending due to thermal shock must be repaired
				19	Shaft bending due to thermal shock	19	Shaft bending can be caused by thermal shock of uneven cooling. Shaft bending can reduce the rotational speed of turbine since it makes the rotation not smooth. Also shaft bending has a high possibility to crack. The worst case consequences is when the shaft starts to crack and the its pieces damage the turbine casing and also people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Shaft bending due to thermal shock must be repaired
				20	Crack on rotor due to wear out of oil pump	20	Wear out of pump can cause oil to be stuck and not flowed to the rotor. Loss of lubrication can make the temperature around the rotor become hotter and also reduce rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to wear out of oil pump must be replaced
				21	Crack on bearing due to wear out of oil pump	21	Wear out of pump can cause oil to be stuck and not flowed to the bearing. Loss of lubrication can make the temperature around the bearing become hotter and also reduce bearing

							lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to wear out of oil pump must be replaced
				22	Crack on rotor due to short circuit of oil pump	22	Short circuit of electrical component on oil pump can cause oil to be stuck and not flowed to the rotor. Loss of lubrication can make the temperature around the rotor become hotter and also reduce rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to short circuit of oil pump must be replaced
				23	Crack on bearing due to short circuit of oil pump	23	Short circuit of electrical component on oil pump can cause oil to be stuck and not flowed to the bearing. Loss of lubrication can make the temperature around the bearing become hotter and also reduce rotor lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to short circuit of oil pump must be replaced
				24		24	

					Crack on rotor due to wear out of oil pipe		Wear out of oil pipe can cause leakage of oil. Loss of lubrication can make the temperature around the rotor become hotter and also reduce rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to wear out of oil pipe must be replaced
				25	Crack on bearing due to wear out of oil pipe	25	Wear out of pump can cause leakage of oil. Loss of lubrication can make the temperature around the bearing become hotter and also reduce bearing lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to wear out of oil pipe must be replaced
				26	Crack on rotor due to contaminated oil	26	Contaminated oil can cause the lubrication on the rotor less effective which results in increased temperature and also reduction of rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to contaminated oil must be replaced

				27	Crack on bearing due to contaminated oil	27	Contaminated oil can cause the lubrication on the bearing less effective which results in increased temperature and also reduction of bearing lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to contaminated oil must be replaced
				28	Speed sensor fails to detect actual rotational speed due to wear out	28	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. If the speed sensor fails to detect the actual speed on turbine, it will also make the control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of speed sensor must be replaced
				29	Speed sensor fails to detect actual rotational speed due to high temperature of turbine exceeding its operational design	29	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. High temperature exceeding the operational design can damage the speed sensor. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Broken speed sensor due to high temperature must be replaced

				30	Speed sensor fails to detect actual rotational speed due to high pressure of turbine exceeding its operational design	30	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. High pressure exceeding the operational design can damage the speed sensor. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Broken speed sensor due to high pressure must be replaced
				31	Speed sensor fails to detect actual rotational speed due to short circuit	31	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. Short circuit can damage the speed sensor or even cause small fire nearby. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. Also, fire created by short circuit can damage the component nearby. Broken speed sensor due to short circuit must be replaced

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	SUB - SYSTEM Intermediate Pressure Turbine	SUB - SYSTEM Nº MAB	Auditor	Date	of	

FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
2	To control the steam flow rate at between 303.8 - 584 kg/s by adjusting control valve in load condition	A	Steam is not injected	1	Broken hydraulic power supply due to wear out	1	This failure mode can easily be noticed on the control room. Wear out of hydraulic power supply can cause the whole governor system stop working which results in closed control valve. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of hydraulic power supply must be replaced
				2	Broken hydraulic power supply due to short circuit	2	This failure mode can easily be noticed on the control room. Short circuit of hydraulic power supply can cause the whole governor system stop working which results in closed control valve. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Wear out of hydraulic power supply must be replaced

				3	Hydraulic servo valve fails to open the control valve due to wear out	3	This failure mode can easily be noticed on the control room. Wear out of hydraulic servomotor can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of hydraulic servomotor must be replaced
				4	Hydraulic servo valve fails to open the control valve due to short circuit	4	This failure mode can easily be noticed on the control room. Short circuit of hydraulic servomotor can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Short circuit of hydraulic servomotor must be replaced
				5	Broken selenoid valve due to wear out	5	This failure mode can easily be noticed on the control room. Wear out of selenoid valve can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of selenoid valve must be replaced

				6	Broken selenoid valve due to short circuit	6	This failure mode can easily be noticed on the control room. Short circuit of selenoid valve can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Short circuit of selenoid valve must be replaced
				7	Broken control valve actuator due to wear out	7	This failure mode can easily be noticed on the control room. Wear out of control valve actuator can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of control valve actuator must be replaced
				8	Broken control valve actuator due to short circuit	8	This failure mode can easily be noticed on the control room. Short circuit of control valve actuator can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Short circuit of control valve actuator must be replaced

				9	Stop valve wrong in receiving the actual signal which results in closing due to wear out	9	This failure mode can easily be noticed on the control room. Wear out of stop valve can be wrong in receiving the actual needs of steam. It results in closing the stop valve and no steam is flowed. No steam flowed means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of stop valve must be replaced
				10	Control valve fails to open due to built-up deposit	10	This failure mode can easily be noticed on the control room. Build-up deposit can make control valve stuck and fails to be opened which means no steam is flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on control valve must be repaired

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	SUB - SYSTEM: Intermediate Pressure Turbine	SUB - SYSTEM Nº: MAB	Auditor	Date	of	

FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
2	To control the steam flow rate at between 303.8 - 584 kg/s by adjusting control valve in load condition	B	Steam is injected more than 584 kg/s	1	Speed sensor fails to control actual needs of steam due to wear out	1	This failure mode can easily be noticed on the control room. Wear out of speed sensor can cause a wrong detection of actual needs of steam. It can inject exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of hydraulic servomotor must be replaced
				2	Servo valve fails to receive the actual needs of steam flow rate due to wear out	2	This failure mode can easily be noticed on the control room. Wear out of servo valve can be wrong in receiving the actual needs of steam. It results injecting exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of servo valve must be replaced

				3	Selenoid valve fails to receive the actual needs of steam flow rate due to wear out	3	This failure mode can easily be noticed on the control room. Wear out of selenoid valve can be wrong in receiving the actual needs of steam. It results injecting exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of selenoid valve must be replaced
				4	Control valve actuator fails to receive actual needs of steam flow rate due to wear out	4	This failure mode can easily be noticed on the control room. Wear out of control valve actuator can be wrong in receiving the actual needs of steam. It results injecting exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of control valve actuator must be replaced
				5	Control valve is difficult to be controlled due to built-up deposit	5	This failure mode can easily be noticed on the control room. Build-up deposit can make control valve difficult to be controlled which possibly make the steam is injected more than the required flow rate. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. . Build-up deposit on control valve must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
2	To control the steam flow rate at between 303.8 - 584 kg/s by adjusting control valve in load condition	C	Steam is injected less than 303.8 kg/s	1	Servo valve fails to receive the actual needs of steam flow rate due to wear out	1	This failure mode can easily be noticed on the control room. Wear out of servo valve can cause a wrong detection of actual needs of steam. It can inject less amount of steam than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of servo valve must be replaced
				2	Selenoid valve fails to receive the actual needs of steam flow rate due to wear out	2	This failure mode can easily be noticed on the control room. Wear out of selenoid valve can cause a wrong detection of actual needs of steam. It can inject less amount of steam than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of selenoid valve must be replaced

				3	Control valve actuator fails to receive the actual needs of steam flow rate due to wear out	3	This failure mode can easily be noticed on the control room. Wear out of control valve actuator can cause a wrong detection of actual needs of steam. It can inject less amount of steam than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of control valve actuator must be replaced
				4	Control valve is difficult to be controlled due to built-up deposit	4	This failure mode can easily be noticed on the control room. Build-up deposit can make control valve difficult to be controlled which possibly make the steam is injected less than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on control valve must be repaired
				5	Steam leakage due to seal wear out	5	This failure mode can easily be noticed on the control room. Wear out of seal can cause steam leakage which means less steam will be injected to the turbine. Steam leaked also can harm people nearby since it is high pressure and temperature. Wear out of seal must be replaced
				6	Steam leakage due to erosion on seal caused by contaminated steam	6	Contaminated steam can damage the seal components which results erosion. Erosion on seal will cause the steam leaks outside of the turbine which means less steam will be injected

							to the turbine. Steam leaked also can harm people nearby since it is high pressure and temperature. Erosion seal caused by unfunctional filter must be repaired
				7	Nozzle is hard to inject the steam as required due to built-up deposit	7	This failure mode can easily be noticed on the control room. Build-up deposit can cover the nozzle which exactly reduces the amount of steam injected. The more deposit the nozzle has, the less steam nozzle will inject. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on nozzle must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
3	To control the steam flow rate at between 90 kg/s by adjusting control valve in start-up condition	A	Steam is not injected	1	Broken hydraulic power supply due to wear out	1	This failure mode can easily be noticed on the control room. Wear out of hydraulic power supply can cause the whole governor system stop working which results in closed control valve. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of hydraulic power supply must be replaced
				2	Broken hydraulic power supply due to short circuit	2	This failure mode can easily be noticed on the control room. Short circuit of hydraulic power supply can cause the whole governor system stop working which results in closed control valve. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Wear out of hydraulic power supply must be replaced

				3	Hydraulic servo valve fails to open the control valve due to wear out	3	This failure mode can easily be noticed on the control room. Wear out of hydraulic servomotor can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of hydraulic servomotor must be replaced
				4	Hydraulic servo valve fails to open the control valve due to short circuit	4	This failure mode can easily be noticed on the control room. Short circuit of hydraulic servomotor can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Short circuit of hydraulic servomotor must be replaced
				5	Broken selenoid valve due to wear out	5	This failure mode can easily be noticed on the control room. Wear out of selenoid valve can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of selenoid valve must be replaced

				6	Broken selenoid valve due to short circuit	6	This failure mode can easily be noticed on the control room. Short circuit of selenoid valve can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Short circuit of selenoid valve must be replaced
				7	Broken control valve actuator due to wear out	7	This failure mode can easily be noticed on the control room. Wear out of control valve actuator can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of control valve actuator must be replaced
				8	Broken control valve actuator due to short circuit	8	This failure mode can easily be noticed on the control room. Short circuit of control valve actuator can cause the control valve remain closed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no production. Short circuit also can triggers small fire which can damage component nearby. Short circuit of control valve actuator must be replaced

				9	Stop valve wrong in receiving the actual signal which results in closing due to wear out	9	This failure mode can easily be noticed on the control room. Wear out of stop valve can be wrong in receiving the actual needs of steam. It results in closing the stop valve and no steam is flowed. No steam flowed means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of stop valve must be replaced
				11	Control valve fails to open due to built-up deposit	11	This failure mode can easily be noticed on the control room. Build-up deposit can make control valve stuck and fails to be opened which means no steam is flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on control valve must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
3	To control the steam flow rate at between 90 kg/s by adjusting control valve in start-up condition	B	Steam is injected more than 90 kg/s	1	Speed sensor fails to control actual needs of steam due to wear out	1	This failure mode can easily be noticed on the control room. Wear out of speed sensor can cause a wrong detection of actual needs of steam. It can inject exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of hydraulic servomotor must be replaced
				2	Servo valve fails to receive the actual needs of steam flow rate due to wear out	2	This failure mode can easily be noticed on the control room. Wear out of servo valve can be wrong in receiving the actual needs of steam. It results injecting exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of servo valve must be replaced

				3	Selenoid valve fails to receive the actual needs of steam flow rate due to wear out	3	This failure mode can easily be noticed on the control room. Wear out of selenoid valve can be wrong in receiving the actual needs of steam. It results injecting exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of selenoid valve must be replaced
				4	Control valve actuator fails to receive actual needs of steam flow rate due to wear out	4	This failure mode can easily be noticed on the control room. Wear out of control valve actuator can be wrong in receiving the actual needs of steam. It results injecting exceeding amount of steam although it is not needed actually. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. Wear out of control valve actuator must be replaced
				5	Control valve is difficult to be controlled due to built-up deposit	5	This failure mode can easily be noticed on the control room. Build-up deposit can make control valve difficult to be controlled which possibly make the steam is injected more than the required flow rate. The worst case consequences is exceeding steam can trigger overspeed on turbine and cause a destruction of turbine component. Destruction of turbine component also can lead to an explosion if the steam meets the hydrogen from the generator. . Build-up deposit on control valve must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
3	To control the steam flow rate at between 90 kg/s by adjusting control valve in start-up condition	C	Steam is injected less than 90 kg/s	1	Servo valve fails to receive the actual needs of steam flow rate due to wear out	1	This failure mode can easily be noticed on the control room. Wear out of servo valve can cause a wrong detection of actual needs of steam. It can inject less amount of steam than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of servo valve must be replaced
				2	Selenoid valve fails to receive the actual needs of steam flow rate due to wear out	2	This failure mode can easily be noticed on the control room. Wear out of selenoid valve can cause a wrong detection of actual needs of steam. It can inject less amount of steam than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of selenoid valve must be replaced
				3		3	

					Control valve actuator fails to receive the actual needs of steam flow rate due to wear out		This failure mode can easily be noticed on the control room. Wear out of control valve actuator can cause a wrong detection of actual needs of steam. It can inject less amount of steam than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of control valve actuator must be replaced
				4	Control valve is difficult to be controlled due to built-up deposit	4	This failure mode can easily be noticed on the control room. Build-up deposit can make control valve difficult to be controlled which possibly make the steam is injected less than the required flow rate. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on control valve must be repaired
				5	Steam leakage due to seal wear out	5	This failure mode can easily be noticed on the control room. Wear out of seal can cause steam leakage which means less steam will be injected to the turbine. Steam leaked also can harm people nearby since it is high pressure and temperature. Wear out of seal must be replaced
				6	Steam leakage due to abassive seal caused by unfunctional filter	6	This failure mode can easily be noticed on the control room. Unfunctional filter can cause the steam contaminated. Contaminated steam can damage the seal components which results abrassion. Abrassive seal will cause the steam leaks outside of the turbine which means less steam will be injected

							to the turbine. Steam leaked also can harm people nearby since it is high pressure and temperature. Abrassive seal caused by unfunctional filter must be repaired
				7	Nozzle is hard to inject the steam as required due to built-up deposit	7	This failure mode can easily be noticed on the control room. Build-up deposit can cover the nozzle which exactly reduces the amount of steam injected. The more deposit the nozzle has, the less steam nozzle will inject. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on nozzle must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
4	To prevent overspeed rotation from more than 3300 rpm	A	Inactive of overspeed protection	1	Magnetic speed sensor fails to detect the rotational speed and transmit the signal to signal processing unit due to wear out	1	The failure is difficult to be detected in normal condition. Wear out of magnetic speed sensor will cause the trip signal not to be transmitted to the signal processing unit which in the end it will keep the turbine rotating exceedingly from the operational design. If there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of agnetic speed sensor must be replaced
				2	Magnetic speed sensor fails to detect the rotational speed and transmit the signal to signal processing unit due to short circuit	2	The failure is difficult to be detected in normal condition. Short circuit of speed sensor will cause the trip signal not to be transmitted to the signal processing unit which in the end it will keep the turbine rotating exceedingly from the operational design. Also, short circuit of speed sensor has a possibility to make a fire which can burn the component nearby. And the worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from

							generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Short circuit of speed sensor must be replaced
				3	Signal processing unit fails to process and transmit the signal to trip unit due to wear out	3	The failure is difficult to be detected in normal condition. Wear out of signal processing unit will cause the trip signal not to be transmitted to the trip unit which in the end it will keep the turbine rotating exceedingly from the operational design**.** If there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of signal processing system must be replaced
				4	Signal processing unit fails to process and transmit the signal to trip unit due to short circuit	4	The failure is difficult to be detected in normal condition. Short circuit of signal processing unit will cause the trip signal not to be transmitted to the trip unit which in the end it will keep the turbine rotating exceedingly from the operational design. Also, short circuit of signal processing unit has a possibility to make a fire which can burn the component nearby. And the worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Short circuit of signal processing unit must be replaced

				5	Trip unit fails to open oil dump valve due to wear out	5	The failure is difficult to be detected in normal condition. Wear out of trip unit will cause the oil dump valve remain closed. Closed oil dump valve will cause the pressure of oil remain high or not reduced. Oil pressure not reduced will keep the emergency stop valve to remain close and then the turbine will keep rotating exceedingly the operational design. If there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of trip unit must be replaced
				6	Trip unit fails to open oil dump valve due to short circuit	6	The failure is difficult to be detected in normal condition. Short circuit of trip unit will cause the oil dump valve remain closed. Closed oil dump valve will cause the pressure of oil remain high or not reduced. Oil pressure not reduced will keep the emergency stop valve to remain close which can turn the turbine to keep rotating exceedingly the operational design. Also, short circuit of trip unit has possibility to make a fire which can burn the component nearby. The worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of trip unit must be replaced

				7	Oil dump valve fails to open due to a build-up deposits	7	The failure is difficult to be detected in normal condition. Deposits on oil dump valve stem can cause the valve stuck and remain closed. Closed oil dump valve will cause the pressure of oil remain high or not reduced. Oil pressure not reduced will keep the emergency stop valve remaining closed which can turn the turbine to keep rotating exceedingly the operational design. The worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Build-up deposit on oil dump valve must be repaired
				8	Emergency stop valve fails to close due to a build-up deposits on its stem	8	The failure is difficult to be detected in normal condition. Deposits on emergency stop valve stem can cause the valve stuck and remain open. If the emeregency stop valve fails to be opened while in overspeed situation, it will cause the turbine to keep rotating exceedingly the operational design. The worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Build-up deposit on emergency stop valve must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
4	To prevent overspeed rotation from more than 3300 rpm	B	Overspeed protection activates at safe rpm (3000 rpm)	1	Magnetic speed sensor fails to detect actual rotational speed due to wear out	1	This failure can be easily detected in control room or even on site. Wear out of magnetic speed sensor can possibly misread the actual rpm of the turbine. If speed sensor wrongly detects that the rpm is above the operational design, speed sensor will send a trip signal to signal processing unit which can cause the overspeed protection active in the end. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of magnetic speed must be replaced.
				2	Signal processing unit is wrong in reading the signal from speed sensor due to wear out	2	This failure can be easily detected in control room or even on site. Wear out of signal processing unit can possibly misinterpret the actual signal from the speed sensor. If the signal processing unit misinterpret the signal from speed sensor as a trip signal, that trip signal will be sent to trip unit which can cause the overspeed protection active in the end. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of signal processing unit must be replaced.
				3		3	

					Trip unit is wrong in reading the signal from signal processing unit due to wear out		This failure can be easily detected in control room or even on site. Wear out of trip unit can possibly misinterpret the actual signal from the signal processing unit. If the trip unit misinterpret the signal from signal processing unit as a trip signal, trip unit will open the oil dump valve which can cause the overspeed protection active . There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of trip must be replaced.

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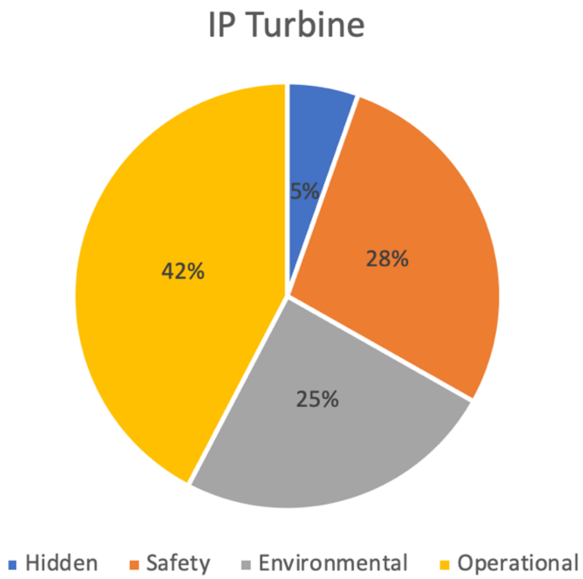
FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
4	To prevent overspeed rotation from more than 3300 rpm	C	Overspeed protection activates more than 3300 rpm	1	Magnetic speed sensor detects the rotational speed late due to wear out	1	The consequences of this failure is easy to be detected from the control room. Wear out of magnetic speed sensor will cause a late transmission of trip signal which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of magnetic speed sensor must be replaced
				2	Signal processing unit processes and transmits the trip signal to trip unit late due to wear out	2	The consequences of this failure is easy to be detected from the control room. Wear out of signal processing unit will cause a late transmission of trip signal which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has

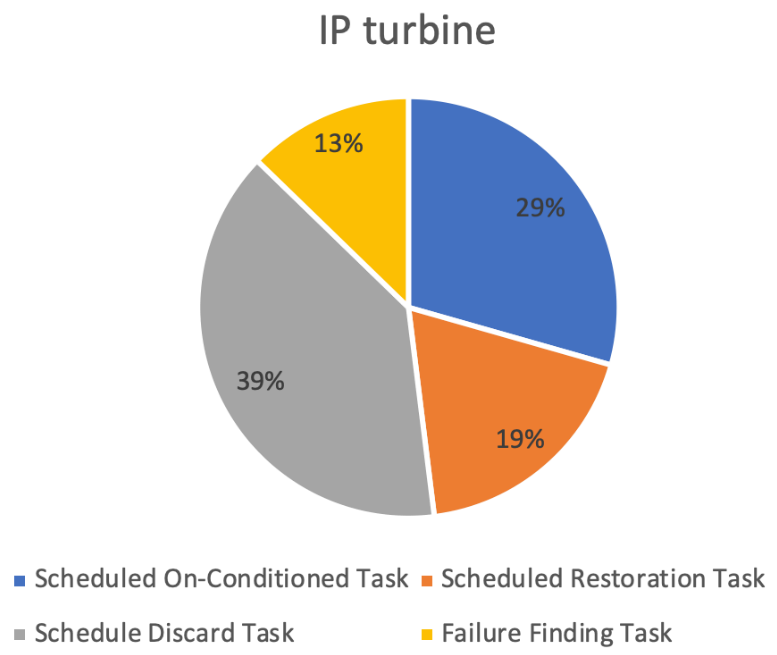
							operational consequences which the operation will be stopped due to reparation. Wear out of signal processing unit must be replaced
				3	Trip unit opens the oil dump valve late due to wear out	3	The consequences of this failure is easy to be detected from the control room. Wear out of trip unit will cause the oil dump valve to be opened late which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of trip unit must be replaced
				4	Oil dump valve is opened late due to a build-up deposits	4	The consequences of this failure can be detected from the control room. A build-up deposit can make the oil dump valve take longer time to be opened which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped

							due to reparation. A build-up deposit on oil dump valve must be repaired
				5	Emergency stop valve is closed late due to a build-up deposits	5	The consequences of this failure can be detected from the control room. A build-up deposit can make the emergency stop valve take longer time to be closed. The worst case consequences is when the overspeed condition cause a damage to the turbine component before the emergency stop valve is closed. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. A build-up deposit on emergency stop valve must be repaired

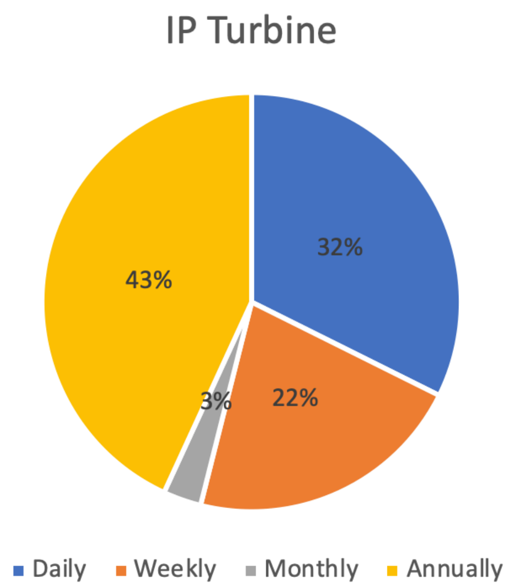
Hidden	Safety	Environmental	Operational
13	67	59	102



Scheduled On-Conditioned Task	Scheduled Restoration Task	Schedule Discard Task	Failure Finding Task
30	19	40	13



Daily	Weekly	Monthly	Annually
33	22	3	44



ATTACHMENT 07
FMEA LPT 1 (MAC10)

RCM II INFORMATION WORKSHEET © 1996 ALADON LTD	SYSTEM Steam Turbine	SYSTEM Nº 117844	Facilitator	Date	Sheet Nº	FORM 01
	SUB - SYSTEM Low Pressure Turbine 1	SUB - SYSTEM Nº MAC10	Auditor	Date	of	

FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	A	Rotational speed is not produced	1	Stuck steam in governor due to wear out	1	This failure can easily be noticed by the operator from the situation on site or in the control room. Wear out of governor system can cause the steam stuck and not enter the turbine. Steam which is not entered absolutely stops the production which means huge loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of governor must be replaced
				2	Stuck steam in governor due to short circuit	2	This failure can easily be noticed by the operator from the situation on site or in the control room. Short circuit of governor can cause the steam stuck and not enter the turbine. Steam which is not entered absolutely stops the production which means huge loss of cost and productivity. Also, short circuit can cause a small fire in the governor system which can affect the component nearby. Short circuit of governor can be replaced
				3	Erosion on seal due to contaminated steam	3	This failure can easily be noticed on site or in the control room since the steam is visible. Contaminated steam can damage the seal component which results in erosion. Erosion on seal will cause thinning and hole which results in steam leakage. The worst case is steam leakage makes no steam rotates the turbine.

							No rotational energy from the turbine means no operation at all which also directly affects to financial and operational consequences. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on seal due to contaminated steam must be repaired.
				4	Erosion on seal due to contaminated steam	4	This failure can easily be noticed on site or in the control room since the steam is visible. Contaminated steam can damage the seal component which results in erosion. Erosion on seal will cause thinning and hole which results in steam leakage. The worst case is steam leakage makes no steam rotates the turbine. No rotational energy from the turbine means no operation at all which also directly affects to financial and operational consequences. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on seal due to contaminated steam must be repaired.
				5	Crack on seal due to wear out	5	This failure can easily be noticed on the control room. Build-up deposit can make control valve stuck and fails to be opened which means no steam is flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on control valve must be repaired
				6	Control valve fails to open due to build-up deposit	6	This failure can easily be noticed on the control room. Build-up deposit can make control valve stuck and fails to be opened which means no steam is flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial

							and operational consequences. Build-up deposit on control valve must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	B	Rotational speed is more than 3000 rpm	1	Erosion on valve due to contaminated steam	1	Contaminated steam can damage the valve components which results erosion. Erosion on valve can cause thinning and hole which the steam will leak from it. Less energy from the steam that will be absorbed by the rotor means less energy produced. Less energy produced results in loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on valve due to contaminated steam must be repaired
				2	Crack on valve due to wear out	2	Crack on valve can cause the steam flow rate exceeds from the required rate which can damage the turbine component. Turbine component which is damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Crack on valve due to wear out must be replaced

				3	Corrosion on valve due to contaminated steam	3	Contaminated steam can damage the valve and cause corrosion. corrosion on valve can cause the steam flow rate exceeds from the required rate which can damage the turbine component. Turbine component which is damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Corrosion on valve due to contaminated steam must be repaired
				4	Corrosion on valve due to wear out	4	Corrosion on valve can cause the steam flow rate exceeds from the required rate which can damage the turbine component. Turbine component which is damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Corrosion on valve due to wear out must be replaced
				5	Broken speed sensor due to wear out	5	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. If the speed sensor fails to detect the actual speed on turbine, it will also make the control valve does not close or open precisely as required. If the control valve opens wider than what is required, it can cause the turbine the turbine overspeed. If there is no action taken or the safety device also fails to work, the turbine components will be damaged. The worst-case scenario is the turbine components damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine

							can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Broken speed sensor due to wear out must be replaced
				6	Broken speed sensor due to short circuit	6	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. Short circuit can damage the speed sensor or even cause small fire nearby. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve opens wider than what is required, it can cause the turbine the turbine overspeed. If there is no action taken or the safety device also fails to work, the turbine components will be damaged. The worst-case scenario is the turbine components damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Broken speed sensor due to short circuit must be replaced

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	C	Rotational speed is less than 3000 rpm	1	Erosion on seal due to contaminated steam	1	Contaminated steam can damage the seal components which results erosion. Erosion on seal can cause thinning and hole which the steam will leak from it. Less energy from the steam that will be absorbed by the rotor means less energy produced. Less energy produced results in loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on seal due to contaminated steam must be repaired
				2	Crack on seal due to wear out	2	Crack on seal can cause the steam fully or partially leaks outside the turbine. Partial steam which leaks outside the turbine causes the rotor doesn't absorb the energy from the steam efficiently and results less energy produced. Less energy produced means loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Crack on seal due to wear out must be replaced
				3	Corrosion on seal due to contaminated steam	3	Contaminated steam can damage the seal components which results corrosion. Corrosion on seal can cause extensive pitting which the steam will leak from it. Less energy from the

							steam that will be absorbed by the rotor means less energy produced. Less energy produced results in loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Corrosion on seal due to contaminated steam must be repaired
				4	Corrosion on seal due to wear out	4	Corrosion on seal can cause extensive pitting which the steam will fully or partially leaks outside the turbine. Partial steam which leaks outside the turbine causes the rotor doesn't absorb the energy from the steam efficiently and results less energy produced. Less energy produced means loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Corrosion on seal due to wear out must be replaced
				5	Erosion on rotor due to contaminated steam	5	Contaminated steam can damage the rotor components which results erosion. Erosion on rotor can cause thinning which reduces efficiency of the turbine. Besides, thinning of rotor can also trigger initial crack. Cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Erosion on rotor due to contaminated steam must be repaired
				6	Crack on rotor due to wear out	6	Crack on rotor can cause fracture which reduces efficiency of the turbine. Besides, cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause

							an explosion if it meets the hydrogen from generator. Crack on rotor due to contaminated steam must be repaired
				7	Corrosion on rotor due to contaminated steam	7	Contaminated steam can damage the rotor components which results corrosion. Corrosion on rotor can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Corrosion on rotor due to contaminated steam must be repaired
				8	Corrosion on rotor due to wear out	8	Corrosion on rotor can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on rotor due to contaminated steam must be repaired
				9	Erosion on stator due to contaminated steam	9	Contaminated steam can damage the stator components which results erosion. Erosion on stator can cause thinning which reduces efficiency of the turbine. Besides, thinning of stator can also trigger initial crack. Cracked stator can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can

							cause an explosion if it meets the hydrogen from generator. Erosion on stator due to contaminated steam must be repaired
				10	Crack on stator due to wear out	10	Crack on stator can cause fracture which reduces efficiency of the turbine. Besides, cracked stator can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on stator due to contaminated steam must be repaired
				11	Corrosion on stator due to contaminated steam	11	Contaminated steam can damage the stator components which results corrosion. Corrosion on stator can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked stator can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Corrosion on stator due to contaminated steam must be repaired
				12	Corrosion on stator due to wear out	12	Corrosion on stator can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of stator can also trigger initial crack. Cracked stator can damage the whole turbine casing and widespread to the turbine room The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can

							cause an explosion if it meets the hydrogen from generator. Crack on stator due to contaminated steam must be repaired
				13	Erosion on shaft due to contaminated steam	13	Contaminated steam can damage the shaft which results erosion. Erosion on shaft can cause thinning which reduces efficiency of the turbine. Besides, thinning of shaft can also trigger initial crack. Cracked shaft can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Erosion on shaft due to contaminated steam must be repaired
				14	Crack on shaft due to wear out	14	Crack on shaft can cause fracture which reduces efficiency of the turbine. Besides, cracked shaft can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on shaft due to contaminated steam must be repaired
				15	Corrosion on shaft due to contaminated steam	15	Contaminated steam can damage the shaft components which results corrosion. Corrosion on shaft can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked shaft can damage the whole turbine casing and

							widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Corrosion on shaft due to contaminated steam must be repaired
				16	Corrosion on shaft due to wear out	16	Corrosion on shaft can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of shaft can also trigger initial crack. Cracked shaft can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on shaft due to contaminated steam must be repaired
				17	Rotor bending due to thermal shock	17	Rotor bending can be caused by thermal shock of uneven cooling. Rotor bending can reduce the rotational speed of turbine since it makes the rotation not smooth. Also rotor bending has a high possibility to crack. The worst case consequences is when the rotor starts to crack and the its pieces damage the turbine casing and also people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Rotor bending due to thermal shock must be repaired
				18	Stator bending due to thermal shock	18	Stator bending can be caused by thermal shock of uneven cooling. Stator bending can affect the energy from the steam which reduce rotational speed of turbine. Also stator bending has a high possibility to crack. The worst case consequences is when the stator starts to crack and the its pieces damage the

							turbine casing and also people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Stator bending due to thermal shock must be repaired
				19	Shaft bending due to thermal shock	19	Shaft bending can be caused by thermal shock of uneven cooling. Shaft bending can reduce the rotational speed of turbine since it makes the rotation not smooth. Also shaft bending has a high possibility to crack. The worst case consequences is when the shaft starts to crack and the its pieces damage the turbine casing and also people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Shaft bending due to thermal shock must be repaired
				20	Crack on rotor due to wear out of oil pump	20	Wear out of pump can cause oil to be stuck and not flowed to the rotor. Loss of lubrication can make the temperature around the rotor become hotter and also reduce rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to wear out of oil pump must be replaced
				21	Crack on bearing due to wear out of oil pump	21	Wear out of pump can cause oil to be stuck and not flowed to the bearing. Loss of lubrication can make the temperature around the bearing become hotter and also reduce bearing

							lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to wear out of oil pump must be replaced
				22	Crack on rotor due to short circuit of oil pump	22	Short circuit of electrical component on oil pump can cause oil to be stuck and not flowed to the rotor. Loss of lubrication can make the temperature around the rotor become hotter and also reduce rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to short circuit of oil pump must be replaced
				23	Crack on bearing due to short circuit of oil pump	23	Short circuit of electrical component on oil pump can cause oil to be stuck and not flowed to the bearing. Loss of lubrication can make the temperature around the bearing become hotter and also reduce rotor lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to short circuit of oil pump must be replaced
				24		24	

					Crack on rotor due to wear out of oil pipe		Wear out of oil pipe can cause leakage of oil. Loss of lubrication can make the temperature around the rotor become hotter and also reduce rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to wear out of oil pipe must be replaced
				25	Crack on bearing due to wear out of oil pipe	25	Wear out of pump can cause leakage of oil. Loss of lubrication can make the temperature around the bearing become hotter and also reduce bearing lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to wear out of oil pipe must be replaced
				26	Crack on rotor due to contaminated oil	26	Contaminated oil can cause the lubrication on the rotor less effective which results in increased temperature and also reduction of rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to contaminated oil must be replaced

				27	Crack on bearing due to contaminated oil	27	Contaminated oil can cause the lubrication on the bearing less effective which results in increased temperature and also reduction of bearing lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to contaminated oil must be replaced
				28	Speed sensor fails to detect actual rotational speed due to wear out	28	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. If the speed sensor fails to detect the actual speed on turbine, it will also make the control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of speed sensor must be replaced
				29	Speed sensor fails to detect actual rotational speed due to high temperature of turbine exceeding its operational design	29	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. High temperature exceeding the operational design can damage the speed sensor. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Broken speed sensor due to high temperature must be replaced

				30	Speed sensor fails to detect actual rotational speed due to high pressure of turbine exceeding its operational design	30	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. High pressure exceeding the operational design can damage the speed sensor. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Broken speed sensor due to high pressure must be replaced
				31	Speed sensor fails to detect actual rotational speed due to short circuit	31	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. Short circuit can damage the speed sensor or even cause small fire nearby. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. Also, fire created by short circuit can damage the component nearby. Broken speed sensor due to short circuit must be replaced

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
2	To prevent overspeed rotation from more than 3300 rpm	A	Inactive of overspeed protection	1	Magnetic speed sensor fails to detect the rotational speed and transmit the signal to signal processing unit due to wear out	1	The failure is difficult to be detected in normal condition. Wear out of magnetic speed sensor will cause the trip signal not to be transmitted to the signal processing unit which in the end it will keep the turbine rotating exceedingly from the operational design. If there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of agnetic speed sensor must be replaced
				2	Magnetic speed sensor fails to detect the rotational speed and transmit the signal to signal processing unit due to short circuit	2	The failure is difficult to be detected in normal condition. Short circuit of speed sensor will cause the trip signal not to be transmitted to the signal processing unit which in the end it will keep the turbine rotating exceedingly from the operational design. Also, short circuit of speed sensor has a possibility to make a fire which can burn the component nearby. And the worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from

							generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Short circuit of speed sensor must be replaced
				3	Signal processing unit fails to process and transmit the signal to trip unit due to wear out	3	The failure is difficult to be detected in normal condition. Wear out of signal processing unit will cause the trip signal not to be transmitted to the trip unit which in the end it will keep the turbine rotating exceedingly from the operational design. If there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of signal processing system must be replaced
				4	Signal processing unit fails to process and transmit the signal to trip unit due to short circuit	4	The failure is difficult to be detected in normal condition. Short circuit of signal processing unit will cause the trip signal not to be transmitted to the trip unit which in the end it will keep the turbine rotating exceedingly from the operational design. Also, short circuit of signal processing unit has a possibility to make a fire which can burn the component nearby. And the worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Short circuit of signal processing unit must be replaced

				5	Trip unit fails to open oil dump valve due to wear out	5	The failure is difficult to be detected in normal condition. Wear out of trip unit will cause the oil dump valve remain closed. Closed oil dump valve will cause the pressure of oil remain high or not reduced. Oil pressure not reduced will keep the emergency stop valve to remain close and then the turbine will keep rotating exceedingly the operational design. If there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of trip unit must be replaced
				6	Trip unit fails to open oil dump valve due to short circuit	6	The failure is difficult to be detected in normal condition. Short circuit of trip unit will cause the oil dump valve remain closed. Closed oil dump valve will cause the pressure of oil remain high or not reduced. Oil pressure not reduced will keep the emergency stop valve to remain close which can turn the turbine to keep rotating exceedingly the operational design. Also, short circuit of trip unit has possibility to make a fire which can burn the component nearby. The worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of trip unit must be replaced

				7	Oil dump valve fails to open due to a build-up deposits	7	The failure is difficult to be detected in normal condition. Deposits on oil dump valve stem can cause the valve stuck and remain closed. Closed oil dump valve will cause the pressure of oil remain high or not reduced. Oil pressure not reduced will keep the emergency stop valve remaining closed which can turn the turbine to keep rotating exceedingly the operational design. The worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Build-up deposit on oil dump valve must be repaired
				8	Emergency stop valve fails to close due to a build-up deposits on its stem	8	The failure is difficult to be detected in normal condition. Deposits on emergency stop valve stem can cause the valve stuck and remain open. If the emeregency stop valve fails to be opened while in overspeed situation, it will cause the turbine to keep rotating exceedingly the operational design. The worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Build-up deposit on emergency stop valve must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
2	To prevent overspeed rotation from more than 3300 rpm	B	Overspeed protection activates at safe rpm (3000 rpm)	1	Magnetic speed sensor fails to detect actual rotational speed due to wear out	1	This failure can be easily detected in control room or even on site. Wear out of magnetic speed sensor can possibly misread the actual rpm of the turbine. If speed sensor wrongly detects that the rpm is above the operational design, speed sensor will send a trip signal to signal processing unit which can cause the overspeed protection active in the end. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of magnetic speed must be replaced.
				2	Signal processing unit is wrong in reading the signal from speed sensor due to wear out	2	This failure can be easily detected in control room or even on site. Wear out of signal processing unit can possibly misinterpret the actual signal from the speed sensor. If the signal processing unit misinterpret the signal from speed sensor as a trip signal, that trip signal will be sent to trip unit which can cause the overspeed protection active in the end. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of signal processing unit must be replaced.
				3		3	

					Trip unit is wrong in reading the signal from signal processing unit due to wear out		This failure can be easily detected in control room or even on site. Wear out of trip unit can possibly misinterpret the actual signal from the signal processing unit. If the trip unit misinterpret the signal from signal processing unit as a trip signal, trip unit will open the oil dump valve which can cause the overspeed protection active . There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of trip must be replaced.

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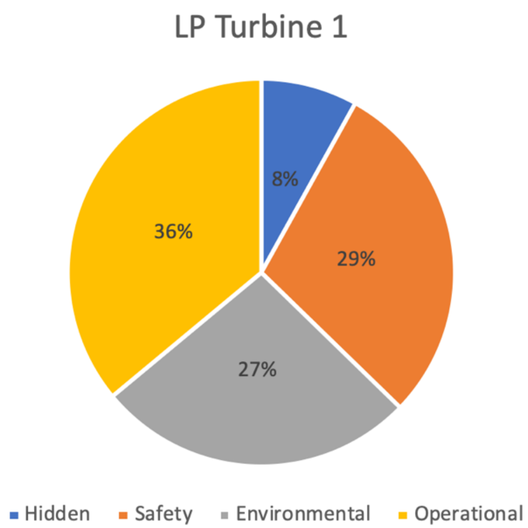
FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
2	To prevent overspeed rotation from more than 3300 rpm	C	Overspeed protection activates more than 3300 rpm	1	Magnetic speed sensor detects the rotational speed late due to wear out	1	The consequences of this failure is easy to be detected from the control room. Wear out of magnetic speed sensor will cause a late transmission of trip signal which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of magnetic speed sensor must be replaced
				2	Signal processing unit processes and transmits the trip signal to trip unit late due to wear out	2	The consequences of this failure is easy to be detected from the control room. Wear out of signal processing unit will cause a late transmission of trip signal which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has

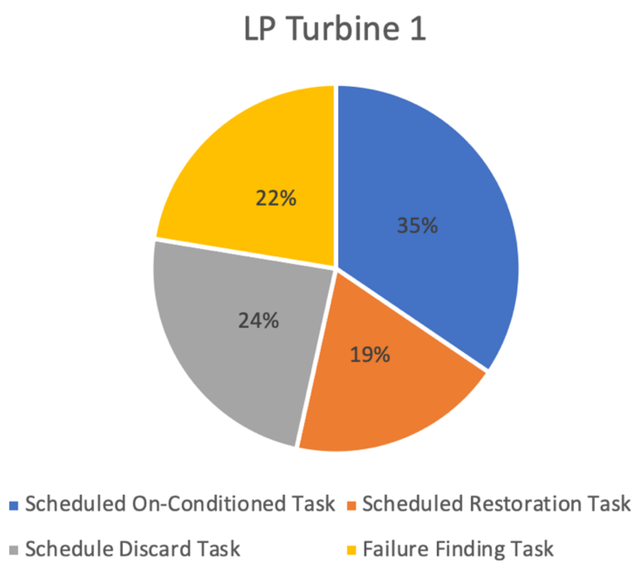
							operational consequences which the operation will be stopped due to reparation. Wear out of signal processing unit must be replaced
				3	Trip unit opens the oil dump valve late due to wear out	3	The consequences of this failure is easy to be detected from the control room. Wear out of trip unit will cause the oil dump valve to be opened late which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of trip unit must be replaced
				4	Oil dump valve is opened late due to a build-up deposits	4	The consequences of this failure can be detected from the control room. A build-up deposit can make the oil dump valve take longer time to be opened which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped

							due to reparation. A build-up deposit on oil dump valve must be repaired
				5	Emergency stop valve is closed late due to a build-up deposits	5	The consequences of this failure can be detected from the control room. A build-up deposit can make the emergency stop valve take longer time to be closed. The worst case consequences is when the overspeed condition cause a damage to the turbine component before the emergency stop valve is closed. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. A build-up deposit on emergency stop valve must be repaired

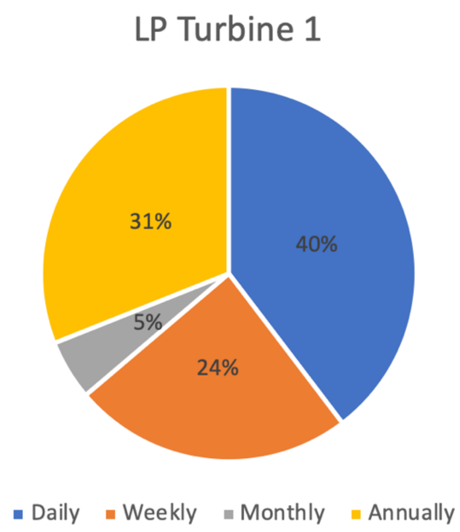
Hidden	Safety	Environmental	Operational
13	47	43	58


LP Turbine 1
8%
29%
27%
36%
Hidden
Safety
Environmental
Operational

Scheduled On-Conditioned Task	Scheduled Restoration Task	Schedule Discard Task	Failure Finding Task
20	11	14	13



Daily	Weekly	Monthly	Annually
23	14	3	18



ATTACHMENT 08
FMEA LPT 2 (MAC20)

RCM II INFORMATION WORKSHEET © 1996 ALADON LTD	SYSTEM Steam Turbine SUB - SYSTEM Low Pressure Turbine 2	SYSTEM NΩ 117844 SUB - SYSTEM NΩ MAC20	Facilitator Auditor	Date Date	Sheet NΩ of	FORM 01

FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	A	Rotational speed is not produced	1	Stuck steam in governor due to wear out	1	This failure can easily be noticed by the operator from the situation on site or in the control room. Wear out of governor system can cause the steam stuck and not enter the turbine. Steam which is not entered absolutely stops the production which means huge loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of governor must be replaced
				2	Stuck steam in governor due to short circuit	2	This failure can easily be noticed by the operator from the situation on site or in the control room. Short circuit of governor can cause the steam stuck and not enter the turbine. Steam which is not entered absolutely stops the production which means huge loss of cost and productivity. Also, short circuit can cause a small fire in the governor system which can affect the component nearby. Short circuit of governor can be replaced
				3	Erosion on seal due to contaminated steam	3	This failure can easily be noticed on site or in the control room since the steam is visible. Contaminated steam can damage the seal component which results in erosion. Erosion on seal will cause thinning and hole which results in steam leakage. The worst case is steam leakage makes no steam rotates the turbine.

							No rotational energy from the turbine means no operation at all which also directly affects to financial and operational consequences. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on seal due to contaminated steam must be repaired.
				4	Erosion on seal due to contaminated steam	4	This failure can easily be noticed on site or in the control room since the steam is visible. Contaminated steam can damage the seal component which results in erosion. Erosion on seal will cause thinning and hole which results in steam leakage. The worst case is steam leakage makes no steam rotates the turbine. No rotational energy from the turbine means no operation at all which also directly affects to financial and operational consequences. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on seal due to contaminated steam must be repaired.
				5	Crack on seal due to wear out	5	This failure can easily be noticed on the control room. Build-up deposit can make control valve stuck and fails to be opened which means no steam is flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Build-up deposit on control valve must be repaired
				6	Control valve fails to open due to build-up deposit	6	This failure can easily be noticed on the control room. Build-up deposit can make control valve stuck and fails to be opened which means no steam is flowed to the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial

							and operational consequences. Build-up deposit on control valve must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	B	Rotational speed is more than 3000 rpm	1	Erosion on valve due to contaminated steam	1	Contaminated steam can damage the valve components which results erosion. Erosion on valve can cause thinning and hole which the steam will leak from it. Less energy from the steam that will be absorbed by the rotor means less energy produced. Less energy produced results in loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on valve due to contaminated steam must be repaired
				2	Crack on valve due to wear out	2	Crack on valve can cause the steam flow rate exceeds from the required rate which can damage the turbine component. Turbine component which is damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Crack on valve due to wear out must be replaced

				3	Corrosion on valve due to contaminated steam	3	Contaminated steam can damage the valve and cause corrosion. corrosion on valve can cause the steam flow rate exceeds from the required rate which can damage the turbine component. Turbine component which is damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Corrosion on valve due to contaminated steam must be repaired
				4	Corrosion on valve due to wear out	4	Corrosion on valve can cause the steam flow rate exceeds from the required rate which can damage the turbine component. Turbine component which is damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Corrosion on valve due to wear out must be replaced
				5	Broken speed sensor due to wear out	5	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. If the speed sensor fails to detect the actual speed on turbine, it will also make the control valve does not close or open precisely as required. If the control valve opens wider than what is required, it can cause the turbine the turbine overspeed. If there is no action taken or the safety device also fails to work, the turbine components will be damaged. The worst-case scenario is the turbine components damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine

							can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Broken speed sensor due to wear out must be replaced
				6	Broken speed sensor due to short circuit	6	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. Short circuit can damage the speed sensor or even cause small fire nearby. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve opens wider than what is required, it can cause the turbine the turbine overspeed. If there is no action taken or the safety device also fails to work, the turbine components will be damaged. The worst-case scenario is the turbine components damaged into pieces can widespread and harm person nearby. The leakage of the hot steam from turbine can cause an explosion if it meets the hydrogen from generator area. This failure also can cause an operational consequences which it will stop the production. Broken speed sensor due to short circuit must be replaced

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	C	Rotational speed is less than 3000 rpm	1	Erosion on seal due to contaminated steam	1	Contaminated steam can damage the seal components which results erosion. Erosion on seal can cause thinning and hole which the steam will leak from it. Less energy from the steam that will be absorbed by the rotor means less energy produced. Less energy produced results in loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Erosion on seal due to contaminated steam must be repaired
				2	Crack on seal due to wear out	2	Crack on seal can cause the steam fully or partially leaks outside the turbine. Partial steam which leaks outside the turbine causes the rotor doesn't absorb the energy from the steam efficiently and results less energy produced. Less energy produced means loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Crack on seal due to wear out must be replaced
				3	Corrosion on seal due to contaminated steam	3	Contaminated steam can damage the seal components which results corrosion. Corrosion on seal can cause extensive pitting which the steam will leak from it. Less energy from the

							steam that will be absorbed by the rotor means less energy produced. Less energy produced results in loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Corrosion on seal due to contaminated steam must be repaired
				4	Corrosion on seal due to wear out	4	Corrosion on seal can cause extensive pitting which the steam will fully or partially leaks outside the turbine. Partial steam which leaks outside the turbine causes the rotor doesn't absorb the energy from the steam efficiently and results less energy produced. Less energy produced means loss of cost and productivity. Also the steam which leaks can harm the operator nearby since it is high temperature and pressure. Corrosion on seal due to wear out must be replaced
				5	Erosion on rotor due to contaminated steam	5	Contaminated steam can damage the rotor components which results erosion. Erosion on rotor can cause thinning which reduces efficiency of the turbine. Besides, thinning of rotor can also trigger initial crack. Cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Erosion on rotor due to contaminated steam must be repaired
				6	Crack on rotor due to wear out	6	Crack on rotor can cause fracture which reduces efficiency of the turbine. Besides, cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause

							an explosion if it meets the hydrogen from generator. Crack on rotor due to contaminated steam must be repaired
				7	Corrosion on rotor due to contaminated steam	7	Contaminated steam can damage the rotor components which results corrosion. Corrosion on rotor can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Corrosion on rotor due to contaminated steam must be repaired
				8	Corrosion on rotor due to wear out	8	Corrosion on rotor can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked rotor can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on rotor due to contaminated steam must be repaired
				9	Erosion on stator due to contaminated steam	9	Contaminated steam can damage the stator components which results erosion. Erosion on stator can cause thinning which reduces efficiency of the turbine. Besides, thinning of stator can also trigger initial crack. Cracked stator can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can

							cause an explosion if it meets the hydrogen from generator. Erosion on stator due to contaminated steam must be repaired
				10	Crack on stator due to wear out	10	Crack on stator can cause fracture which reduces efficiency of the turbine. Besides, cracked stator can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on stator due to contaminated steam must be repaired
				11	Corrosion on stator due to contaminated steam	11	Contaminated steam can damage the stator components which results corrosion. Corrosion on stator can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked stator can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Corrosion on stator due to contaminated steam must be repaired
				12	Corrosion on stator due to wear out	12	Corrosion on stator can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of stator can also trigger initial crack. Cracked stator can damage the whole turbine casing and widespread to the turbine room The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can

							cause an explosion if it meets the hydrogen from generator. Crack on stator due to contaminated steam must be repaired
				13	Erosion on shaft due to contaminated steam	13	Contaminated steam can damage the shaft which results erosion. Erosion on shaft can cause thinning which reduces efficiency of the turbine. Besides, thinning of shaft can also trigger initial crack. Cracked shaft can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Erosion on shaft due to contaminated steam must be repaired
				14	Crack on shaft due to wear out	14	Crack on shaft can cause fracture which reduces efficiency of the turbine. Besides, cracked shaft can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on shaft due to contaminated steam must be repaired
				15	Corrosion on shaft due to contaminated steam	15	Contaminated steam can damage the shaft components which results corrosion. Corrosion on shaft can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of rotor can also trigger initial crack. Cracked shaft can damage the whole turbine casing and

							widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Corrosion on shaft due to contaminated steam must be repaired
				16	Corrosion on shaft due to wear out	16	Corrosion on shaft can cause extensive pitting which reduces efficiency of the turbine. Besides, extensive pitting of shaft can also trigger initial crack. Cracked shaft can damage the whole turbine casing and widespread to the turbine room. The steam which leaks can harm the operator nearby since it is high temperature and pressure. Also the worst case is it can cause an explosion if it meets the hydrogen from generator. Crack on shaft due to contaminated steam must be repaired
				17	Rotor bending due to thermal shock	17	Rotor bending can be caused by thermal shock of uneven cooling. Rotor bending can reduce the rotational speed of turbine since it makes the rotation not smooth. Also rotor bending has a high possibility to crack. The worst case consequences is when the rotor starts to crack and the its pieces damage the turbine casing and also people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Rotor bending due to thermal shock must be repaired
				18	Stator bending due to thermal shock	18	Stator bending can be caused by thermal shock of uneven cooling. Stator bending can affect the energy from the steam which reduce rotational speed of turbine. Also stator bending has a high possibility to crack. The worst case consequences is when the stator starts to crack and the its pieces damage the

							turbine casing and also people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Stator bending due to thermal shock must be repaired
				19	Shaft bending due to thermal shock	19	Shaft bending can be caused by thermal shock of uneven cooling. Shaft bending can reduce the rotational speed of turbine since it makes the rotation not smooth. Also shaft bending has a high possibility to crack. The worst case consequences is when the shaft starts to crack and the its pieces damage the turbine casing and also people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Shaft bending due to thermal shock must be repaired
				20	Crack on rotor due to wear out of oil pump	20	Wear out of pump can cause oil to be stuck and not flowed to the rotor. Loss of lubrication can make the temperature around the rotor become hotter and also reduce rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to wear out of oil pump must be replaced
				21	Crack on bearing due to wear out of oil pump	21	Wear out of pump can cause oil to be stuck and not flowed to the bearing. Loss of lubrication can make the temperature around the bearing become hotter and also reduce bearing

							lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to wear out of oil pump must be replaced
				22	Crack on rotor due to short circuit of oil pump	22	Short circuit of electrical component on oil pump can cause oil to be stuck and not flowed to the rotor. Loss of lubrication can make the temperature around the rotor become hotter and also reduce rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to short circuit of oil pump must be replaced
				23	Crack on bearing due to short circuit of oil pump	23	Short circuit of electrical component on oil pump can cause oil to be stuck and not flowed to the bearing. Loss of lubrication can make the temperature around the bearing become hotter and also reduce rotor lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to short circuit of oil pump must be replaced
				24		24	

					Crack on rotor due to wear out of oil pipe		Wear out of oil pipe can cause leakage of oil. Loss of lubrication can make the temperature around the rotor become hotter and also reduce rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to wear out of oil pipe must be replaced
				25	Crack on bearing due to wear out of oil pipe	25	Wear out of pump can cause leakage of oil. Loss of lubrication can make the temperature around the bearing become hotter and also reduce bearing lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to wear out of oil pipe must be replaced
				26	Crack on rotor due to contaminated oil	26	Contaminated oil can cause the lubrication on the rotor less effective which results in increased temperature and also reduction of rotor lifetime. This failure also can make the rotor crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on rotor due to contaminated oil must be replaced

				27	Crack on bearing due to contaminated oil	27	Contaminated oil can cause the lubrication on the bearing less effective which results in increased temperature and also reduction of bearing lifetime. This failure also can make the bearing crack into pieces and damage the whole turbine. Damaged turbine can harm people nearby and the leakage of steam can cause an explosion if it meets hydrogen from the generator. Crack on bearing due to contaminated oil must be replaced
				28	Speed sensor fails to detect actual rotational speed due to wear out	28	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. If the speed sensor fails to detect the actual speed on turbine, it will also make the control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of speed sensor must be replaced
				29	Speed sensor fails to detect actual rotational speed due to high temperature of turbine exceeding its operational design	29	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. High temperature exceeding the operational design can damage the speed sensor. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Broken speed sensor due to high temperature must be replaced

				30	Speed sensor fails to detect actual rotational speed due to high pressure of turbine exceeding its operational design	30	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. High pressure exceeding the operational design can damage the speed sensor. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Broken speed sensor due to high pressure must be replaced
				31	Speed sensor fails to detect actual rotational speed due to short circuit	31	The consequences of this failure can be noticed in the control room. Speed sensor is an instrument which triggers the angle of opening or closing valve based on the speed detected. Short circuit can damage the speed sensor or even cause small fire nearby. Failure in speed sensor can cause control valve does not close or open precisely as required. If the control valve closes wider than what is required, it can cause efficiency drop which results in loss of cost and productivity. Also, fire created by short circuit can damage the component nearby. Broken speed sensor due to short circuit must be replaced

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
2	To prevent overspeed rotation from more than 3300 rpm	A	Inactive of overspeed protection	1	Magnetic speed sensor fails to detect the rotational speed and transmit the signal to signal processing unit due to wear out	1	The failure is difficult to be detected in normal condition. Wear out of magnetic speed sensor will cause the trip signal not to be transmitted to the signal processing unit which in the end it will keep the turbine rotating exceedingly from the operational design. If there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of agnetic speed sensor must be replaced
				2	Magnetic speed sensor fails to detect the rotational speed and transmit the signal to signal processing unit due to short circuit	2	The failure is difficult to be detected in normal condition. Short circuit of speed sensor will cause the trip signal not to be transmitted to the signal processing unit which in the end it will keep the turbine rotating exceedingly from the operational design. Also, short circuit of speed sensor has a possibility to make a fire which can burn the component nearby. And the worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from

							generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Short circuit of speed sensor must be replaced
				3	Signal processing unit fails to process and transmit the signal to trip unit due to wear out	3	The failure is difficult to be detected in normal condition. Wear out of signal processing unit will cause the trip signal not to be transmitted to the trip unit which in the end it will keep the turbine rotating exceedingly from the operational design**.** If there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of signal processing system must be replaced
				4	Signal processing unit fails to process and transmit the signal to trip unit due to short circuit	4	The failure is difficult to be detected in normal condition. Short circuit of signal processing unit will cause the trip signal not to be transmitted to the trip unit which in the end it will keep the turbine rotating exceedingly from the operational design. Also, short circuit of signal processing unit has a possibility to make a fire which can burn the component nearby. And the worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Short circuit of signal processing unit must be replaced

				5	Trip unit fails to open oil dump valve due to wear out	5	The failure is difficult to be detected in normal condition. Wear out of trip unit will cause the oil dump valve remain closed. Closed oil dump valve will cause the pressure of oil remain high or not reduced. Oil pressure not reduced will keep the emergency stop valve to remain close and then the turbine will keep rotating exceedingly the operational design. If there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of trip unit must be replaced
				6	Trip unit fails to open oil dump valve due to short circuit	6	The failure is difficult to be detected in normal condition. Short circuit of trip unit will cause the oil dump valve remain closed. Closed oil dump valve will cause the pressure of oil remain high or not reduced. Oil pressure not reduced will keep the emergency stop valve to remain close which can turn the turbine to keep rotating exceedingly the operational design. Also, short circuit of trip unit has possibility to make a fire which can burn the component nearby. The worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of trip unit must be replaced

				7	Oil dump valve fails to open due to a build-up deposits	7	The failure is difficult to be detected in normal condition. Deposits on oil dump valve stem can cause the valve stuck and remain closed. Closed oil dump valve will cause the pressure of oil remain high or not reduced. Oil pressure not reduced will keep the emergency stop valve remaining closed which can turn the turbine to keep rotating exceedingly the operational design. The worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Build-up deposit on oil dump valve must be repaired
				8	Emergency stop valve fails to close due to a build-up deposits on its stem	8	The failure is difficult to be detected in normal condition. Deposits on emergency stop valve stem can cause the valve stuck and remain open. If the emeregency stop valve fails to be opened while in overspeed situation, it will cause the turbine to keep rotating exceedingly the operational design. The worst-case consequences is if there is no immediate action prior to that failure, the turbine components will be damaged and the broken pieces will widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside envirnomental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Build-up deposit on emergency stop valve must be repaired

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FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
2	To prevent overspeed rotation from more than 3300 rpm	B	Overspeed protection activates at safe rpm (3000 rpm)	1	Magnetic speed sensor fails to detect actual rotational speed due to wear out	1	This failure can be easily detected in control room or even on site. Wear out of magnetic speed sensor can possibly misread the actual rpm of the turbine. If speed sensor wrongly detects that the rpm is above the operational design, speed sensor will send a trip signal to signal processing unit which can cause the overspeed protection active in the end. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of magnetic speed must be replaced.
				2	Signal processing unit is wrong in reading the signal from speed sensor due to wear out	2	This failure can be easily detected in control room or even on site. Wear out of signal processing unit can possibly misinterpret the actual signal from the speed sensor. If the signal processing unit misinterpret the signal from speed sensor as a trip signal, that trip signal will be sent to trip unit which can cause the overspeed protection active in the end. There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of signal processing unit must be replaced.
				3		3	

					Trip unit is wrong in reading the signal from signal processing unit due to wear out		This failure can be easily detected in control room or even on site. Wear out of trip unit can possibly misinterpret the actual signal from the signal processing unit. If the trip unit misinterpret the signal from signal processing unit as a trip signal, trip unit will open the oil dump valve which can cause the overspeed protection active . There is no safety nor environmental consequences in this failure, only financial and operational consequences. Wear out of trip must be replaced.

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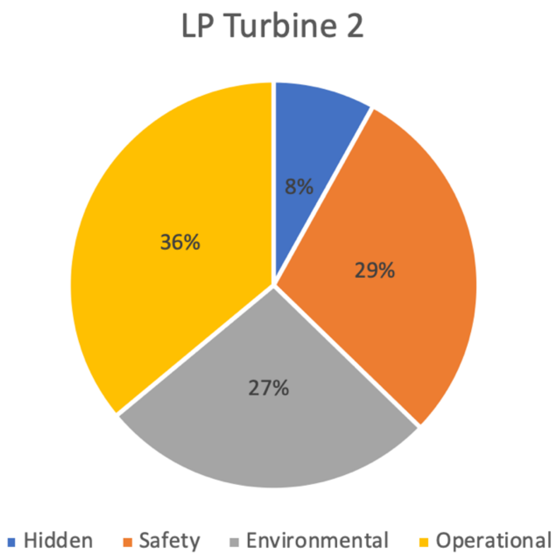
FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE		FAILURE EFFECT	
2	To prevent overspeed rotation from more than 3300 rpm	C	Overspeed protection activates more than 3300 rpm	1	Magnetic speed sensor detects the rotational speed late due to wear out	1	The consequences of this failure is easy to be detected from the control room. Wear out of magnetic speed sensor will cause a late transmission of trip signal which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of magnetic speed sensor must be replaced
				2	Signal processing unit processes and transmits the trip signal to trip unit late due to wear out	2	The consequences of this failure is easy to be detected from the control room. Wear out of signal processing unit will cause a late transmission of trip signal which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has

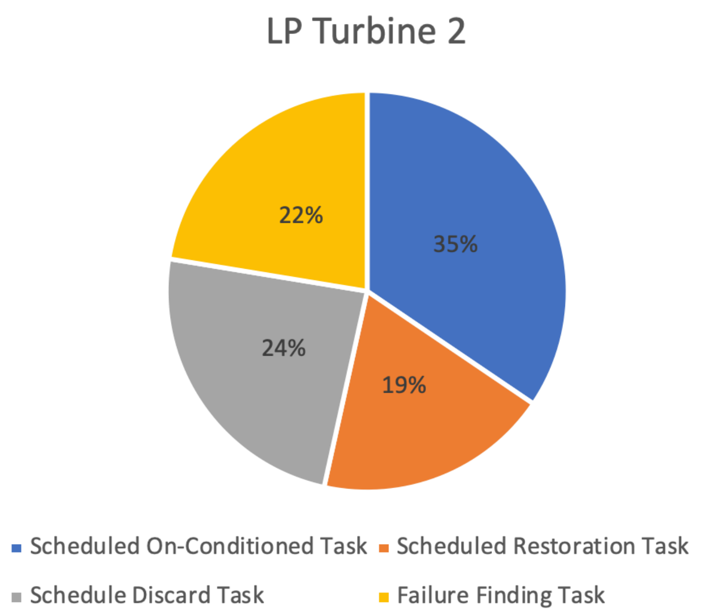
							operational consequences which the operation will be stopped due to reparation. Wear out of signal processing unit must be replaced
				3	Trip unit opens the oil dump valve late due to wear out	3	The consequences of this failure is easy to be detected from the control room. Wear out of trip unit will cause the oil dump valve to be opened late which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. Wear out of trip unit must be replaced
				4	Oil dump valve is opened late due to a build-up deposits	4	The consequences of this failure can be detected from the control room. A build-up deposit can make the oil dump valve take longer time to be opened which also directly makes the overspeed protection active late. If the overspeed protection actives late, it can cause the turbine keep rotating exceedingly from the operational design which can damage turbine component. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped

							due to reparation. A build-up deposit on oil dump valve must be repaired
				5	Emergency stop valve is closed late due to a build-up deposits	5	The consequences of this failure can be detected from the control room. A build-up deposit can make the emergency stop valve take longer time to be closed. The worst case consequences is when the overspeed condition cause a damage to the turbine component before the emergency stop valve is closed. The broken pieces of damaged component can widespread all over the area and harm people nearby. The steam leakage due to damaged turbine also can cause an explosion if it meets the hydrogen from generator. Beside environmental and safety consequences, this failure also has operational consequences which the operation will be stopped due to reparation. A build-up deposit on emergency stop valve must be repaired

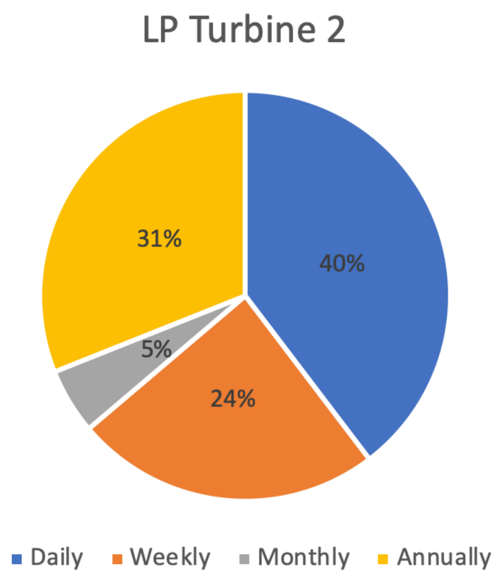
Hidden	Safety	Environmental	Operational
13	47	43	58



Scheduled On-Conditioned Task	Scheduled Restoration Task	Schedule Discard Task	Failure Finding Task
20	11	14	13



Daily	Weekly	Monthly	Annually
23	14	3	18



ATTACHMENT 09
RCM DECISION WORKSHEET

RCM II DECISION WORKSHEET © 1996 ALADON LTD	SYSTEM Steam Turbine SUB-SYSTEM High Pressure Steam Turbine	SYSTEM Nº 117844 SUB-SYSTEM Nº MAA	Facilitator	Date	Sheet Nº of	FORM 2
			Auditor	Date		

Information reference			Consequences Evaluation				H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	Default Action			Proposed Task	Initial Interval	Can be done by
F	FF	FM	H	S	E	O				H4	H5	S4			
1	A	1	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check the governor components such as hydraulic power supply, servo valve, selenoid valve, control valve actuator. Repair or replace is based on each failure. See governor FMEA 1A	Annually	Electrician
		2	N	Y	Y	Y	Y	N	N	N	N	N	(Schedule Discard Task) Monitor the governor components such as hydraulic power supply, servo valve, selenoid valve, control valve actuator if there is abnormalities. Repair or replace is based on each failure. See governor FMEA 1A	Daily	Operator
		3	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination	Daily	Operator
		4	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct inspection on seal and replace if needed	Annually	Mechanic
		5	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct visual inspection on control valve if there is deposit around	Weekly	Mechanic
1	B	1	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		2	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct visual inspection on valve and replace if needed	Annually	Mechanic
		3	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		4	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct visual inspection on valve and replace if needed	Annually	Mechanic
		5	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor and electrical equipment related	Annually	Electrician
		6	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor speed and check electrical equipment related	Daily	Operator
1	C	1	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination	Daily	Operator
		2	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Conduct inspection on valve and replace if needed	Annually	Mechanic
		3	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination	Daily	Operator

		4	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Conduct inspection on valve and replace if needed	Annually	Mechanic
		5	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		6	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and repair if needed	Annually	Mechanic
		7	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		8	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and repair if needed	Annually	Mechanic
		9	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		10	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on stator and repair if needed	Annually	Mechanic
		11	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		12	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on stator and repair if needed	Annually	Mechanic
		13	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		14	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annually	Mechanic
		15	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		16	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annually	Mechanic
		17	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
		18	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
		19	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
		20	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annually	Mechanic
		21	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct inspection on bearing and check lubricating system	Annually	Mechanic
		22	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor lubricating system on rotor and check temperature	Daily	Operator
		23	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor lubricating system on rotor and check temperature	Daily	Operator
		24	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annually	Mechanic
		25	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct inspection on bearing and check lubricating system	Annually	Mechanic
		26	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition and lubricating system	Daily	Operator

		27	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition and lubricating system	Daily	Operator
		28	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor, check the cables, do testing	Annually	Mechanic
		29	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature and rotational speed produced	Daily	Operator
		30	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor pressure and rotational speed produced	Daily	Operator
		31	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor speed and check electrical equipment related	Daily	Operator
2	A	1	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic power supply, check electrical equipment related, and do testing	Annually	Electrician
		2	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of hydraulic power supply and all equipment related	Daily	Operator
		3	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annually	Electrician
		4	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of hydraulic servo valve and all equipment related	Daily	Operator
		5	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		6	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of selenoid valve and all equipment related	Daily	Operator
		7	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician
		8	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of control valve actuator and all equipment related	Daily	Operator
		9	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check electrical equipment related to stop valve, and do testing	Annually	Electrician
		10	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
2	B	1	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check speed sensor, check electrical equipment related, do testing	Annually	Electrician
		2	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annually	Electrician
		3	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		4	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician
		5	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
2	C	1	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annually	Electrician
		2	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		3	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician

		4	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
		5	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check governor's seal	Annually	Mechanic
		6	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor steam contamination	Daily	Operator
		7	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on nozzle	Weekly	Mechanic
3	A	1	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic power supply, check electrical equipment related, and do testing	Annually	Electrician
		2	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of hydraulic power supply and all equipment related	Daily	Operator
		3	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annually	Electrician
		4	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of hydraulic servo valve and all equipment related	Daily	Operator
		5	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		6	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of selenoid valve and all equipment related	Daily	Operator
		7	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician
		8	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of control valve actuator and all equipment related	Daily	Operator
		9	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check electrical equipment related to stop valve, and do testing	Annually	Electrician
		10	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
3	B	1	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check speed sensor, check electrical equipment related, do testing	Annually	Electrician
		2	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annually	Electrician
		3	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		4	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician
		5	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
3	C	1	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annually	Electrician
		2	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		3	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician
		4	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic

		5	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check governor's seal	Annually	Mechanic
		6	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor steam contamination	Daily	Operator
		7	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on nozzle	Weekly	Mechanic
4	A	1	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		2	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		3	Y	Y	Y	Y	N	N	Y	Y	N	N	(Failure Finding) Check signal processing unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		4	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check signal processing unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		5	Y	Y	Y	Y	N	N	Y	Y	N	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		6	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		7	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on oil dump valve	Weekly	Mechanic
		8	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechanic
4	B	1	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor, check abnormalities on cables, measure current and do testing	Monthly	Electrician
		2	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check signal processing unit, check abnormalities on cables, measure current and do testing	Monthly	Electrician
		3	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check trip unit, check abnormalities on cables, measure current and do testing	Monthly	Electrician
4	C	1	Y	Y	Y	Y	N	N	N	N	N	N	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		2	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check signal processing unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		3	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		4	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on oil dump valve	Weekly	Mechanic
		5	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechanic

RCM II DECISION WORKSHEET © 1996 ALADON LTD	SYSTEM Steam Turbine SUB-SYSTEM Intermediate Steam Turbine	SYSTEM Nº 117844 SUB-SYSTEM Nº MAB	Facilitator	Date	Sheet Nº of	FORM 6
			Auditor	Date		

Information reference			Consequences Evaluation				H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	Default Action			Proposed Task	Initial Interval	Can be done by
F	FF	FM	H	S	E	O				H4	H5	S4			
1	A	1	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check the governor components such as hydraulic power supply, servo valve, selenoid valve, control valve actuator. Repair or replace is based on each failure. See governor FMEA 1A	Annually	Electrician
		2	N	Y	Y	Y	Y	N	N	N	N	N	(Schedule Discard Task) Monitor the governor components such as hydraulic power supply, servo valve, selenoid valve, control valve actuator if there is abnormalities. Repair or replace is based on each failure. See governor FMEA 1A	Daily	Operator
		3	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination	Daily	Operator
		4	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct inspection on seal and replace if needed	Annually	Mechanic
		5	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct visual inspection on control valve if there is deposit around	Weekly	Mechanic
1	B	1	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		2	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct visual inspection on valve and replace if needed	Annually	Mechanic
		3	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		4	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct visual inspection on valve and replace if needed	Annually	Mechanic
		5	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor and electrical equipment related	Annually	Electrician
		6	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor speed and check electrical equipment related	Daily	Operator
1	C	1	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination	Daily	Operator
		2	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Conduct inspection on valve and replace if needed	Annually	Mechanic
		3	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination	Daily	Operator
		4	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Conduct inspection on valve and replace if needed	Annually	Mechanic

		5	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		6	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and repair if needed	Annually	Mechanic
		7	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		8	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and repair if needed	Annually	Mechanic
		9	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		10	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on stator and repair if needed	Annually	Mechanic
		11	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		12	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on stator and repair if needed	Annually	Mechanic
		13	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		14	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annually	Mechanic
		15	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		16	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annually	Mechanic
		17	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
		18	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
		19	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
		20	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annually	Mechanic
		21	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct inspection on bearing and check lubricating system	Annually	Mechanic
		22	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor lubcirating system on rotor and check temperature	Daily	Operator
		23	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor lubcirating system on rotor and check temperature	Daily	Operator
		24	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annually	Mechanic
		25	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct inspection on bearing and check lubricating system	Annually	Mechanic
		26	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition and lubricating system	Daily	Operator
		27	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition and lubricating system	Daily	Operator

		28	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor, check the cables, do testing	Annually	Mechanic
		29	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature and rotational speed produced	Daily	Operator
		30	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor pressure and rotational speed produced	Daily	Operator
		31	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor speed and check electrical equipment related	Daily	Operator
2	A	1	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic power supply, check electrical equipment related, and do testing	Annually	Electrician
		2	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of hydraulic power supply and all equipment related	Daily	Operator
		3	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annually	Electrician
		4	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of hydraulic servo valve and all equipment related	Daily	Operator
		5	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		6	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of selenoid valve and all equipment related	Daily	Operator
		7	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician
		8	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of control valve actuator and all equipment related	Daily	Operator
		9	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check electrical equipment related to stop valve, and do testing	Annually	Electrician
		10	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
2	B	1	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check speed sensor, check electrical equipment related, do testing	Annually	Electrician
		2	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annually	Electrician
		3	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		4	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician
		5	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
2	C	1	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annually	Electrician
		2	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		3	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician
		4	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic

		5	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check governor's seal	Annually	Mechanic
		6	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor steam contamination	Daily	Operator
		7	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on nozzle	Weekly	Mechanic
3	A	1	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic power supply, check electrical equipment related, and do testing	Annually	Electrician
		2	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of hydraulic power supply and all equipment related	Daily	Operator
		3	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annually	Electrician
		4	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of hydraulic servo valve and all equipment related	Daily	Operator
		5	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		6	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of selenoid valve and all equipment related	Daily	Operator
		7	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician
		8	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of control valve actuator and all equipment related	Daily	Operator
		9	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check electrical equipment related to stop valve, and do testing	Annually	Electrician
		10	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
3	B	1	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check speed sensor, check electrical equipment related, do testing	Annually	Electrician
		2	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annually	Electrician
		3	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		4	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician
		5	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
3	C	1	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annually	Electrician
		2	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		3	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician
		4	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
		5	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check governor's seal	Annually	Mechanic

		6	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor steam contamination	Daily	Operator
		7	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on nozzle	Weekly	Mechanic
4	A	1	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		2	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		3	Y	Y	Y	Y	N	N	Y	Y	N	N	(Failure Finding) Check signal processing unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		4	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check signal processing unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		5	Y	Y	Y	Y	N	N	Y	Y	N	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		6	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		7	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on oil dump valve	Weekly	Mechanic
		8	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechanic
4	B	1	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor, check abnormalities on cables, measure current and do testing	Monthly	Electrician
		2	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check signal processing unit, check abnormalities on cables, measure current and do testing	Monthly	Electrician
		3	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check trip unit, check abnormalities on cables, measure current and do testing	Monthly	Electrician
4	C	1	Y	Y	Y	Y	N	N	N	N	N	N	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		2	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check signal processing unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		3	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		4	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on oil dump valve	Weekly	Mechanic
		5	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechanic

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			Auditor	Date	of	

Information reference			Consequences Evaluation				H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	Default Action			Proposed Task	Initial Interval	Can be done by
F	FF	FM	H	S	E	O				H4	H5	S4			
1	A	1	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check the governor components such as hydraulic power supply, servo valve, selenoid valve, control valve actuator. Repair or replace is based on each failure. See governor FMEA 1A	Annually	Electrician
		2	N	Y	Y	Y	Y	N	N	N	N	N	(Schedule Discard Task) Monitor the governor components such as hydraulic power supply, servo valve, selenoid valve, control valve actuator if there is abnormalities. Repair or replace is based on each failure. See governor FMEA 1A	Daily	Operator
		3	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination	Daily	Operator
		4	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct inspection on seal and replace if needed	Annually	Mechanic
		5	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct visual inspection on control valve if there is deposit around	Weekly	Mechanic
1	B	1	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		2	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct visual inspection on valve and replace if needed	Annually	Mechanic
		3	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		4	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct visual inspection on valve and replace if needed	Annually	Mechanic
		5	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor and electrical equipment related	Annually	Electrician
		6	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor speed and check electrical equipment related	Daily	Operator
1	C	1	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination	Daily	Operator
		2	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Conduct inspection on valve and replace if needed	Annually	Mechanic
		3	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination	Daily	Operator

		4	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Conduct inspection on valve and replace if needed	Annually	Mechanic
		5	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		6	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and repair if needed	Annually	Mechanic
		7	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		8	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and repair if needed	Annually	Mechanic
		9	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		10	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on stator and repair if needed	Annually	Mechanic
		11	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		12	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on stator and repair if needed	Annually	Mechanic
		13	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		14	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annually	Mechanic
		15	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		16	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annually	Mechanic
		17	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
		18	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
		19	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
		20	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annually	Mechanic
		21	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct inspection on bearing and check lubricating system	Annually	Mechanic
		22	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor lubricating system on rotor and check temperature	Daily	Operator
		23	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor lubricating system on rotor and check temperature	Daily	Operator
		24	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annually	Mechanic
		25	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct inspection on bearing and check lubricating system	Annually	Mechanic
		26	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition and lubricating system	Daily	Operator

		27	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition and lubricating system	Daily	Operator
		28	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor, check the cables, do testing	Annually	Mechanic
		29	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature and rotational speed produced	Daily	Operator
		30	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor pressure and rotational speed produced	Daily	Operator
		31	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor speed and check electrical equipment related	Daily	Operator
2	A	1	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		2	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		3	Y	Y	Y	Y	N	N	Y	Y	N	N	(Failure Finding) Check signal processing unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		4	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check signal processing unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		5	Y	Y	Y	Y	N	N	Y	Y	N	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		6	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		7	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on oil dump valve	Weekly	Mechanic
		8	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechanic
2	B	1	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor, check abnormalities on cables, measure current and do testing	Monthly	Electrician
		2	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check signal processing unit, check abnormalities on cables, measure current and do testing	Monthly	Electrician
		3	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check trip unit, check abnormalities on cables, measure current and do testing	Monthly	Electrician
2	C	1	Y	Y	Y	Y	N	N	N	N	N	N	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		2	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check signal processing unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		3	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		4	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on oil dump valve	Weekly	Mechanic
		5	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechanic

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	SUB-SYSTEM Low Pressure Steam Turbine 1	SUB-SYSTEM Nº MAC20	Auditor	Date	of	

Information reference			Consequences Evaluation				H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	Default Action			Proposed Task	Initial Interval	Can be done by
F	FF	FM	H	S	E	O				H4	H5	S4			
1	A	1	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check the governor components such as hydraulic power supply, servo valve, selenoid valve, control valve actuator. Repair or replace is based on each failure. See governor FMEA 1A	Annually	Electrician
		2	N	Y	Y	Y	Y	N	N	N	N	N	(Schedule Discard Task) Monitor the governor components such as hydraulic power supply, servo valve, selenoid valve, control valve actuator if there is abnormalities. Repair or replace is based on each failure. See governor FMEA 1A	Daily	Operator
		3	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination	Daily	Operator
		4	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct inspection on seal and replace if needed	Annually	Mechanic
		5	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct visual inspection on control valve if there is deposit around	Weekly	Mechanic
1	B	1	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		2	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct visual inspection on valve and replace if needed	Annually	Mechanic
		3	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		4	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct visual inspection on valve and replace if needed	Annually	Mechanic
		5	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor and electrical equipment related	Annually	Electrician
		6	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor speed and check electrical equipment related	Daily	Operator
1	C	1	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination	Daily	Operator
		2	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Conduct inspection on valve and replace if needed	Annually	Mechanic
		3	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination	Daily	Operator

		4	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Conduct inspection on valve and replace if needed	Annually	Mechanic
		5	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		6	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and repair if needed	Annually	Mechanic
		7	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		8	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and repair if needed	Annually	Mechanic
		9	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		10	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on stator and repair if needed	Annually	Mechanic
		11	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		12	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on stator and repair if needed	Annually	Mechanic
		13	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		14	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annually	Mechanic
		15	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
		16	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annually	Mechanic
		17	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
		18	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
		19	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
		20	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annually	Mechanic
		21	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct inspection on bearing and check lubricating system	Annually	Mechanic
		22	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor lubricating system on rotor and check temperature	Daily	Operator
		23	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor lubricating system on rotor and check temperature	Daily	Operator
		24	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annually	Mechanic
		25	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct inspection on bearing and check lubricating system	Annually	Mechanic
		26	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition and lubricating system	Daily	Operator

		27	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition and lubricating system	Daily	Operator
		28	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor, check the cables, do testing	Annually	Mechanic
		29	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature and rotational speed produced	Daily	Operator
		30	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor pressure and rotational speed produced	Daily	Operator
		31	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor speed and check electrical equipment related	Daily	Operator
2	A	1	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		2	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		3	Y	Y	Y	Y	N	N	Y	Y	N	N	(Failure Finding) Check signal processing unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		4	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check signal processing unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		5	Y	Y	Y	Y	N	N	Y	Y	N	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		6	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		7	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on oil dump valve	Weekly	Mechanic
		8	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechanic
2	B	1	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor, check abnormalities on cables, measure current and do testing	Monthly	Electrician
		2	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check signal processing unit, check abnormalities on cables, measure current and do testing	Monthly	Electrician
		3	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check trip unit, check abnormalities on cables, measure current and do testing	Monthly	Electrician
2	C	1	Y	Y	Y	Y	N	N	N	N	N	N	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		2	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check signal processing unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		3	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		4	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on oil dump valve	Weekly	Mechanic
		5	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechanic

ATTACHMENT 10
WORK PACKAGES

Maintenance Schedule	
HIGH PRESSURE TURBINE (MAA)	
Interval	Done by
WEEKLY	MECHANIC

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Check condition of control valve, oil dump valve, and emergency stop valve, and nozzle
   Run a test to check functionality of those equipment
2. Analyse damage mechanism on those equipment
3. Clean the built-up deposit around those equipment
4. Repair or replace if needed

<table>
<tr><td colspan="2" align="center">Maintenance Schedule</td></tr>
<tr><td colspan="2" align="center">HIGH PRESSURE TURBINE (MAA)</td></tr>
<tr><td align="center">Interval</td><td align="center">Done by</td></tr>
<tr><td align="center">ANNUALLY</td><td align="center">MECHANIC</td></tr>
<tr><td colspan="2">These are lists of recommended action that can reduce potential failure of steam turbine:

1. Check condition of seal, control valve, rotor, stator, and shaft
2. Check lubricating system of those equipment
3. Analyse damage mechanism on those equipment
4. Check condition of speed sensor
5. Run a test to check functionality of those equipment
6. Run a test to check accuracy of speed sensor
7. Clean built-up deposit on those equipment
8. Repair or replace if it is needed</td></tr>
</table>

Maintenance Schedule	
HIGH PRESSURE TURBINE (MAA)	
Interval	Done by
WEEKLY	ELECTRICIAN

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Check physical condition of speed sensor
2. Run a test to check functionality of speed sensor
3. Run a test to check accuracy of speed sensor
4. Clean built-up deposit on speed sensor
5. Replace if it is needed

Maintenance Schedule	
HIGH PRESSURE TURBINE (MAA)	
Interval	Done by
MONTHLY	ELECTRICIAN

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Check physical condition of speed sensor, signal processing unit and trip unit
2. Run a test to check functionality of those equipment
3. Run a test to check accuracy of those equipment
4. Check abnormalities on all electrical component such as cables on those equipment
5. Clean built-up deposit on those equipment
6. Repair or replace if it is needed

Maintenance Schedule	
HIGH PRESSURE TURBINE (MAA)	
Interval	Done by
ANNUALLY	ELECTRICIAN

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Check physical condition of hydraulic power supply, servo valve, solenoid valve, control valve actuator and speed sensor
2. Run a test to check functionality of those equipment
3. Run a test to check accuracy of those equipment
4. Clean built-up deposit on speed sensor
5. Repair or replace if it is needed

Maintenance Schedule	
HIGH PRESSURE TURBINE (MAA)	
Interval	Done by
DAILY	OPERATOR

These are lists of recommended action that can reduce potential failure of steam turbine:

10. Monitor hydraulic supply power, servo valve, solenoid valve, control valve actuator, control valve and seal
11. Monitor the electrical flow within those equipment
12. Conduct visual inspection on seal. Ensure there is no leakage
13. Check water and steam purity. Ensure it is not contaminated
14. Monitor operational speed of turbine. Ensure it is not overspeed
15. Monitor lubricating system. Ensure it is flowed with no obstacles and not contaminated
16. Monitor temperature and pressure of turbine. Ensure the temperature is at range of operational design
17. Conduct inspection if there is abnormalities
18. Repair or replace if it is needed

Maintenance Schedule	
INTERMEDIATE PRESSURE TURBINE (MAB)	
Interval	Done by
WEEKLY	MECHANIC
These are lists of recommended action that can reduce potential failure of steam turbine: 1. Check condition of control valve, oil dump valve, and emergency stop valve, and nozzle 2. Run a test to check functionality of those equipment 3. Analyse damage mechanism on those equipment 4. Clean the built-up deposit around those equipment 5. Repair or replace if needed	

Maintenance Schedule	
INTERMEDIATE PRESSURE TURBINE (MAB)	
Interval	Done by
ANNUALLY	MECHANIC

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Check condition of seal, control valve, rotor, stator, and shaft
2. Check lubricating system of those equipment
3. Analyse damage mechanism on those equipment
4. Check condition of speed sensor
5. Run a test to check functionality of those equipment
6. Run a test to check accuracy of speed sensor
7. Clean built-up deposit on those equipment
8. Repair or replace if it is needed

Maintenance Schedule	
INTERMEDIATE PRESSURE TURBINE (MAB)	
Interval	Done by
WEEKLY	ELECTRICIAN

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Check physical condition of speed sensor
2. Run a test to check functionality of speed sensor
3. Run a test to check accuracy of speed sensor
4. Clean built-up deposit on speed sensor
5. Replace if it is needed

Maintenance Schedule	
INTERMEDIATE PRESSURE TURBINE (MAB)	
Interval	Done by
MONTHLY	ELECTRICIAN

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Check physical condition of speed sensor, signal processing unit and trip unit
2. Run a test to check functionality of those equipment
3. Run a test to check accuracy of those equipment
4. Check abnormalities on all electrical component such as cables on those equipment
5. Clean built-up deposit on those equipment
6. Repair or replace if it is needed

Maintenance Schedule	
INTERMEDIATE PRESSURE TURBINE (MAB)	
Interval	Done by
ANNUALLY	ELECTRICIAN

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Check physical condition of hydraulic power supply, servo valve, solenoid valve, control valve actuator and speed sensor
2. Run a test to check functionality of those equipment
3. Run a test to check accuracy of those equipment
4. Clean built-up deposit on speed sensor
5. Repair or replace if it is needed

Maintenance Schedule	
INTERMEDIATE PRESSURE TURBINE (MAB)	
Interval	Done by
DAILY	OPERATOR

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Monitor hydraulic supply power, servo valve, solenoid valve, control valve actuator, control valve and seal
2. Monitor the electrical flow within those equipment
3. Conduct visual inspection on seal. Ensure there is no leakage
4. Check water and steam purity. Ensure it is not contaminated
5. Monitor operational speed of turbine. Ensure it is not overspeed
6. Monitor lubricating system. Ensure it is flowed with no obstacles and not contaminated
7. Monitor temperature and pressure of turbine. Ensure the temperature is at range of operational design
8. Conduct inspection if there is abnormalities
9. Repair or replace if it is needed

Maintenance Schedule	
LOW PRESSURE TURBINE (MAC10 & MAC20)	
Interval	Done by
WEEKLY	MECHANIC

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Check condition of control valve, oil dump valve, and emergency stop valve
2. Run a test to check functionality of those equipment
3. Analyse damage mechanism on those equipment
4. Clean the built-up deposit around those equipment
5. Repair or replace if needed

Maintenance Schedule

LOW PRESSURE TURBINE (MAC10 & MAC20)

Interval	Done by
ANNUALLY	MECHANIC

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Check condition of seal, control valve, rotor, stator, and shaft
2. Check lubricating system of those equipment
3. Analyse damage mechanism on those equipment
4. Check condition of speed sensor
5. Run a test to check functionality of those equipment
6. Run a test to check accuracy of speed sensor
7. Clean built-up deposit on those equipment
8. Repair or replace if it is needed

LOW PRESSURE TURBINE (MAC10 & MAC20)

Interval	Done by
WEEKLY	ELECTRICIAN

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Check physical condition of speed sensor
2. Run a test to check functionality of speed sensor
3. Run a test to check accuracy of speed sensor
4. Clean built-up deposit on speed sensor
5. Replace if it is needed

Maintenance Schedule	
LOW PRESSURE TURBINE (MAC10 & MAC20)	
Interval	Done by
ANNUALLY	ELECTRICIAN

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Check physical condition of speed sensor
2. Run a test to check functionality of speed sensor
3. Run a test to check accuracy of speed sensor
4. Clean built-up deposit on speed sensor
5. Repair or replace if it is needed

LOW PRESSURE TURBINE (MAC10 & MAC20)

Interval	Done by
DAILY	OPERATOR

These are lists of recommended action that can reduce potential failure of steam turbine:

1. Conduct visual inspection on seal. Ensure there is no leakage
2. Check water and steam purity. Ensure it is not contaminated
3. Monitor operational speed of turbine. Ensure it is not overspeed
4. Monitor lubricating system. Ensure it is flowed with no obstacles and not contaminated
5. Monitor temperature and pressure of turbine. Ensure the temperature is at range of operational design
6. Conduct inspection if there is abnormalities
7. Repair or replace if it is needed