

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 INSTITUT TEKNOLOGI SEPULUH NOPEMBER 2020



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TUGAS AKHIR - ME184841

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

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Digital Marine Operational and Maintenance (DMOM) Bachelor Program Department of Marine Engineering Faculty of Marine Technology Institut Teknologi Sepuluh Nopember

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Muhamad Noval Fahmy

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

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

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.

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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 coalfired 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

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

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**

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

Table 2.1 Catastrophic Incident Caused by Turbine

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; watertube 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**

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 				

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

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 highquality 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 conditionbased 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. Oncondition 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 Č

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										System Nº	Facilitator:		Date		Sheet Nº
								Sub-system Nº	atem Nº Auditor:		Date		of							
Information Conse reference eval				que	nce	HS	11	H2 S2	H3 53	De	Defai	ult m	Propos	sed task		Ini		Ca	an be	
F	FF	FM	н	S	E	0	N	11	N2	03 N3	H4	H5	S4		int					ne by

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.

- \Rightarrow Data collected from document control room
 - Specification
 - P&ID
 - Historical Operation
 - Historical Failure
 - Historical Maintenance
- \Rightarrow 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**.

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

 Table 4.1 Functional Failure

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**.

Maintenance Schedule										
HIGH PRESSURE TURBINE										
Interval Done by										
DAILY OPERATOR										
These are lists of recommended action that can reduce potential failure of steam turbine:										
 Monitor hydraulic supply p actuator, control valve and Monitor the electrical flow Conduct visual inspection of Check water and steam pur Monitor operational speed of Monitor lubricating system contaminated Monitor temperature and pr range of operational design Conduct inspection if there Repair or replace if it is need 	ower, servo valve, solenoid valve, control valve seal within those equipment on seal. Ensure there is no leakage ity. Ensure it is not contaminated of turbine. Ensure it is not overspeed . Ensure it is flowed with no obstacles and not ressure of turbine. Ensure the temperature is at is abnormalities eded									

Table 4.2 Work Package of High Pressure Turbine

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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



ATTACHMENT 04 FUNCTIONAL BLOCK DIAGRAM

FUNCTIONAL BLOCK DIAGRAM



ATTACHMENT 04 FUNCTIONAL FAILURE
FUNCTIONAL FAILURE

RCM II	TON	SYSTEM		SYSTEM N ^Ω	Facilitator	Date	Sheet N ^Ω	FORM				
© 1996 AL	ET ADON LTD	SUB - SYSTEM		SUB - SYSTEM N ^Ω	Auditor	Date	of	01				
			Equipment	: 610 MW High-Pressure T	urbine (MAA)							
		Function		Functional Failure								
Item No.	Fun	ctional Statement	Function Type	Item No.	Fu	unctional Failur	e					
				1.1	Rotational speed is not produc							
1	To produce at 3000 rpm	rotational speed of shaft in 50 Hz	Primary	1.2	Rotational speed is more than							
	-			1.3	Rotational speed is less than 3	Rotational speed is less than 3000 rpm						
	To control the	he steam flow rate at		2.1	Steam is not injected							
2	between 303 adjusting co	3.8 - 584 kg/s by ntrol valve in load	Secondary	2.2	Steam is injected more than 5	84 kg/s						
	condition			2.3	Steam is injected less than 30	3.8 kg/s						
	To control t	he steam flow rate at		3.1	Steam is not injected							
3	between 90	n 90 kg/s by adjusting control Secondary		1 90 kg/s by adjusting control Secondary		3.2	Steam is injected more than 9	0 kg/s				
	valve in load condition			3.3	Steam is injected less than 90	kg/s						
	_			4.1	.1 Inactive of overspeed protection							
4	To prevent of more than 3	overspeed rotation from 300 rpm	Secondary	4.2	Overspeed protection activates at safe rpm (3000 rpm)							
				4.3	Overspeed protection activates more than 3300 rpm							

RCM II	TON	SYSTEM		SYSTEM N ^Ω	Facilitator	Date	Sheet N^{Ω}	FORM				
WORKSHE	ET ADON LTD	SUB - SYSTEM		SUB - SYSTEM N [®]	Auditor	Date	of	01				
			Equipment: 61	0 MW Intermediate-Pressu	re Turbine (MAA)							
		Function			Functional Fail	ure						
Item No.	Fun	ctional Statement	Function Type	Item No.	Fu	inctional Failur	c					
				1.1	Rotational speed is not produced							
1	To produce at 3000 rpm	rotational speed of shaft in 50 Hz	Primary	1.2	Rotational speed is more than	3000 rpm						
	-			1.3	Rotational speed is less than 3	Rotational speed is less than 3000 rpm						
	To control t	he steam flow rate at		2.1	Steam is not injected							
2	between 303 adjusting co	3.8 - 584 kg/s by ntrol valve in load	Secondary	2.2	Steam is injected more than 5	84 kg/s						
	condition			2.3	Steam is injected less than 30	3.8 kg/s						
	To control t	he steam flow rate at		3.1	Steam is not injected							
3	between 90	kg/s by adjusting control	Secondary	3.2	Steam is injected more than 9	0 kg/s						
	valve in load condition			3.3	Steam is injected less than 90	kg/s						
				4.1	Inactive of overspeed protecti	on						
4	To prevent of more than 3	overspeed rotation from 300 rpm	Secondary	ndary 4.2 Overspeed protection activates at safe rpm (3000 rpm)								
				4.3	Overspeed protection activate	s more than 330	00 rpm					

RCM II	0N	SYSTEM		SYSTEM N	lα	Facilitator	Date	Sheet N ^Ω	FORM		
WORKSHEE		SUB - SYSTEM		SUB - SYS	STEM N ^Ω	Auditor	Date	of	01		
U IJJU ALA	DON LID	I	Equipment: 610	MW Low-Press	sure Turbine (N	1AC10)					
		Function				Functional Fail	ure				
Item No.	Func	tional Statement	Function Type	Item No.		Functional Failure					
				1.1	Rotational s	peed is not produced					
1	To produce ro 3000 rpm in 5	otational speed of shaft at 0 Hz	Primary	1.2	Rotational s	peed is more than 3000 rp	m				
				1.3	Rotational s	peed is less than 3000 rpm	I				
				2.1	Inactive of c	verspeed protection					
2 To prevent more than 3		erspeed rotation from 00 rpm	Secondary	2.2 Overspeed		protection activates at safe	rpm (3000 r	pm)			
				2.3	Overspeed p	protection activates more t	:han 3300 rp	m			

RCM II		SYSTEM		SYSTEM N	lα	Facilitator	Date	Sheet N^{Ω}		
INFORMATI	ON								FORM	
WORKSHEE		SUB - SYSTEM		SUB - SYS	STEM N ^Ω	Auditor	Date	of	01	
			Equipment: 610	MW Low-Press	sure Turbine (N	/AC20)				
		Function				Functional Fail	ure			
Item No.	Item No. Functional Statement Ty					Functio	nal Failure			
				Rotational		peed is not produced				
1	To produce ro 3000 rpm in 5	tational speed of shaft at 0 Hz	Primary	1.2	Rotational s	peed is more than 3000 rp	m			
				1.3	Rotational s	peed is less than 3000 rpm	I			
				2.1	Inactive of c	overspeed protection				
2 To prevent of more than 3		erspeed rotation from 00 rpm	Secondary	2.2 Overspeed		eed protection activates at safe rpm (3000 rpm)				
				2.3	Overspeed	protection activates more than 3300 rpm				

ATTACHMENT 05 FMEA HPT (MAA)

RCM II			SYSTEM		SYSTEM	NΩ		Facilitator	Date	Sheet N^{Ω}		
IN	IFORMATION		Steam Turbine			117844						FORM
w	ORKSHEET		SUB - SYSTEM		SUB - SYSTEM N				Auditor	Date	of	01
©	1996 ALADON LTD		High Pressure Turbine			MAA						
	FUNCTION	F	UNCTIONAL FAILURE		FAILURE MO	DE 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 gov to wear out	/ernor due	1	This fa situation system Steam which safety financ must b	ailure can easily be not on on site or in the cor or a can cause the steam s which is not entered a means huge loss of cor nor environmental cor ial and operational cor be replaced	ticed by the ttrol room. ¹ stuck and no bsolutely st and prod sequences asequences.	operator from Wear out of go t enter the turl ops the produc uctivity. There in this failure, Wear out of g	the wernor bine. ction : is no only overnor
				2	Stuck steam in gov to short circuit	vernor due	2	This fa situatii goverr Steam which circuit affect replace	ailure can easily be not on on site or in the cor for can cause the stean which is not entered a means huge loss of cc can cause a small fire the component nearby ed	ticed by the throl room. So a stuck and bsolutely st st and prod in the gove . Short circu	operator from Short circuit of not enter the tr ops the produc uctivity. Also, rnor system w uit of governor	the f urbine. ction short hich can c an be
				3	Erosion on seal du contaminated stear	e to n	3	This fa since t seal co cause worst	ailure can easily be not the steam is visible. Co omponent which result thinning and hole which case is steam leakage	ticed on site ontaminated s in erosion ch results in nakes no st	or in the cont steam can dar . Erosion on se steam leakage eam rotates the	rol room nage the eal will e. The e 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

F	RCM II		SYSTEM		SYSTEM	NΩ		Facilitator	Date	Sheet N^{Ω}		
INFORMATION Steam Turbine 117844										FORM		
۷	VORKSHEET	SUB - SYSTEM SUB - SYSTEM					EM N ^Ω	Auditor	Date	of	01	
(1996 ALADON LTD		High Pressure Turbine			MAA						
	FUNCTION		FUNCTIONAL FAILURE		FAILURE MO	DE			FAILURE	EFFECT		
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	В	Rotational speed is more than 3000 rpm	1	Erosion on valve d contaminated stear	ue to n	1	Contar results which that wi Less e Also tl it is hij contan	ninated steam can dama erosion. Erosion on val the steam will leak fron ill be absorbed by the ro nergy produced results i ne steam which leaks ca gh temperature and pres ninated steam must be ro	ge the val ve can cau n it. Less e tor means n loss of c n harm the sure. Eros epaired	ve component: use thinning an energy from the less energy pr ost and produc e operator near ion on valve d	s which d hole e steam oduced. tivity. by since ue to
				2	Crack on valve du out	e to wear	2	Crack require compo harm p can ca area. T which out mu	on valve can cause the s ed rate which can damag ment which is damaged person nearby. The leaka use an explosion if it mo ihis failure also can caus it will stop the production st be replaced	steam flow ge the turb into piece age of the sets the hy se an oper on. Crack	rate exceeds to ine component s can widespre- hot steam fron drogen from g ational conseque on valve due t	from the t. Turbine ad and n turbine enerator uences o wear

		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

RC			SYSTEM		SYSTEM	NΩ		Facilitator	Date	Sheet N^{Ω}		
IN	FORMATION		Steam Turbine			117844						FORM
w	ORKSHEET		SUB - SYSTEM			SUB - SY	STE	M NΩ	Auditor	Date	of	01
©	1996 ALADON LTD		High Pressure Turbine			MAA						
	FUNCTION	F	UNCTIONAL FAILURE		FAILURE MOI	DE FAILURE EFFECT						
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	С	Rotational speed is less than 3000 rpm	1	Erosion on seal di contaminated stea	ie to m	1	Conta result which that v Less Also since to con	aminated steam can dar ts erosion. Erosion on s h the steam will leak fro vill be absorbed by the energy produced result the steam which leaks o it is high temperature a ntaminated steam must	nage the se eal can cau om it. Less rotor mean s in loss of can harm tl ind pressur be repaired	eal components use thinning an energy from t is less energy p cost and produ- ne operator nea e. Erosion on s d	s which d hole he steam produced. uctivity. arby seal due
				2	Crack on seal due out	to wear	2	Cracl outsid turbin steam energ steam high must	k on seal can cause the s de the turbine. Partial st ne causes the rotor does n efficiently and results gy produced means loss n which leaks can harm temperature and pressu- be replaced	steam fully eam which n't absorb less energ of cost an- the operat re. Crack c	v or partially le h leaks outside the energy from the produced. Le d productivity. or nearby since on seal due to v	aks the m the ess Also the e it is vear out
				3	Corrosion on seal contaminated stea	due to m	3	Conta result pittin	aminated steam can dar ts corrosion. Corrosion g which the steam will	nage the se on seal car leak from	al components a cause extensi it. Less energy	s which ive 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

RCM II	SYSTEM			SYSTEM	NΩ		Facilitator	Date	Sheet N^{Ω}	
INFORMATION	Steam Turbine	117844						FORM		
WORKSHEET	SUB - SYSTEM		SUB - SYSTEM N^{Ω}			Auditor	Date	of	01	
© 1996 ALADON LTD	High Pressure Turbine		МАА							
FUNCTION F	UNCTIONAL FAILURE	DE FAILURE EFFECT								
2 To control the steam flow A rate at between 303.8 - 584 kg/s by adjusting control valve in load condition	Steam is not injected	1	Broken hydraulic supply due to we	power ar out	1 T W g v. tu T fa o		failure mode can easily out of hydraulic power rnor system stop workin control valve n ne. No steam flowed to t e is no safety nor environ re, only financial and op draulic power supply m	be noticed supply ca g which re neans no s the turbine nmental co erational c ust be repl	I on the contro n cause the wh esults in closed team flowed to e means no pro onsequences in consequences. laced	l room. hole l control o the duction. h this Wear out
		2	Broken hydraulic supply due to sho	power rt circuit	2	This t Short gover valve turbir Short comp be rep	failure mode can easily circuit of hydraulic pov rnor system stop workin c. Closed control valve n ne. No steam flowed to t circuit also can triggers sonent nearby. Wear out placed	be noticed wer supply g which re neans no s the turbine s small fire of hydrau	l on the contro y can cause the esults in closec team flowed to e means no pro e which can da lic power supp	l room. whole d control o the duction. mage oly must

		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	Hudroulia corre valvo faile	4	This failure made can assily be noticed on the control room
		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

ſ	RCM II		SYSTEM	SYSTEM N ^Ω			Facilitator	Date	Sheet N^{Ω}			
	INFORMATION		Steam Turbine			117844						FORM
	WORKSHEET		SUB - SYSTEM			SUB - SYSTEM N^{Ω}			Auditor	Date	of	01
	© 1996 ALADON LTD		High Pressure Turbine		MAA							
	FUNCTION	FU	JNCTIONAL FAILURE		FAILURE MO	DE			FAILUR	E EFFECT		
	2 To control the steam flow rate at between 303.8 - 584 kg/s by adjusting control valve in load condition		Steam is injected more than 584 kg/s	1	Speed sensor fails actual needs of ste wear out	to control am due to	1	This failure mode can easily be noticed on the contro Wear out of speed sensor can cause a wrong detection needs of steam. It can inject exceeding amount of ste although it is not needed actually. The worst case con- is exceeding steam can trigger overspeed on turbine a destruction of turbine component. Destruction of tur- component also can lead to an explosion if the steam hydrogen from the generator. Wear out of hydraulic a must be replaced			on the control rong detection amount of stear vorst case cons d on turbine ar uction of turbi n if the steam r of hydraulic se	room. of actual m equences ad cause a ne neets the rvomotor
				2	Servo valve fails t the actual needs of flow rate due to w	o receive f steam ear out	2	This fa Wear needs althou is exca destru compo hydrog replac	ailure mode can easily out of servo valve can of steam. It results injo gh it is not needed actr ceding steam can trigg ction of turbine compo onent also can lead to a gen from the generator ed	be noticed be wrong in ecting exceed hally. The wer overspeed ment. Destr n explosion . Wear out	on the control n receiving the eding amount of vorst case cons d on turbine ar uction of turbi n if the steam r of servo valve	room. actual of steam equences dd cause a ne neets the must be

		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

RCM II		SYSTEM	SYSTEM N^{Ω}			Facilitator	Date	Sheet N^{Ω}			
INFORMATION		Steam Turbine			117844						FORM
WORKSHEET		SUB - SYSTEM			SUB - SYSTEM N^{Ω}			Auditor	Date	of	01
© 1996 ALADON LTD		High Pressure Turbine		MAA							
FUNCTION	FU	JNCTIONAL FAILURE		FAILURE MOI	DE			FAILURE EFFECT			
2 To control the steam flow rate at between 303.8 - 584 kg/s by adjusting control valve in load condition	S S 3	iteam is injected less than 1 03.8 kg/s		Servo valve fails to the actual needs of flow rate due to we	o receive steam ar out	1	 This failure mode can easily be noticed on the control room Wear out of servo valve can cause a wrong detection of act 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 				room. f actual the al onal ed
			2	Selenoid valve fail receive the actual r steam flow rate due out	s to needs of e to wear	2	This fa Wear c actual the rec consec	ailure mode can easily be out of selenoid valve can needs of steam. It can in juired flow rate. There is juences in this failure, or juences. Wear out of sele	noticed of cause a v ject less a no safety ily financ moid valv	on the control vrong detectio mount of stear v nor environm ial and operati ve must be repl	room. n of m than tental onal laced

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

R	СМ II	SYSTEM	SYSTEM					Facilitator	Date	Sheet N^{Ω}		
I	NFORMATION		Steam Turbine			117844						FORM
w	/ORKSHEET		SUB - SYSTEM	SUB - SYSTEM				MΝ ^Ω	Auditor	Date	of	01
C	1996 ALADON LTD	High Pressure Turbine		MAA								
	FUNCTION	FUNCTIONAL FAILURE		FAILURE MO	DE			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	Broken hydraulic supply due to we	power ar out	1	This 5 Wear gover valve turbin There failur of hy	failure mode can easily b out of hydraulic power mor system stop working . Closed control valve m ne. No steam flowed to th e is no safety nor enviror e, only financial and ope draulic power supply mu	be noticed supply ca g which re- leans no s he turbine umental co- rrational co- rrati	I on the contro n cause the wh esults in closed team flowed to e means no pro onsequences in consequences. laced	l room. nole l control o the duction. n this Wear out	
				2	Broken hydraulic supply due to sho	power rt circuit	2	This 5 Short gover valve turbir Short comp be rep	failure mode can easily b circuit of hydraulic pow mor system stop working . Closed control valve m ne. No steam flowed to th circuit also can triggers onent nearby. Wear out placed	be noticed yer supply g which re- leans no s he turbine small fire of hydrau	I on the contro v can cause the esults in closec team flowed to e means no pro e which can da dlic power supp	l room. whole l control o the duction. mage oly must

		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	4	This failure mode can easily be noticed on the control room.
			to open the control valve due to short circuit		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

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		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

R	CM II	SYSTEM	SYSTEM N ^Ω			Facilitator	Date	Sheet N^{Ω}				
I	NFORMATION		Steam Turbine			117844						FORM
W	/ORKSHEET		SUB - SYSTEM			SUB - SYSTEM N^{Ω}			Auditor	Date	of	01
C	1996 ALADON LTD		High Pressure Turbine		МАА							
	FUNCTION	FUNCTIONAL FAILURE		FAILURE MO	DE	DE FAILURE EFFECT						
3	To control the steam flow rate at between 90 kg/s by adjusting control valve in load condition	В	Steam is injected more than 90 kg/s	ed more than 1		to control am due to	1	This failure mode can easily be noticed on the control r Wear out of speed sensor can cause a wrong detection of needs of steam. It can inject exceeding amount of steam although it is not needed actually. The worst case conso is exceeding steam can trigger overspeed on turbine an a destruction of turbine component. Destruction of turb component also can lead to an explosion if the steam rr hydrogen from the generator. Wear out of hydraulic set must be replaced				
				2	Servo valve fails t the actual needs o flow rate due to w	o receive f steam ear out	2	This fa Wear of needs althou is exce a destr compo- hydrog replace	ailure mode can easily out of servo valve can of steam. It results inje gh it is not needed actu eeding steam can trigge uction of turbine comp onent also can lead to a gen from the generator ed	be noticed be wrong in ecting exceed aally. The v er overspee boonent. Des n explosion . Wear out	on the control n receiving the eding amount of vorst case cons d on turbine ar struction of turl n if the steam n of servo valve	room. actual of steam equences id cause bine neets the must be

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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R	CM II	SYSTEM			SYSTEM	NΩ		Facilitator	Date	Sheet N^{Ω}		
I	NFORMATION		Steam Turbine			117844						FORM
v	/ORKSHEET		SUB - SYSTEM			SUB - SYSTEM N^{Ω}			Auditor	Date	of	01
6	1996 ALADON LTD		High Pressure Turbine			MAA						
	FUNCTION FU		UNCTIONAL FAILURE	FAILURE MC		DE			FAILURE EFFECT			
3	To control the steam flow rate at between 90 kg/s by adjusting control valve in load condition	С	Steam is injected less than 90 kg/s		Servo valve fails t the actual needs of flow rate due to w	o receive f steam ear out	1	This fa Wear - needs require consec consec	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			room. f actual the al onal ed
				2	Selenoid valve fai receive the actual steam flow rate du out	ls to needs of ie to wear	2	This fa Wear actual the rec consec consec	ailure mode can easily out of selenoid valve c: needs of steam. It can quired flow rate. There quences in this failure, quences. Wear out of so	be noticed an cause a inject less a is no safet only finance elenoid value	on the control wrong detectio amount of stea y nor environm ial and operati ve must be rep	room. n of m than nental onal laced

			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

R	CM II		SYSTEM	SYSTEM			NΩ		Facilitator	Date	Sheet N^{Ω}	
I	NFORMATION		Steam Turbine			117844						FORM
w	/ORKSHEET		SUB - SYSTEM			SUB - SYSTEM N^{Ω}			Auditor	Date	of	01
©	1996 ALADON LTD		High Pressure Turbine			MAA	MAA					
	FUNCTION	FUNCTIONAL FAILURE		FAILURE MO	DE	DE FAILURE EFFEC						
4	4 To prevent overspeed A rotation from more than 3300 rpm		Inactive of overspeed protection	1	 Magnetic speed sensor to detect the rotational s and transmit the signal signal processing unit d wear out 		ls 1 The fa eed 0 out of transn to will ke design turbin wides steam explos envirr operat due to replac		failure is difficult to be detected in normal condition. Wear of magnetic speed sensor will cause the trip signal not to be smitted to the signal processing unit which in the end it keep the turbine rotating exceedingly from the operational gn. If there is no immediate action prior to that failure, the ine components will be damaged and the broken pieces will sepred all over the area and harm people nearby. The m leakage due to damaged turbine also can cause an osion if it meets the hydrogen from generator. Beside rnomental and safety consequences, this failure also has ational consequences which the operation will be stopped to reparation. Wear out of agnetic speed sensor must be aced			
			2	Magnetic speed set to detect the rotati and transmit the si signal processing short circuit	nsor fails onal speed gnal to unit due to	2	The fa circuit transn keep t desigr make worst- prior t and th harm j also ca	ailure is difficult to be de t of speed sensor will cau nitted to the signal proces he turbine rotating excee 1. Also, short circuit of sp a fire which can burn the case consequences is if t too that failure, the turbine he broken pieces will wid people nearby. The stean an cause an explosion if	tected in the trip ssing unit dingly from the technology ecomponent there is not ecomponent espread a n leakage it meets the tector of the technology the tector of technology the technology the technology the technology the technology the technology the technology the technology the technology the technology the technology the technology the techno	normal conditi p signal not to which in the e om the operation or has a possible ent nearby. An o immediate accents will be da all over the area due to damage he hydrogen fr	on. Short be and it will onal ility to d the tion maged a and ed turbine om	

					generator. Beside environmental 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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R	CM II		SYSTEM			SYSTEM	NΩ		Facilitator	Date	Sheet N^{Ω}	
IN	FORMATION		Steam Turbine			117844						FORM
w	ORKSHEET		SUB - SYSTEM			SUB - SI	STE	M N ^Ω	Auditor	Date	of	01
©	1996 ALADON LTD		High Pressure Turbine			MAA						
	FUNCTION	FU	JNCTIONAL FAILURE	FAILURE MC		DE						
4	To prevent overspeed B rotation from more than 3300 rpm	3 (Overspeed protection activates at safe rpm (3000 rpm)	1	Magnetic speed se to detect actual rot speed due to wear	nsor fails ational out	1	This fa site. W the act that th send a oversp enviro operat replace	ailure can be easily de Vear out of magnetic s tual rpm of the turbine e rpm is above the ope trip signal to signal p beed protection active ionmental consequences ional consequences. W ed.	tected in con peed sensor . If speed se rational des rocessing ur in the end. 7 s in this failt Vear out of r	ntrol room or e can possibly n nsor wrongly s sign, speed sen nit which can c Chere is no safe ure, only finan nagnetic speed	even on nisread detects sor will cause the ety nor cial and 1 must be
			2	Signal processing wrong in reading t from speed sensor wear out	unit is he signal due to	2	This fa site. W misint signal as a tri can ca no safe financ proces	ailure can be easily de /ear out of signal proc erpret the actual signa processing unit misim ip signal, that trip sign use the overspeed pro- ety nor environmental ial and operational con- ssing unit must be repl	tected in con essing unit of l from the sy terpret the s al will be se tection activ consequences. aced.	ntrol room or e can possibly peed sensor. If ignal from spe ent to trip unit re in the end. T tes in this failu Wear out of si	even on the ed sensor which there is re, only ignal	
				3			3					

Trip unit is w the signal fro processing u out	vrong in reading om signal nit due to wearThis 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. Wear out of trip must be replaced.
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RCM II	SYSTEM		SYSTEM	NΩ	Facilitator	Date	Sheet N^{Ω}			
INFORMATION	Steam Turbine		117844					FORM		
WORKSHEET	SUB - SYSTEM		SUB - SYSTEM N^{Ω}		Auditor	Date	of	01		
© 1996 ALADON LTD	High Pressure Turbine		MAA							
FUNCTION FU	JNCTIONAL FAILURE	IONAL FAILURE MO			FAILURE EFFECT					
4 To prevent overspeed C G a a 3300 rpm	Overspeed protection activates more than 3300 pm	1 Magnetic speed se detects the rotation late due to wear of	nsor ial speed it	late transmission of trip signal which also directly mak overspeed protection active late. If the overspeed prote actives late, it can cause the turbine keep rotating exce from the operational design which can damage turbine component. The broken pieces of damaged component widespread all over the area and harm people nearby. 7 steam leakage due to damaged turbine also can cause a explosion if it meets the hydrogen from generator. Bes environmental and safety consequences, this failure als operational consequences which the operation will be due to reparation. Wear out of magnetic speed sensor r replaced						
		2 Signal processing processes and tran trip signal to trip u due to wear out	unit smits the init late	2 The c control late tr oversy active from 1 comp wides steam exploi enviro	onsequences of this failu ol room. Wear out of sigr ansmission of trip signal peed protection active lat s late, it can cause the tu the operational design wl onent. The broken pieces pread all over the area ar leakage due to damaged sion if it meets the hydro onmental and safety cons	re is easy mal process which als te. If the o rbine keep hich can d s of damag nd harm p turbine a gen from requences,	to be detected sing unit will c to directly make verspeed prote o rotating exce amage turbine egel component cople nearby. T lso can cause a generator. Bes this failure als	from the cause a tes the section eedingly t can The m ide so 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



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



Daily	Weekly	Monthly	Annually
33	22	3	44



ATTACHMENT 06 FMEA IPT (MAB)

R			SYSTEM				M N	Ω	Facilitator	Date	Sheet N^{Ω}	
IN	IFORMATION		Steam Turbine									FORM
w	ORKSHEET		SUB - SYSTEM			SUB - SYSTEM N^{Ω}			Auditor	Date	of	01
©	1996 ALADON LTD		Intermediate Pressure Turbine				МАВ					
	FUNCTION		FUNCTIONAL FAILURE	E FAILURE MOI					FAILUR	E EFFECT		
1	1 To produce rotational speed of shaft at 3000 rpm in 50 Hz A Rotational speed is no produced			1	Stuck steam in gove to wear out	mor due	1	This fail situation system of Steam w which m safety no financia must be	ure can easily be not a on site or in the con can cause the steam s which is not entered a leans huge loss of co or environmental cor l and operational con replaced	iced by the trol room. T tuck and no bsolutely si st and prod isequences sequences.	operator from Wear out of go ot enter the turk ops the produc uctivity. There in this failure, Wear out of g	the overnor bine. ction c is no only overnor
				2		mor due	2	This fail situation governo Steam w which m circuit c affect th replaced	ure can easily be not on site or in the con r can cause the steam thich is not entered a neans huge loss of co an cause a small fire e component nearby.	iced by the trol room. I a stuck and bsolutely si st and prod in the gove Short circu	operator from Short circuit of not enter the tr ops the produc uctivity. Also, rnor system w it of governor	the f urbine. ction short hich can can be
				3	Erosion on seal due contaminated steam	to	3	This fail since the seal com cause th worst ca	ure can easily be not e steam is visible. Co aponent which results inning and hole which se is steam leakage r	iced on site ntaminated s in erosion h results in nakes no st	or in the contr steam can dan . Erosion on se steam leakage eam rotates the	rol room nage the eal will e. The e 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	SYSTE	M N	Ω	Facilitator	Date	Sheet N^{Ω}			
INFORMATION		Steam Turbine			117844						FORM
WORKSHEET		SUB - SYSTEM				SYS	ΤΕΜ Ν ^Ω	Auditor	Date	of	01
© 1996 ALADON LTD		Intermediate Pressure Tur	MAB	МАВ							
FUNCTION		FUNCTIONAL FAILURE	NCTIONAL FAILURE FAILURE MOD					FAILUR	E EFFECT		
1 To produce rotational speed of shaft at 3000 rpm in 50 Hz	В	Rotational speed is more than 3000 rpm	1	1 Erosion on valve due to contaminated steam			 Contaminated steam can dam. results erosion. Erosion on va which the steam will leak fron that will be absorbed by the ro Less energy produced results Also the steam which leaks ca it is high temperature and pres contaminated steam must be r 		age the val alve can cau m it. Less e otor means in loss of c an harm the ressure. Eros repaired	ge the valve components wh ve can cause thinning and ho i it. Less energy from the ste tor means less energy produ n loss of cost and productivi n harm the operator nearby s sure. Erosion on valve due to paired	
			2	Crack on valve due t out	o wear	2	Crack or required compone harm per can caus area. Thi which it out must	valve can cause the rate which can dama ent which is damaged son nearby. The leal e an explosion if it n s failure also can can will stop the product be replaced	steam flow age the turb I into piece cage of the neets the hy ase an oper- cion. Crack	v rate exceeds t ine component s can widespre hot steam from drogen from g ational consequ on valve due to	from the t. Turbine ad and n turbine enerator dences o wear

		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

R	СМ 11		SYSTEM			SYSTE	MΝ ^Ω	2	Facilitator	Date	Sheet N^{Ω}	
IN	FORMATION		Steam Turbine	117844						FORM		
w	ORKSHEET		SUB - SYSTEM	SUB - SYSTEM N^{Ω}			Auditor	Date	of	01		
©	1996 ALADON LTD		Intermediate Pressure Tur		МАВ							
	FUNCTION]	FUNCTIONAL FAILURE		FAILURE MODI	3			FAILURE	EFFECT		
1	1 To produce rotational speed of shaft at 3000 rpm in 50 Hz C Rotational speed is less 3000 rpm				Erosion on seal due contaminated steam	to	1	Contan results which t that wil Less en Also th since it to conta	hinated steam can dar erosion. Erosion on s the steam will leak fro ll be absorbed by the hergy produced result e steam which leaks of is high temperature a aminated steam must	nage the se eal can cau om it. Less rotor mean s in loss of can harm tu nd pressur be repaired	eal components use thinning an energy from t is less energy p cost and produ- ne operator nea e. Erosion on s d	s which d hole he steam produced. activity. arby seal due
				2	Crack on seal due to out	o wear	2	Crack o outside turbine steam e energy steam v high ter must be	on seal can cause the the turbine. Partial st causes the rotor does officiently and results produced means loss which leaks can harm mperature and pressu e replaced	steam fully eam which n't absorb less energ of cost an- the operat re. Crack c	r or partially le n leaks outside the energy fro y produced. Le d productivity. or nearby since n seal due to v	aks the m the ess Also the e it is vear out
			3	Corrosion on seal d contaminated steam	ue to	3	Contan results pitting	ninated steam can dar corrosion. Corrosion which the steam will	nage the se on seal car leak from	eal components n cause extensi it. Less energy	s which ve 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

RCM II			SYSTEM				MΝ ^Ω	2	Facilitator	Date	Sheet N^{Ω}	
I	NFORMATION		Steam Turbine									FORM
w	/ORKSHEET		SUB - SYSTEM	SUB - SYSTEM N $^{\Omega}$			Auditor	Date	of	01		
C	1996 ALADON LTD		Intermediate Pressure Tur	bine		МАВ						
FUNCTION			FUNCTIONAL FAILURE		FAILURE MODE	3			FAILUR	E 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 p supply due to wear	ower out	1	1 This failure mode can easily be noticed on the control. Wear out of hydraulic power supply can cause the video governor system stop working which results in clos valve. Closed control valve means no steam flowed turbine. No steam flowed to the turbine means no p There is no safety nor environmental consequences failure, only financial and operational consequences of hydraulic power supply must be replaced			I on the contro n cause the wh esults in closed team flowed to e means no pro consequences in consequences. laced	l room. nole l control o the duction. n this Wear out
				2	Broken hydraulic p supply due to short	ower circuit	2	This fai Short c governo valve. (turbine. Short c compor be repla	ilure mode can easily ircuit of hydraulic po or system stop worki Closed control valve No steam flowed to ircuit also can trigger tent nearby. Wear ou teed	be noticed ower supply ng which ro means no s the turbine rs small fire tt of hydrau	l on the contro v can cause the esults in closec team flowed to e means no pro e which can da lic power supp	l room. whole d control o the duction. mage oly must
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 row Wear out of hydraulic servomotor can cause the control romain closed. Closed control valve means no steam flow the turbine. No steam flowed to the turbine means no production. There is no safety nor environmental consequences in this failure, only financial and operation consequences. Wear out of hydraulic servomotor must b replaced 4 Hydraulic servo valve fails to open the control valve due to short circuit 4 5 Hydraulic servo valve fails to open the control valve due to short circuit 4												
---	--	---	--	--								
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 ro Short circuit of hydraulic servomotor can cause the control valve remain closed. Closed control valve means no steat flowed to the turbine. No steam flowed to the turbine mean no production. Short circuit also can triggers small fire we demend to the turbine of the turbine for the turbine of the turbine.		3 Hydraulic servo valve to open the control va due to wear out	e fails alve 3 This failure mode can easily be notice Wear out of hydraulic servomotor can remain closed. Closed control valve n the turbine. No steam flowed to the tu production. There is no safety nor env consequences in this failure, only fina consequences. Wear out of hydraulic replaced	d on the control room. cause the control valve leans no steam flowed to rbine means no ironmental ncial and operational servomotor must be								
servomotor must be replaced		4 Hydraulic servo valve to open the control va due to short circuit	e fails alve 4 This failure mode can easily be notice Short circuit of hydraulic servomotor valve remain closed. Closed control v flowed to the turbine. No steam flowe no production. Short circuit also can t can damage component nearby. Short servomotor must be replaced	d on the control room. can cause the control alve means no steam d to the turbine means riggers small fire which circuit of hydraulic								
5 Broken selenoid valve due to wear out 5 This failure mode can easily be noticed on the control row Wear out of selenoid valve can cause the control valve reclosed. Closed control valve means no steam flowed to the turbine. No steam flowed to the turbine means no produc There is no safety nor environmental consequences in the failure, only financial and operational consequences. We of selenoid valve must be replaced		5 Broken selenoid valve to wear out	7e due 5 This failure mode can easily be notice Wear out of selenoid valve can cause closed. Closed control valve means no turbine. No steam flowed to the turbin There is no safety nor environmental failure, only financial and operational of selenoid valve must be replaced	d on the control room. the control valve remain o steam flowed to the e means no production. consequences in this consequences. Wear out								

		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

Γ	RCM II		SYSTEM			SYSTEM	NΩ		Facilitator	Date	Sheet N^{Ω}	
	INFORMATION		Steam Turbine			117844						FORM
	WORKSHEET		SUB - SYSTEM			SUB - SY	STI	EM N ^Ω	Auditor	Date	of	01
	© 1996 ALADON LTD		Intermediate Pressure Tu	rbine	2	MAB						
	FUNCTION	FU	JNCTIONAL FAILURE		FAILURE MO	DE			FAILUR	E EFFECT		
	2 To control the steam flow B rate at between 303.8 - 584 kg/s by adjusting control valve in load condition		Steam is injected more than 584 kg/s	1	Speed sensor fails actual needs of ste wear out	to control am due to	1	This fa Wear of needs althou is exco destruc compo hydrog must b	ailure mode can easily out of speed sensor ca of steam. It can inject gh it is not needed act eeding steam can trigg ction of turbine compo- ment also can lead to a gen from the generator e replaced	be noticed n cause a wr exceeding <i>z</i> hally. The w er overspee nent. Destr n explosion . Wear out	on the control rong detection umount of stear vorst case conss d on turbine ar uction of turbi i if the steam n of hydraulic se	room. of actual m eequences ad cause a ne neets the rrvomotor
				2	Servo valve fails t the actual needs of flow rate due to w	o receive Esteam ear out	2	This fa Wear of needs althou is exco destruc compo hydrog replace	ailure mode can easily out of servo valve can of steam. It results inj gh it is not needed act reeding steam can trigg ction of turbine compo- ment also can lead to a gen from the generator ed	be noticed be wrong in ecting exceed hally. The v er overspee onent. Destr in explosion . Wear out	on the control n receiving the eding amount of vorst case cons d on turbine ar uction of turbi n if the steam n of servo valve	room. actual of steam equences ud cause a ne neets the must be

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

RCM II			SYSTEM	SYSTEM N ^Ω			Facilitator	Date	Sheet N^{Ω}			
	INFORMATION		Steam Turbine	Steam Turbine								FORM
	WORKSHEET		SUB - SYSTEM			SUB - SYSTEM N^{Ω}			Auditor	Date	of	01
	© 1996 ALADON LTD		Intermediate Pressure Tur		MAB							
	FUNCTION		FUNCTIONAL FAILURE		FAILURE MODI	3			FAILURE	EFFECT		
	2 To control the steam flow rate at between 303.8 - 584 kg/s by adjusting control valve in load condition	С	Steam is injected less than 303.8 kg/s	1	Servo valve fails to r the actual needs of st flow rate due to wear	eceive ream r out	1	This fail Wear ou needs of required conseque conseque	ure mode can easily b t of servo valve can ca 'steam. It can inject le flow rate. There is no ences in this failure, o ences. Wear out of ser	e noticed o ause a wrc ss amount safety no nly financ vo valve i	on the control ong detection o of steam than r environmenta ial and operati nust be replace	room. f actual the al onal ed
				2	Selenoid valve fails f receive the actual ne steam flow rate due f out	to eds of to wear	2	This fail Wear ou actual no the requi conseque conseque	ure mode can easily b t of selenoid valve car ceds of steam. It can ir ired flow rate. There is ences in this failure, or ences. Wear out of sel	e noticed (1 cause a v nject less a s no safety nly financ enoid valv	on the control i vrong detectio imount of stear v nor environm ial and operati ve must be repl	room. n of m than ental onal laced

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

R	CM II		SYSTEM			SYSTE	M N ^g	2	Facilitator	Date	Sheet N^{Ω}	
I	NFORMATION		Steam Turbine	Steam Turbine								FORM
W	/ORKSHEET		SUB - SYSTEM	SUB -	SYST	ΈΜ Ν ^Ω	Auditor	Date	of	01		
C	1996 ALADON LTD		Intermediate Pressure Tur	bine		MAB						
	FUNCTION		FUNCTIONAL FAILURE		FAILURE MODE	3			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 p supply due to wear	ower out	1	This fa Wear o governo valve. (turbine There i failure, of hydr	ilure mode can easily b ut of hydraulic power or system stop working Closed control valve m . No steam flowed to t s no safety nor enviror only financial and ope aulic power supply mu	be noticed supply ca g which re- leans no s he turbine umental co- rrational co- rrati	I on the control n cause the wh esults in closed team flowed to e means no pro onsequences in consequences. laced	l room. nole l control o the duction. n this Wear out
				2	Broken hydraulic p supply due to short	ower circuit	2	This fa Short c governo valve. (turbine Short c compor be repla	ilure mode can easily b ircuit of hydraulic pow or system stop working Closed control valve m . No steam flowed to ti ircuit also can triggers nent nearby. Wear out aced	be noticed yer supply g which ra- leans no s he turbine small fire of hydrau	l on the control y can cause the esults in closed team flowed to e means no pro e which can da llic power supp	l room. whole d control o the duction. mage oly must

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 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 can cause the control replaced 4 Hydraulic servo valve fails to open the control valve due to short circuit 4 5 Broken sclenoid valve due to wear out 5 6 Broken sclenoid valve due to wear out 5 7 Broken sclenoid valve due to wear out 5					
4 Hydraulic servo valve fails to open the control valve due to short circuit of hydraulic servomotor can cause 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 6 Broken selenoid valve due to sam flowed to the turbine. No steam flowed to the control room. Wear out of selenoid valve can cause the control valve remain closed. Closed control valve means no production. There is no safety nor environmental consequences in this failure. No steam flowed to the turbine closed. Closed control valve means no production. There is no safety nor environmental consequences. Wear out		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
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. No steam flowed to the failure is no safety nor environmental consequences in this failure. only financial and operational consequences. Wear out		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
of selenoid valve 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

RCM II		SYSTEM			SYSTEM	NΩ		Facilitator	Date	Sheet N^{Ω}	
INFORMATION		Steam Turbine	Steam Turbine								FORM
WORKSHEET		SUB - SYSTEM		SUB - SYSTEM N^{Ω}			Auditor	Date	of	01	
© 1996 ALADON LTD		Intermediate Pressure Tu	rbine	e	МАВ						
FUNCTION	I	FUNCTIONAL FAILURE		FAILURE MO	DE FAILURE EFFECT						
3 To control the steam flow rate at between 90 kg/s by adjusting control valve in start-up condition	В	Steam is injected more than 90 kg/s	1	Speed sensor fails actual needs of ste wear out	to control am due to	1	This fa Wear of needs althou is exco a destri compo hydrog must b	ailure mode can easily b out of speed sensor can of steam. It can inject ey gh it is not needed actua eeding steam can trigger ruction of turbine compo onent also can lead to an gen from the generator.	e noticed cause a wi kceeding a illy. The v overspee onent. Des explosion Wear out	on the control rong detection umount of stear vorst case cons d on turbine ar truction of turl n if the steam n of hydraulic se	room. of actual m equences dd cause bine neets the rrvomotor
			2	Servo valve fails t the actual needs o flow rate due to w	o receive f steam ear out	2	This fa Wear of needs althou is exco a destri compo- hydrog replace	ailure mode can easily b out of servo valve can b of steam. It results injec gh it is not needed actua eeding steam can trigger ruction of turbine compo onent also can lead to an gen from the generator. ed	e noticed e wrong in ting exceed ully. The v overspee onent. Des explosion Wear out	on the control n receiving the eding amount of vorst case cons d on turbine ar truction of turl n if the steam n of servo valve	room. actual of steam equences ad cause bine neets the must be

		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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1	RCM II		SYSTEM			SYSTEM	NΩ		Facilitator	Date	Sheet N^{Ω}	
1	INFORMATION		Steam Turbine	Steam Turbine								FORM
١	WORKSHEET		SUB - SYSTEM	SUB - SYSTEM N^{Ω}			Auditor	Date	of	01		
(© 1996 ALADON LTD		Intermediate Pressure Tu	е	МАВ							
	FUNCTION	UNCTIONAL FAILURE	1	FAILURE MO	DE	E FAILURE EFFECT						
	I o 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 t the actual needs of flow rate due to w	o receive f steam ear out	1	This fa Wear of needs require consectorsectors	alture mode can easily out of servo valve can o of steam. It can inject 1 ed flow rate. There is n quences in this failure, quences. Wear out of so	be noticed cause a wro ess amouni o safety no only financ ervo valve n	on the control ong detection c t of steam than r environment cial and operati must be replac	room. of actual the al ional ed
				2	Selenoid valve fai receive the actual steam flow rate du out	ls to needs of ie to wear	2	This fa Wear of actual the reconsect consect	ailure mode can easily out of selenoid valve ca needs of steam. It can quired flow rate. There quences in this failure, quences. Wear out of so	be noticed an cause a v inject less a is no safety only financ lenoid valv	on the control wrong detectio amount of stea / nor environm ial and operative we must be rep	room. n of m than hental ional laced

			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

R	CM II		SYSTEM		SYSTEM N^{Ω}			Facilitator	Date	Sheet N^{Ω}		
I	NFORMATION		Steam Turbine	Steam Turbine								FORM
w	/ORKSHEET		SUB - SYSTEM	SUB - SYSTEM N^{Ω}			Auditor	Date	of	01		
C	1996 ALADON LTD		Intermediate Pressure Tu	e	МАВ							
	FUNCTION	F	FUNCTIONAL FAILURE		FAILURE MO	DE FAILURE EFFECT						
4	To prevent overspeed rotation from more than 3300 rpm	A	Inactive of overspeed protection	1	Magnetic speed set to detect the rotati and transmit the si signal processing wear out	nsor fails onal speed gnal to unit due to	1	The fa out of transn will ke design turbin- widesj steam explos envirn operat due to replac	illure is difficult to be de magnetic speed sensor v nitted to the signal proce eep the turbine rotating e . If there is no immediat e components will be da pread all over the area ar leakage due to damaged sion if it meets the hydro iomental and safety cons ional consequences whic reparation. Wear out of ed	tected in r vill cause sssing uni xceeding e action p maged an id harm p turbine a gen from equences, ch the ope agnetic sp	normal conditi the trip signal t which in the ly from the op orior to that fai d the broken p eople nearby. lso can cause a generator. Bes this failure all eration will be peed sensor mu	on. Wear not to be end it erational lure, the ieces will The in ide so has stopped ist be
				2	Magnetic speed set to detect the rotati and transmit the si signal processing short circuit	nsor fails onal speed gnal to unit due to	2	The fa circuit transm keep t design make worst- prior t and th harm j also ca	tilure is difficult to be de tof speed sensor will can hitted to the signal proce he turbine rotating excee h. Also, short circuit of sp a fire which can burn the case consequences is if to that failure, the turbing e broken pieces will wid people nearby. The stean an cause an explosion if	tected in the trip ssing unit dingly from the technologies of technolo	normal conditi p signal not to which in the e om the operation or has a possible ent nearby. An o immediate accents will be da all over the area due to damage he hydrogen fr	on. Short be and it will onal ility to d the tion maged a and ed turbine om

					generator. Beside environmental 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

1	1			1		
			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 emergency 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

R	RCM II	SYSTEM		SYSTEM N^{Ω}			Facilitator	Date	Sheet N^{Ω}		
I	NFORMATION	Steam Turbine			117844						FORM
v	VORKSHEET	SUB - SYSTEM	SUB - SYSTEM N^{Ω}			Auditor	Date	of	01		
(1996 ALADON LTD	Intermediate Pressure Tu	e	MAB	МАВ						
	FUNCTION	FUNCTIONAL FAILURE	ONAL FAILURE FAILURE MOI				DE FAILURE EFFECT				
4	To prevent overspeed B rotation from more than 3300 rpm	Overspeed protection activates at safe rpm (3000 rpm)	1	Magnetic speed so to detect actual ro speed due to wear	ensor fails tational out	1	This fa site. W the act that th send a oversp enviro operat replac	ailure can be easily det Vear out of magnetic sp tual rpm of the turbine. e rpm is above the ope trip signal to signal pr beed protection active in mmental consequences ional consequences. W ed.	ected in con eed sensor If speed se rational des occessing ur n the end. 7 in this fail ear out of n	ntrol room or e can possibly r nsor wrongly sign, speed sen nit which can c Chere is no safe ure, only finan nagnetic speed	even on nisread detects isor will cause the ety nor cial and d must be
			2	Signal processing wrong in reading t from speed sensor wear out	unit is he signal due to	2	This fa site. W misint signal as a tr can ca no safi financ proces	ailure can be easily dete Vear out of signal proce erpret the actual signal processing unit misinte ip signal, that trip signa use the overspeed prote ety nor environmental of ial and operational con ssing unit must be repla	ected in con ssing unit of from the sp erpret the s l will be se- ection activ sequences. ced.	ntrol room or e can possibly peed sensor. If ignal from spe nt to trip unit re in the end. T res in this failu Wear out of si	even on the ed sensor which 'here is re, only ignal
1			5			5					

R	CM II		SYSTEM		SYSTEM N ^Ω			Facilitator	Date	Sheet N^{Ω}			
I	FORMATION		Steam Turbine			117844						FORM	
w	ORKSHEET		SUB - SYSTEM	SUB - SYSTEM N^{Ω}			Auditor	Date	of	01			
©	1996 ALADON LTD		Intermediate Pressure Tu	e	MAB	r							
FUNCTION			UNCTIONAL FAILURE	DE FAILURE EFFECT									
4	To prevent overspeed rotation from more than 3300 rpm	C	Overspeed protection activates more than 3300 rpm	1	Magnetic speed se detects the rotation late due to wear of	insor i nal speed ut		The co control late tra oversp actives from t compo widesj steam explos enviro operat due to replac	the consequences of this failure is easy to be detected from the ontrol room. Wear out of magnetic speed sensor will cause a te transmission of trip signal which also directly makes the /erspeed protection active late. If the overspeed protection tives late, it can cause the turbine keep rotating exceedingly om the operational design which can damage turbine omponent. The broken pieces of damaged component can idespread all over the area and harm people nearby. The eam leakage due to damaged turbine also can cause an cplosion if it meets the hydrogen from generator. Beside twironmental and safety consequences, this failure also has berational consequences which the operation will be stopped te to reparation. Wear out of magnetic speed sensor must be placed				
				2	Signal processing processes and tran trip signal to trip u due to wear out	unit smits the init late	2	The co control late tra oversp actives from t compo widesj steam explos enviro	onsequences of this fa l room. Wear out of s ansmission of trip sign opeed protection active s late, it can cause the he operational design onent. The broken piec pread all over the area leakage due to damag tion if it meets the hyo mmental and safety co	ilure is easy ignal proces al which als late. If the of turbine keep which can of ees of damag and harm p red turbine a brogen from onsequences.	to be detected sing unit will of so directly mak verspeed prote portating exce amage turbine ged component cople nearby. 7 lso can cause a generator. Bes this failure also	from the cause a ces the section eedingly t can The an side so 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 remonstrian A build up demosit on ail dume 1
					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-	Scheduled	Schedule	Failure Finding			
Conditioned Task	Restoration Task	Discard Task	Task			
30	19	40	13			



Daily	Weekly	Monthly	Annually		
33	22	3	44		



ATTACHMENT 07 FMEA LPT 1 (MAC10)

R			SYSTEM		SYSTEM N^{Ω}			Facilitator	Date	Sheet N^{Ω}		
IN	FORMATION		Steam Turbine			117844						FORM
WORKSHEET			SUB - SYSTEM			SUB - SYSTEM N^{Ω}			Auditor	Date	of	01
©	1996 ALADON LTD	Low Pressure Turbine 1	MAC10									
FUNCTION F			UNCTIONAL FAILURE	AL FAILURE FAILURE MC					FAILUR	E EFFECT		
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	A	Rotational speed is not produced	1	Stuck steam in gov to wear out	ernor due	1	This fa situati systen Steam which safety financ must b	ailure can easily be not on on site or in the cor n can cause the steam s which is not entered a means huge loss of cc nor environmental cor ial and operational cor be replaced	ticed by the htrol room. T stuck and no ibsolutely si st and prod nsequences asequences.	operator from Wear out of go ot enter the turk ops the produc uctivity. There in this failure, Wear out of g	the overnor bine. ction c is no only overnor
				2	Stuck steam in gov to short circuit	ernor due	2	This fa situati govern Steam which circuit affect replac	ailure can easily be not on on site or in the cor nor can cause the stean which is not entered a means huge loss of cc can cause a small fire the component nearby ed	ticed by the ntrol room. I n stuck and ibsolutely st ost and prod in the gove . Short circu	operator from Short circuit of not enter the tr ops the produc uctivity. Also, rnor system w iit of governor	the f urbine. ction short hich can c an be
				3	Erosion on seal du contaminated stear	e to m	3	This fa since t seal co cause worst	ailure can easily be not he steam is visible. Co omponent which result thinning and hole which case is steam leakage r	ticed on site ontaminated s in erosion ch results in makes no st	or in the contr steam can dar . Erosion on se steam leakage eam rotates the	rol room nage the eal will e. The e 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										
F	RCM II		SYSTEM		SYSTEM N ^Ω			Facilitator	Date	Sheet N^{Ω}			
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I	NFORMATION		Steam Turbine			117844						FORM	
v	VORKSHEET		SUB - SYSTEM	SUB - SYSTEM			YST	EM N ^Ω	Auditor	Date	of	01	
(1996 ALADON LTD	Low Pressure Turbine 1	Low Pressure Turbine 1				MAC10						
FUNCTION FU			FUNCTIONAL FAILURE		DE FAILURE EFFECT								
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	В	Rotational speed is more than 3000 rpm	1	Erosion on valve c contaminated stear	lue to n	1	Contai results which that wi Less e Also tl it is hij contan	ninated steam can dama erosion. Erosion on val the steam will leak fror ill be absorbed by the ro nergy produced results ne steam which leaks ca gh temperature and pres ninated steam must be r	age the val ive can cau n it. Less e tor means in loss of c n harm the ssure. Eros epaired	ve component use thinning ar energy from th less energy pr ost and produce operator near ion on valve d	s which d hole e steam oduced. tivity. by since ue to	
				2	Crack on valve du out	e to wear	2	Crack require compo harm p can ca area. T which out mu	on valve can cause the sed rate which can damagent which is damaged berson nearby. The leak use an explosion if it more than a splosion if it will stop the product is the replaced	steam flow ge the turb into piece age of the eets the hy se an oper on. Crack	v rate exceeds ine componen s can widespre hot steam fron drogen from g ational conseq on valve due t	from the t. Turbine ad and n turbine enerator uences o wear	

		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

RC			SYSTEM		SYSTEM N^{Ω}			Facilitator	Date	Sheet N^{Ω}		
IN	FORMATION		Steam Turbine			117844						FORM
w	ORKSHEET		SUB - SYSTEM		SUB - SYSTEM N $^{\Omega}$			Auditor	Date	of	01	
©	1996 ALADON LTD	Low Pressure Turbine 1		MAC10								
	FUNCTION	UNCTIONAL FAILURE		FAILURE MOI	DE			FAILURE	E EFFECT			
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	C Rotational speed is less than 3000 rpm			Erosion on seal di contaminated stea	ie to im	1	Conta result which that v Less Also since to con	aminated steam can dar ts erosion. Erosion on s h the steam will leak fro vill be absorbed by the energy produced result the steam which leaks o it is high temperature a ntaminated steam must	nage the se eal can cau om it. Less rotor mean s in loss of can harm tl nd pressur be repaired	eal components use thinning an energy from t is less energy p cost and produ- ne operator nea e. Erosion on s d	s which d hole he steam produced. uctivity. arby seal due
				2	Crack on seal due out	to wear	2	Crack outsid turbin steam energ steam high must	k on seal can cause the s de the turbine. Partial st ne causes the rotor does n efficiently and results gy produced means loss n which leaks can harm temperature and pressu- be replaced	steam fully eam which n't absorb less energ of cost an- the operat re. Crack c	v or partially le h leaks outside the energy from y produced. Le d productivity. or nearby since on seal due to v	aks the m the ess Also the e it is wear out
				3	Corrosion on seal contaminated stea	due to m	3	Conta result pittin	aminated steam can dar ts corrosion. Corrosion g which the steam will	nage the se on seal car leak from	eal components a cause extensi it. Less energy	s which ive 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

R	CM II		SYSTEM		SYSTEM	NΩ		Facilitator	Date	Sheet N^{Ω}			
I	NFORMATION		Steam Turbine	117844						FORM			
w	ORKSHEET		SUB - SYSTEM	SUB - SYSTEM N^{Ω}			Auditor	Date	of	01			
©	1996 ALADON LTD		Low Pressure Turbine 1			MAC10							
FUNCTION			UNCTIONAL FAILURE		FAILURE MO	DE			FAILURE EFFECT				
2	To prevent overspeed rotation from more than 3300 rpm	A	Inactive of overspeed protection	1 Magnetic speed sensor fail to detect the rotational spear and transmit the signal to signal processing unit due wear out			1	The fa out of transn will ke design turbin- widesj steam explos envinn operat due to replac	illure is difficult to be detected in normal condition. Wear magnetic speed sensor will cause the trip signal not to be nitted to the signal processing unit which in the end it eep the turbine rotating exceedingly from the operational 1. If there is no immediate action prior to that failure, the e components will be damaged and the broken pieces will pread all over the area and harm people nearby. The leakage due to damaged turbine also can cause an sion if it meets the hydrogen from generator. Beside toomental and safety consequences, this failure also has tional consequences which the operation will be stopped or reparation. Wear out of agnetic speed sensor must be ted				
				2	Magnetic speed so to detect the rotati and transmit the si signal processing short circuit	ensor fails onal speed ignal to unit due to	2	The fa circuit transm keep t design make worst- prior t and th harm j also ca	tilure is difficult to be d t of speed sensor will ca nitted to the signal proce- he turbine rotating excer a fire which can burn the case consequences is if o that failure, the turbin e broken pieces will wi people nearby. The stea an cause an explosion if	etected in inuse the trip essing unit redingly from speed sense the component there is not be component despread a m leakage f it meets the	normal conditi p signal not to which in the e om the operation or has a possible ent nearby. An o immediate acc ents will be da ill over the area due to damage he hydrogen fr	on. Short be and it will onal ility to d the tion maged a and ed turbine om	

					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 emergency 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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R	CM II		SYSTEM	S	SYSTEM N ^Ω			Facilitator	Date	Sheet N^{Ω}				
I	FORMATION		Steam Turbine	117844							FORM			
w	VORKSHEET SUB - SYSTEM SUB - SYSTEM N					Μ Ν ^Ω	Auditor	Date	of	01				
©	1996 ALADON LTD		Low Pressure Turbine 1	MAC10										
FUNCTION F			UNCTIONAL FAILURE		FAILURE MO	DE	2	FAILURE EFFECT						
2	To prevent overspeed B rotation from more than 3300 rpm	1	Overspeed protection activates at safe rpm (3000 rpm)	1	Magnetic speed se to detect actual ro speed due to wear	enso tati	or fails onal t	1	This fa site. W the act that th send a oversp enviro operat replace	ailure can be easily de Vear out of magnetic s tual rpm of the turbine e rpm is above the ope trip signal to signal p beed protection active ional consequences ional consequences. W ed.	tected in corpeed sensor . If speed se crational des rocessing un in the end. 7 s in this fail Vear out of r	ntrol room or e can possibly n nsor wrongly sign, speed sen nit which can c Chere is no safe ure, only finan- nagnetic speed	even on nisread detects sor will cause the ety nor cial and 1 must be	
				2	Signal processing wrong in reading t from speed sensor wear out	un the r du	it is signal le to	2	This fa site. W misint signal as a tri can ca no safe financ proces	ailure can be easily de Vear out of signal proc erpret the actual signa processing unit misin ip signal, that trip sign use the overspeed prov ety nor environmental ial and operational con ssing unit must be repl	tected in con- essing unit l from the s- terpret the s- al will be se- tection active consequences. aced.	ntrol room or e can possibly peed sensor. If ignal from spe nt to trip unit ' re in the end. T ses in this failu Wear out of si	even on the ed sensor which 'here is re, only ignal	
				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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R	CM II		SYSTEM		SYSTEM	NΩ		Facilitator	Date	Sheet N^{Ω}		
IN	FORMATION Steam Turbine 117844										FORM	
w	ORKSHEET		SUB - SYSTEM			SUB - S	YSTI	E M N Ω	Auditor	Date	of	01
©	1996 ALADON LTD		Low Pressure Turbine 1			MAC10						
FUNCTION			UNCTIONAL FAILURE	FAILURE MO	DE FAILURE EFFECT							
2	To prevent overspeed C rotation from more than 3300 rpm		Overspeed protection activates more than 3300 rpm	1	Magnetic speed se detects the rotation late due to wear of	nsor hal speed it	1	The cc contro late tra oversp active: from t compc widesj steam explos enviro operat due to replac	onsequences of this fail I room. Wear out of m ansmission of trip signa- seed protection active I is late, it can cause the the he operational design v onent. The broken piece pread all over the area leakage due to damage sion if it meets the hydro- nmental and safety cor ional consequences wh reparation. Wear out co ed	ure is easy agnetic spe al which als ate. If the c rurbine keep which can d es of damag and harm p ed turbine a rogen from isequences, ich the ope of magnetic	to be detected ed sensor will so directly mak verspeed prote protating excee lamage turbine ged component eople nearby. 7 lso can cause a generator. Bes this failure als ration will be speed sensor r	from the cause a tes the section edingly t can The tran tide so has stopped nust be
				2	Signal processing processes and tran trip signal to trip u due to wear out	unit smits the nit late	2	The co control late tra oversp actives from t compo widesj steam explos enviro	onsequences of this fail of room. Wear out of signal ansmission of trip signa- beed protection active l is late, it can cause the t he operational design v onent. The broken piece pread all over the area leakage due to damage sion if it meets the hydro- mmental and safety con-	ure is easy gnal proces al which als ate. If the o urbine keep which can c es of damag and harm p ed turbine a rogen from asequences	to be detected sing unit will c so directly mak verspeed prote protating exce lamage turbine ged component ecople nearby. Iso can cause a generator. Bes this failure also	from the cause a ces the cction eedingly t can The un cide so has

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					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		



ſ	Scheduled On-	Scheduled	Schedule Discard	Eailuro Einding Task		
	Conditioned Task	Restoration Task	Task			
	20	11	14	13		





Daily	Weekly	Monthly	Annually		
23	14	3	18		





ATTACHMENT 08 FMEA LPT 2 (MAC20)

R			SYSTEM			SYSTEM N^{Ω}			Facilitator	Date	Sheet N^{Ω}			
IN	INFORMATION Steam Turbine 117844									FORM				
w	ORKSHEET		SUB - SYSTEM	SUB - SYSTEM			ST	EM N ^Ω	Auditor	Date	of	01		
©	1996 ALADON LTD		Low Pressure Turbine 2	Low Pressure Turbine 2					MAC20					
	FUNCTION	I	FUNCTIONAL FAILURE		FAILURE MO	DE			FAILURE	EFFECT				
1	To produce rotational speed of shaft at 3000 rpm in 50 Hz	A	Rotational speed is not produced	2	Stuck steam in gov to wear out	vernor due vernor due	1	This fa situati systen Steam which safety financ must b This fa	ailure can easily be notion on on site or in the cont in can cause the steam sti which is not entered ab means huge loss of cos nor environmental cons ial and operational cons be replaced	ced by the rol room. Y uck and no solutely st t and prod sequences equences.	operator from Wear out of go ot enter the turk ops the produc uctivity. There in this failure, Wear out of g	the overnor bine. ction c is no only overnor the		
				3	Erosion on seal du contaminated stear	e to n	3	This fa since t seal co cause worst	ailure can easily be notified the steam is visible. Con omponent which results the interval above the steam is visible. Con the steam is visible. Con the steam is visible which results thinning and hole which case is steam leakage m	ced on site traminated in results in cest on site	or in the contract of steam can data	rol room nage the eal will b. The e 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	NΩ		Facilitator	Date	Sheet N^{Ω}	
INFORMATION	Steam Turbine	Steam Turbine								FORM	
WORKSHEET		SUB - SYSTEM	SUB - SYSTEM				EM N ^Ω	Auditor	Date	of	01
© 1996 ALADON LTD		Low Pressure Turbine 2	Low Pressure Turbine 2								
FUNCTION	F	FUNCTIONAL FAILURE		FAILURE MO	DE			EFFECT			
1 To produce rotational speed of shaft at 3000 rpm in 50 Hz	В	Rotational speed is more than 3000 rpm	1	Erosion on valve d contaminated stear	ue to n	1	Contar results which that wi Less er Also th it is hig contan	ninated steam can dama, erosion. Erosion on valv the steam will leak from Il be absorbed by the rot nergy produced results in ne steam which leaks car gh temperature and press ninated steam must be re	ge the val ve can cau it. Less e or means 1 loss of c h harm the sure. Eros paired	ve components use thinning an energy from the less energy pr ost and produc e operator near ion on valve d	s which d hole e steam oduced. tivity. by since ue to
			2	Crack on valve du out	e to wear	2	Crack require compo harm p can cau area. T which out mu	on valve can cause the s ed rate which can damag nent which is damaged i erson nearby. The leaka use an explosion if it me 'his failure also can caus it will stop the production st be replaced	team flow e the turb nto piece: ge of the ets the hy e an opera n. Crack	rate exceeds t ine component s can widespre hot steam from drogen from g ational consequ on valve due to	from the at Turbine ad and a turbine enerator dences o wear

		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

R			SYSTEM	SYSTEM					Facilitator	Date	Sheet N^{Ω}	
IN	IFORMATION		Steam Turbine	117844						FORM		
w	ORKSHEET		SUB - SYSTEM			SUB - SYSTEM N^{Ω}			Auditor	Date	of	01
©	1996 ALADON LTD		Low Pressure Turbine 2			MAC20						
1	FUNCTION	F	UNCTIONAL FAILURE	1	FAILURE MOI		1	Cont	FAILURE	EFFECT		which
1	of shaft at 3000 rpm in 50 Hz		3000 rpm	1	contaminated stea	um	1	result which that v Less Also since to co	ts erosion. Erosion on see h the steam will leak fro vill be absorbed by the r energy produced results the steam which leaks c it is high temperature an ntaminated steam must b	age the scalar can can m it. Less otor meam in loss of an harm th nd pressure be repaired	ise thinning an energy from t is less energy p cost and produ- te operator ner- te. Erosion on s d	s which d hole he steam produced. uctivity. arby seal due
				2	Crack on seal due out	to wear	2	Cracl outsid turbin stean energ stean high must	k on seal can cause the s de the turbine. Partial sto ne causes the rotor doesn n efficiently and results l gy produced means loss of n which leaks can harm to temperature and pressur be replaced	team fully eam which a't absorb less energ of cost an- the operat e. Crack c	v or partially le h leaks outside the energy fro y produced. Le d productivity. or nearby since on seal due to v	eaks the m the ess Also the e it is wear out
				3	Corrosion on seal contaminated stea	due to am	3	Conta result pittin	aminated steam can dam ts corrosion. Corrosion o g which the steam will l	hage the se on seal car leak from	al components n cause extensi it. Less energy	s which ive 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
ГГ					
----	--	---	--	---	--
		7	Corrocion on rotor due to	7	an explosion if it meets the hydrogen from generator. Crack on rotor due to contaminated steam must be repaired
		/	contaminated steam	,	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

R	CM II		SYSTEM		SYSTEM N ^Ω			Facilitator	Date	Sheet N^{Ω}		
I	NFORMATION		Steam Turbine	117844						FORM		
w	/ORKSHEET		SUB - SYSTEM	SUB - SYSTEM N^{Ω}			Auditor	Date	of	01		
C	1996 ALADON LTD		Low Pressure Turbine 2			MAC20						
FUNCTION			FUNCTIONAL FAILURE	FAILURE MO	DE FAILURE EFFECT							
2	To prevent overspeed rotation from more than 3300 rpm	A	Inactive of overspeed protection	1	Magnetic speed set to detect the rotati and transmit the si signal processing wear out	nsor fails onal speed gnal to unit due to	1	The fa out of transn will kd desigr turbin wides steam explos envirn operat due to replac	illure is difficult to be de magnetic speed sensor v nitted to the signal proce eep the turbine rotating e a. If there is no immediat e components will be da pread all over the area ar leakage due to damaged sion if it meets the hydro iomental and safety cons ional consequences which reparation. Wear out of ed	tected in r vill cause sssing uni xceeding e action p maged an id harm p turbine a gen from equences, ch the ope agnetic sp	normal conditi the trip signal t which in the op rior to that fail d the broken p eople nearby. Iso can cause a generator. Bes this failure als eration will be peed sensor mu	on. Wear not to be end it erational lure, the ieces will The m ide so has stopped 1st be
				2	Magnetic speed set to detect the rotati and transmit the si signal processing short circuit	nsor fails onal speed gnal to unit due to	2	The fa circuit transn keep t desigr make worst- prior t and th harm j also ca	illure is difficult to be de t of speed sensor will cau hitted to the signal process he turbine rotating excees h. Also, short circuit of sp a fire which can burn the case consequences is if to o that failure, the turbine e broken pieces will wid people nearby. The stean an cause an explosion if	tected in the trip ssing unit dingly from the technology of the technology ecomponent of the technology of tec	normal conditi p signal not to which in the e om the operatio or has a possib ent nearby. An o immediate ac ents will be dan Il over the area due to damage he hydrogen fr	on. Short be and it will onal ility to d the tion maged a and ed turbine om

		3	Signal processing unit fails	3	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
			to process and transmit the signal to trip unit due to wear out	5	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 emergency 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

R	CM II		SYSTEM			SYS	TEM	NΩ		Facilitator	Date	Sheet N^{Ω}		
I	FORMATION		Steam Turbine			1178	844						FORM	
w	ORKSHEET		SUB - SYSTEM			SUB	- SY	STE	Μ Ν ^Ω	Auditor	Date	of	01	
©	1996 ALADON LTD		Low Pressure Turbine 2	Ν			MAC20							
	FUNCTION	FU	UNCTIONAL FAILURE		FAILURE MO	DE		FAILURE EFFECT						
2	To prevent overspeed B rotation from more than 3300 rpm		Overspeed protection activates at safe rpm (3000 rpm)	1	Magnetic speed se to detect actual rot speed due to wear	ensor fails 1 tational • out			This failure can be easily detected in control room site. Wear out of magnetic speed sensor can possi the actual rpm of the turbine. If speed sensor wron that the rpm is above the operational design, spee- send a trip signal to signal processing unit which overspeed protection active in the end. There is no environmental consequences in this failure, only for operational consequences. Wear out of magnetic speed.				even on nisread detects isor will cause the ety nor cial and d must be	
				2	Signal processing wrong in reading t from speed sensor wear out	unit is he sign due to	nal	2 3	This fa site. W misint signal as a tri can ca no safe financ proces	ailure can be easily det /ear out of signal proc- erpret the actual signal processing unit misint ip signal, that trip sign use the overspeed prot ety nor environmental ial and operational cor ssing unit must be repla	ected in con essing unit of from the sp erpret the s al will be see ection activ consequences. sequences.	ntrol room or e can possibly peed sensor. If ignal from spe- nt to trip unit ' e in the end. T res in this failu Wear out of si	even on the ed sensor which 'here is re, only ignal	
				5				5						

R	CM II		SYSTEM			SYSTEM	NΩ		Facilitator	Date	Sheet N^{Ω}		
I	FORMATION		Steam Turbine			117844						FORM	
w	ORKSHEET		SUB - SYSTEM			SUB - SYSTEM N^{Ω}			Auditor	Date	of	01	
©	1996 ALADON LTD		Low Pressure Turbine 2			MAC20							
	FUNCTION	F	UNCTIONAL FAILURE		FAILURE MO	DE	FAILURE EFFECT						
2	To prevent overspeed rotation from more than 3300 rpm	С	Overspeed protection activates more than 3300 rpm		Magnetic speed se detects the rotation late due to wear of	nsor hal speed it	1	The cc control late tra oversg active: from t compo widesj steam explos enviro operat due to replac	The consequences of this failure is easy to be detected from th 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 processes and tran trip signal to trip u due to wear out	unit smits the nit late	2	The co control late tra oversp actives from t compo widesj steam explos enviro	onsequences of this failu- onsequences of this failu- l room. Wear out of sig ansmission of trip signa beed protection active la s late, it can cause the he operational design w onent. The broken piece pread all over the area a leakage due to damaged sion if it meets the hydro- mmental and safety com	Ire is easy nal proces I which als te. If the o Irbine keep hich can d s of damag nd harm p I turbine a ogen from sequences.	to be detected sing unit will c so directly mak verspeed prote portating exce lamage turbine ged component eople nearby. 7 lso can cause a generator. Bes this failure also	from the cause a ces the ection eedingly t can The un cide so 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

					den 4. manual and A. Levild and den este an etil den and the second second second second second second second s
					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



Hidden Safety Environmental Operational

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



Daily	Weekly	Monthly	Annually
23	14	3	18



ATTACHMENT 09 RCM DECISION WORKSHEET

R	RCM II							SYS	TEM					SYSTEM N ^Ω	Facilitator	Date	Sheet N^{Ω}				
D	ECIS	ION						Stea	m Tur	bine				117844				FORM			
w	ORK	SHEE	г					SUB	-SYS	ГЕМ				SUB-SYSTEM N^{Ω}	Auditor	Date	of	2			
©	1990	5 ALA	DON	I LTI	D			High	Press	ure S	team	Turbi	ne	e MAA							
In	form	tion	C	oncar	nuano	200	H1	H2	H3	1	Defaul	t		l							
1	referei	nce		Evalı	ation	1	S1	S2	S3		Action	1					T 1	G 1			
							01	02	03					Proposed Task							
F	FF	FM	Н	s	Е	0	N1	N2	N3	H4	Н5	S4									
1	A	1	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Ta servo valve, selenoid failure. See governor	ask) Check the governor components	s such as hydraulic p r or replace is based	oower supply, on each	Annually	Electrician			
		2	N	Y	Y	Y	Y	N	N	N	N	N	(Schedule Discard Ta servo valve, selenoid is based on each failu	e power supply, epair or replace	Daily	Operator					
		3	Ν	Ν	Ν	Y	Y	Ν	N	Ν	N N Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination						Daily	Operator			
		4	Ν	Ν	Ν	Y	Ν	Ν	Y	Ν	N	N	(Schedule Discard Ta	ask) Conduct inspection on seal and	replace if needed		Annually	Mechanic			
		5	N	N	N	Y	N	Y	Ν	N	N	N	(Scheduled Restorati around	on Task) Conduct visual inspection	on control valve if th	nere is deposit	Weekly	Mechanic			
1	В	1	Ν	Y	Y	Y	Y	Ν	N	N	N	N	(Scheduled On-Cond	litioned Task) Check steam contamin	nation		Daily	Operator			
		2	Ν	Y	Y	Y	N	N	Y	Ν	N	N	(Schedule Discard Ta	ask) Conduct visual inspection on va	lve and replace if ne	eeded	Annually	Mechanic			
		3	Ν	Y	Y	Y	Y	Ν	N	Ν	N	N	(Scheduled On-Cond	litioned Task) Check steam contamin	nation		Daily	Operator			
		4	Ν	Y	Y	Y	Ν	Ν	Y	Ν	Ν	Ν	(Schedule Discard Ta	ask) Conduct visual inspection on va	lve and replace if ne	eeded	Annually	Mechanic			
		5	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Ta	(Schedule Discard Task) Check speed sensor and electrical equipment related							
		6	N	Y	Y	Y	Y	Ν	N	Ν	N	N	(Scheduled On-Cond	Daily	Operator						
1	С	1	N	Y	Ν	Y	Y	N	N	N	N	N	(Scheduled On-Cond contamination	litioned Task) Conduct visual inspec	tion on seal and che	ck the steam	Daily	Operator			
		2	N	Y	N	Y	N	N	Y	Ν	N	N	(Scheduled Discard	Task) Conduct inspection on valve as	nd replace if needed		Annually	Mechanic			
		3	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Cond contamination	Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination							

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	Ν	Y	Y	Y	Y	Ν	N	Ν	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
6	Ν	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	Ν	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	Ν	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	Ν	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on stator and repair if needed	Annually	Mechanic
13	Ν	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
14	Ν	Y	Y	Y	Ν	Y	N	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annually	Mechanic
15	Ν	Y	Y	Y	Y	Ν	N	Ν	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
16	N	Y	Y	Y	Ν	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	Ν	Y	Y	Y	Y	Ν	N	Ν	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	Ν	Y	Y	Y	Ν	Y	N	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annually	Mechanic
25	Ν	Y	Y	Y	Ν	Ν	Y	Ν	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	Ν	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition and lubricating system	Daily	Operator
		28	N	N	Ν	Y	Ν	N	Y	Ν	Ν	N	(Schedule Discard Task) Check speed sensor, check the cables, do testing	Annually	Mechanic
		29	N	N	Ν	Y	Y	Ν	Ν	Ν	N	N	(Scheduled On-Conditioned Task) Monitor temperature and rotational speed produced	Daily	Operator
		30	N	N	N	Y	Y	Ν	Ν	Ν	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	А	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	Ν	N	Ν	Y	Ν	Ν	Y	Ν	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	Ν	Y	Ν	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
2	В	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	Ν	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	Ν	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		4	Ν	Y	Y	Y	N	N	Y	Ν	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician
		5	Ν	N	N	Y	N	Y	Ν	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
2	С	1	N	Ν	N	Y	Ν	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	Ν	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	Ν	Y	Ν	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician

		4	Ν	N	N	Y	Ν	Y	Ν	N	Ν	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
		5	Ν	Y	N	Y	Ν	Ν	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	Ν	Y	Ν	Y	Ν	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on nozzle	Weekly	Mechanic
3	А	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	Ν	Y	N	Ν	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annually	Electrician
		4	N	Y	Y	Y	Y	Ν	Ν	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	Ν	Ν	Y	Ν	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annually	Electrician
		6	N	Y	Y	Y	Y	Ν	Ν	Ν	N	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of selenoid valve and all equipment related	Daily	Operator
		7	N	N	Ν	Y	N	Ν	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	Ν	Ν	Ν	Ν	N	(Scheduled On-Conditioned Task) Monitor the electrical flow of control valve actuator and all equipment related	Daily	Operator
		9	N	Ν	N	Y	Ν	Ν	Y	Ν	Ν	N	(Scheduled Discard Task) Check electrical equipment related to stop valve, and do testing	Annually	Electrician
		10	N	N	N	Y	Ν	Y	Ν	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
3	В	1	N	Y	Y	Y	N	Ν	Y	N	N	N	(Scheduled Discard Task) Check speed sensor, check electrical equipment related, do testing	Annually	Electrician
		2	N	Y	Y	Y	N	Ν	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	Ν	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	Ν	Y	N	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annually	Electrician
		5	N	N	Ν	Y	N	Y	Ν	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechanic
3	С	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	А	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	Ν	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	Ν	Ν	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	Ν	Ν	Y	Y	Ν	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		6	Y	Y	Y	Y	Ν	Ν	Ν	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	Ν	N	Y	N	N	(Failure Finding) Conduct inspection on oil dump valve	Weekly	Mechanic
		8	Y	Y	Y	Y	N	Ν	N	Y	N	N	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechanic
4	В	1	N	N	N	Y	Ν	Ν	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	Ν	Y	N	N	N	(Schedule Discard Task) Check trip unit, check abnormalities on cables, measure current and do testing	Monthly	Electrician
4	С	1	Y	Y	Y	Y	Ν	Ν	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	Ν	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

R	СМ	11								SYS	STEN	1		SYSTEM N ^Ω	Facilitator	Date	Shee	et N ^Ω	
D	ECI	SIO	N							Stea	am T	urbi	ne	117844					FORM
v	VOR	KSH	EET							SUE	3-SY	STE	M	SUB-SYSTEM N^{Ω}	Auditor	Date	of		6
0) 19	96 A		ON	I LT	D				Inte	rme	diate	e Steam Turbine	МАВ					
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r	efere	nce	E	valu	atio	n	5 1	2	3	A	Act10	n		Proposed Task				Initial Interv	Can be
	F	F		~			0 1	0 2	0 3	н	н	s		Tioposed Task				al	by
F	F	М	н	S	Е	0	N 1	N 2	N 3	4	5	4							
1	А	1	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check the go	o valve, seleno	id .	Annual	Electrici		
		2	N	Y	Y	Y	Y	N	N	N	N	N	(Schedule Discard Task) Monitor the g valve, control valve actuator if there is FMEA 1A	noid	Daily	Operato r			
		3	N	N	N	Y	Y	N	N	Ν	N	N	(Scheduled On-Conditioned Task) Con	nduct visual inspection on seal and cl	heck the steam conta	mination	1	Daily	Operato r
		4	Ν	N	Ν	Y	N	Ν	Y	Ν	Ν	N	(Schedule Discard Task) Conduct insp	ection on seal and replace if needed			4	Annual	Mechan
		5	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct	t visual inspection on control value if	f there is deposit aro	und	,	Weekly	Mechan
1	В	1	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Che	eck steam contamination			1	Daily	Operato r
		2	N	Y	Y	Y	Ν	N	Y	Ν	Ν	N	(Schedule Discard Task) Conduct visu	al inspection on valve and replace if	needed		1	Annual ly	Mechan
		3	N	Y	Y	Y	Y	N	N	Ν	N	N	(Scheduled On-Conditioned Task) Che	eck steam contamination]	Daily	Operato r
		4	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct visu	al inspection on valve and replace if	needed		1	Annual ly	Mechan ic
		5	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed	sensor and electrical equipment rela-	ted		1	Annual ly	Electrici an
		6	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Mo	nitor speed and check electrical equi	pment related		1	Daily	Operato r
1	С	1	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Con	1	Daily	Operato r			
		2	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Conduct ins	1	Annual lv	Mechan ic			
		3	N	Y	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Con	nduct visual inspection on seal and c	heck the steam conta	mination	1	Daily	Operato r
		4	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Conduct ins	pection on valve and replace if need	ed		1	Annual ly	Mechan ic

5	N	Y	Y	Y	Y	N	N	Ν	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operato r
6	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and repair if needed	Annual ly	Mechan ic
7	N	Y	Y	Y	Y	Ν	Ν	N	Ν	Ν	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operato r
8	N	Y	Y	Y	N	Y	Ν	N	Ν	Ν	(Scheduled Restoration Task) Conduct inspection on rotor and repair if needed	Annual lv	Mechan ic
9	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operato r
1	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on stator and repair if needed	Annual lv	Mechan
1	N	Y	Y	Y	Y	N	Ν	Ν	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operato r
1 2	N	Y	Y	Y	N	Y	Ν	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on stator and repair if needed	Annual lv	Mechan ic
1	N	Y	Y	Y	Y	Ν	N	N	N	Ν	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operato r
1 4	N	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annual lv	Mechan ic
1	N	Y	Y	Y	Y	N	Ν	Ν	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operato r
1	N	Y	Y	Y	N	Y	Ν	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annual lv	Mechan ic
1 7	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operato r
1 8	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operato r
1 9	N	Y	Y	Y	Y	Ν	Ν	N	Ν	Ν	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operato r
2	N	Y	Y	Y	N	Y	Ν	N	Ν	Ν	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annual lv	Mechan ic
2	N	Y	Y	Y	N	Ν	Y	N	N	Ν	(Schedule Discard Task) Conduct inspection on bearing and check lubricating system	Annual lv	Mechan ic
2	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor lubcirating system on rotor and check temperature	Daily	Operato r
2	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor lubcirating system on rotor and check temperature	Daily	Operato r
2 4	N	Y	Y	Y	N	Y	N	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annual lv	Mechan
2	N	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard Task) Conduct inspection on bearing and check lubricating system	Annual	Mechan
2	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition and lubricating system	Daily	Operato
2 7	N	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition and lubricating system	Daily	Operato r

		2 8	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor, check the cables, do testing	Annual lv	Mechan ic
		2 9	N	N	N	Y	Y	Ν	N	Ν	N	N	(Scheduled On-Conditioned Task) Monitor temperature and rotational speed produced	Daily	Operato r
		3	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor pressure and rotational speed produced	Daily	Operato r
		3	N	N	N	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor speed and check electrical equipment related	Daily	Operato r
2	Α	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	Annual lv	Electrici
		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	Operato r
		3	N	N	N	Y	N	Ν	Y	Ν	N	Ν	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annual ly	Electrici an
		4	N	Y	Y	Y	Y	Ν	Ν	Ν	N	Ν	(Scheduled On-Conditioned Task) Monitor the electrical flow of hydraulic servo valve and all equipment related	Daily	Operato r
		5	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annual ly	Electrici an
		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	Operato r
		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	Annual ly	Electrici an
		8	N	Y	Y	Y	Y	N	N	N	N	Ν	(Scheduled On-Conditioned Task) Monitor the electrical flow of control valve actuator and all equipment related	Daily	Operato r
		9	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check electrical equipment related to stop valve, and do testing	Annual ly	Electrici an
		1 0	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechan ic
2	В	1	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check speed sensor, check electrical equipment related, do testing	Annual ly	Electrici an
		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	Annual ly	Electrici an
		3	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annual ly	Electrici an
		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	Annual ly	Electrici an
		5	N	Ν	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechan ic
2	С	1	N	Ν	N	Y	Ν	Ν	Y	Ν	N	Ν	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annual lv	Electrici an
		2	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annual ly	Electrici an
1		3	N	Ν	N	Y	N	Ν	Y	Ν	N	N	(Scheduled Discard Task) Check control valve actuator, check electrical equipment related, and do testing	Annual ly	Electrici an
		4	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechan ic

		5	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check governor's seal	Annual lv	Mechan ic
		6	N	Y	N	Y	Y	Ν	N	N	N	Ν	(Scheduled On-Conditioned Task) Monitor steam contamination	Daily	Operato r
		7	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on nozzle	Weekly	Mechan
3	Α	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	Annual lv	Electrici
		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	Operato r
		3	N	Ν	N	Y	N	Ν	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annual lv	Electrici an
		4	N	Y	Y	Y	Y	Ν	Ν	N	N	Ν	(Scheduled On-Conditioned Task) Monitor the electrical flow of hydraulic servo valve and all equipment related	Daily	Operato r
		5	N	N	N	Y	N	Ν	Y	N	N	Ν	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annual ly	Electrici an
		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	Operato r
		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	Annual ly	Electrici an
		8	N	Y	Y	Y	Y	N	N	N	N	Ν	(Scheduled On-Conditioned Task) Monitor the electrical flow of control valve actuator and all equipment related	Daily	Operato r
		9	N	Ν	N	Y	N	N	Y	N	N	Ν	(Scheduled Discard Task) Check electrical equipment related to stop valve, and do testing	Annual ly	Electrici an
		1 0	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechan ic
3	В	1	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check speed sensor, check electrical equipment related, do testing	Annual ly	Electrici an
		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	Annual ly	Electrici an
		3	N	Y	Y	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annual ly	Electrici an
		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	Annual ly	Electrici an
		5	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechan ic
3	С	1	N	Ν	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check hydraulic servo valve, check electrical equipment related, and do testing	Annual ly	Electrici an
		2	N	N	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check selenoid valve, check electrical equipment related, and do testing	Annual lv	Electrici an
		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	Annual ly	Electrici an
		4	N	Ν	N	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on control valve	Weekly	Mechan ic
		5	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard Task) Check governor's seal	Annual ly	Mechan ic

		6	N	Y	N	Y	Y	N	N	Ν	N	N	(Scheduled On-Conditioned Task) Monitor steam contamination	Daily	Operato r
		7	N	N	N	Y	N	Y	N	Ν	Ν	N	(Scheduled Restoration Task) Conduct inspection on nozzle	Weekly	Mechan ic
4	А	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	Electrici
		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	Electrici an
		3	Y	Y	Y	Y	N	Ν	Y	Y	N	N	(Failure Finding) Check signal processing unit, check abnormalities on cables, measure current and do testing	Weekly	Electrici an
		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	Electrici an
		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	Electrici an
		6	Y	Y	Y	Y	Ν	N	N	Y	N	N	(Failure Finding) Check trip unit, check abnormalities on cables, measure current and do testing	Weekly	Electrici an
		7	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on oil dump valve	Weekly	Mechan ic
		8	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechan ic
4	В	1	N	N	N	Y	Ν	N	Y	N	N	N	(Schedule Discard Task) Check speed sensor, check abnormalities on cables, measure current and do testing	Monthl y	Electrici an
		2	N	Ν	N	Y	N	N	Y	N	N	N	(Schedule Discard Task) Check signal processing unit, check abnormalities on cables, measure current and do testing	Monthl y	Electrici an
		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	Monthl y	Electrici an
4	С	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	Electrici an
		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	Electrici an
		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	Electrici an
		4	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on oil dump valve	Weekly	Mechan ic
		5	Y	Y	Y	Y	N	N	N	Y	N	N	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechan ic

R	CM 11							SYS	ТЕМ					SYSTEM N ^Ω	Facilitator	Date	Sheet N^{Ω}	
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1	referei	nce		Evalı	lation	1	S1	S2	S3		Action	1					Initial	Conho
							01	02	03					Proposed Task			Initial	done by
F	FF	FM	Н	s	Е	0	N1	N2	N3	H4	H5	S4						
1	A	1	N	N	N	Y	N	N	Y	N	N	N	(Schedule Discard Ta servo valve, selenoid failure See governor	ask) Check the governor component l valve, control valve actuator. Repai	s such as hydraulic p ir or replace is based	oower supply, on each	Annually	Electrician
		2 N Y Y Y N N N 3 N N N Y Y N N N						N	N	N	N	(Schedule Discard Ta servo valve, selenoid is based on each failu	ask) Monitor the governor component l valve, control valve actuator if there ure. See governor FMEA 1A	nts such as hydraulic e is abnormalities. R	e power supply, epair or replace	Daily	Operator	
		3 N N N Y Y N N					N	N	N	(Scheduled On-Cond contamination	litioned Task) Conduct visual inspec	tion on seal and che	ck the steam	Daily	Operator			
		4	Ν	Ν	Ν	Y	N	Ν	Y	Ν	N	N	(Schedule Discard Ta	ask) Conduct inspection on seal and	replace if needed		Annually	Mechanic
		5	N	N	N	Y	N	Y	N	N	N	N	(Scheduled Restorati around	ion Task) Conduct visual inspection	on control valve if the	nere is deposit	Weekly	Mechanic
1	В	1	Ν	Y	Y	Y	Y	Ν	N	N	N	N	(Scheduled On-Cond	litioned Task) Check steam contamin	nation		Daily	Operator
		2	Ν	Y	Y	Y	N	N	Y	Ν	N	N	(Schedule Discard Ta	ask) Conduct visual inspection on va	alve and replace if ne	eeded	Annually	Mechanic
		3	Ν	Y	Y	Y	Y	Ν	N	Ν	N	N	(Scheduled On-Cond	litioned Task) Check steam contamin	nation		Daily	Operator
		4	Ν	Y	Y	Y	Ν	Ν	Y	N	N	N	(Schedule Discard Ta	ask) Conduct visual inspection on va	alve and replace if ne	eeded	Annually	Mechanic
	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$						Ν	N	N	(Schedule Discard Ta	ask) Check speed sensor and electric	al equipment related	1	Annually	Electrician			
	6 N Y Y Y Y					Y	N	N	Ν	N	N	(Scheduled On-Cond	litioned Task) Monitor speed and ch	eck electrical equipr	nent related	Daily	Operator	
1	1 C 1 N Y N Y					Y	N	N	N	N	N	(Scheduled On-Cond contamination	litioned Task) Conduct visual inspec	tion on seal and che	ck the steam	Daily	Operator	
		2	N	Y	Ν	Y	N	N	Y	Ν	Ν	N	(Scheduled Discard	Task) Conduct inspection on valve a	nd replace if needed		Annually	Mechanic
		2 N Y N Y N N Y N N N 3 N Y N Y N N N N N							N	N	N	N	(Scheduled On-Cond contamination	litioned Task) Conduct visual inspec	tion on seal and che	ck the steam	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	Ν	Y	Y	Y	Y	Ν	N	Ν	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
6	Ν	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	Ν	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	Ν	Y	Ν	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	Ν	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on stator and repair if needed	Annually	Mechanic
13	Ν	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
14	Ν	Y	Y	Y	Ν	Y	N	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annually	Mechanic
15	Ν	Y	Y	Y	Y	Ν	N	Ν	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
16	N	Y	Y	Y	Ν	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	Ν	Y	Y	Y	Y	Ν	N	Ν	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	Ν	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	Ν	Y	N	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annually	Mechanic
25	N	Y	Y	Y	Ν	N	Y	Ν	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	Ν	Ν	N	N	(Scheduled On-Conditioned Task) Monitor temperature and rotational speed produced	Daily	Operator				
		30	N	N	N	Y	Y	N	Ν	Ν	N	N	(Scheduled On-Conditioned Task) Monitor pressure and rotational speed produced	Daily	Operator				
		31	N	N	N	Y	Y	Ν	Ν	N	N	N	(Scheduled On-Conditioned Task) Monitor speed and check electrical equipment related	Daily	Operator				
2	А	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	Ν	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	Ν	Ν	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	Ν	Y	N	N	(Failure Finding) Conduct inspection on oil dump valve	Weekly	Mechanic				
		8	Y	Y	Y	Y	N	N	Ν	Y	N	N	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechanic				
2	В	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	Ν	Y	Ν	Ν	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	Ν	Y	Ν	Ν	N	(Schedule Discard Task) Check trip unit, check abnormalities on cables, measure current and do testing	Monthly	Electrician				
2	С	1	Y	Y	Y	Y	Ν	N	Ν	N	N	N	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician				
		2	Y	Y	Y	Y	Ν	N	Ν	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	Ν	N	Ν	Y	N	N	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechanic				
RCM II								SYSTEM						SYSTEM N ^Ω	Facilitator	Date	Sheet N^{Ω}		
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DECISION Steam Turbine									m Tur	bine				117844				FORM	
w	ORK	SHEE	г					SUB	-SYS	ТЕМ				SUB-SYSTEM N^{Ω}	Auditor	Date	of	2	
©	1996	5 ALA	DON	LT	D			Low	Press	ure St	eam	Turbir	ne 1	MAC20					
T.	.f.,	tion	C				H1	H2	H3		Dafau	1+							
1	referei	nce		Evalı	lation	1	S1	S2 S3 Action				n						a 1	
							01	02	02					Proposed Task			Initial Interval	Can be done by	
F	FF	FM	Н	s	Е	0	NI	N2	N3	H4	Н5	S4							
1		1	N	N	N	v	N	N	v	N	N	N	(Sabadula Disaard T	ask) Charle the governor component	a mah as hudraulia r	ower gunnly	Annually	Flaatriaian	
1	A	1	IN	IN	IN	I	IN	IN	I	IN	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	Ν	Y	Y	Y	Y	Ν	Ν	N	N N (Schedule Discard Task) Monitor the governor components such as hydraulic power supply,				Daily	Operator			
												is based on each failure. See governor FMEA 1A							
		3	Ν	N	N	Y	Y	N	Ν	N	N N (Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination				Daily	Operator			
		4	Ν	N	Ν	Y	Ν	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	Ν	Ν	(Scheduled Restoration Task) Conduct visual inspection on control valve if there is deposit around			Weekly	Mechanic		
1	В	1	Ν	Y	Y	Y	Y	N	N	N	N	Ν	(Scheduled On-Conditioned Task) Check steam contamination		Daily	Operator			
		2	Ν	Y	Y	Y	Ν	Ν	Y	Ν	Ν	Ν	(Schedule Discard T	ask) Conduct visual inspection on va	alve and replace if no	eeded	Annually	Mechanic	
		3	Ν	Y	Y	Y	Y	Ν	Ν	N	N	Ν	(Scheduled On-Cond	litioned Task) Check steam contami	nation		Daily	Operator	
		4	Ν	Y	Y	Y	N	N	Y	N	N	N	(Schedule Discard T	ask) Conduct visual inspection on vi	alve and replace if no	eeded	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-Cond	litioned Task) Monitor speed and ch	eck electrical equipr	nent related	Daily	Operator	
1	С	1	N	Y	N	Y	Y	N	N	Ν	Ν	Ν	(Scheduled On-Cond contamination	ditioned Task) Conduct visual inspec	ction on seal and che	ck the steam	Daily	Operator	
		2	N	Y	N	Y	N	N	Y	N	N	N	(Scheduled Discard	Task) Conduct inspection on valve a	nd replace if needed		Annually	Mechanic	
		3	N	Y	N	Y	Y	N	N	N	N	Ν	(Scheduled On-Conditioned Task) Conduct visual inspection on seal and check the steam contamination				Daily	Operator	

4	Ν	Y	Ν	Y	N	Ν	Y	Ν	N	N	(Scheduled Discard Task) Conduct inspection on valve and replace if needed	Annually	Mechanic
5	N	Y	Y	Y	Y	N	Ν	N	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
6	Ν	Y	Y	Y	Ν	Y	Ν	Ν	Ν	N	(Scheduled Restoration Task) Conduct inspection on rotor and repair if needed	Annually	Mechanic
7	Ν	Y	Y	Y	Y	Ν	Ν	Ν	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
8	Ν	Y	Y	Y	N	Y	N	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and repair if needed	Annually	Mechanic
9	Ν	Y	Y	Y	Y	N	N	Ν	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
10	Ν	Y	Y	Y	N	Y	N	N	N	N	(Scheduled Restoration Task) Conduct inspection on stator and repair if needed	Annually	Mechanic
11	Ν	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	Ν	Y	Y	Y	N	Y	Ν	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annually	Mechanic
15	Ν	Y	Y	Y	Y	N	Ν	Ν	N	N	(Scheduled On-Conditioned Task) Check steam contamination	Daily	Operator
16	Ν	Y	Y	Y	N	Y	Ν	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on shaft and repair if needed	Annually	Mechanic
17	Ν	Y	Y	Y	Y	N	Ν	Ν	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
18	Ν	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
19	Ν	Y	Y	Y	Y	N	N	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature in operational condition	Daily	Operator
20	Ν	Y	Y	Y	N	Y	N	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annually	Mechanic
21	Ν	Y	Y	Y	Ν	N	Y	Ν	N	N	(Schedule Discard Task) Conduct inspection on bearing and check lubricating system	Annually	Mechanic
22	Ν	Y	Y	Y	Y	Ν	Ν	Ν	N	N	(Scheduled On-Conditioned Task) Monitor lubricating system on rotor and check temperature	Daily	Operator
23	N	Y	Y	Y	Y	Ν	Ν	Ν	Ν	N	(Scheduled On-Conditioned Task) Monitor lubricating system on rotor and check temperature	Daily	Operator
24	N	Y	Y	Y	Ν	Y	Ν	Ν	N	N	(Scheduled Restoration Task) Conduct inspection on rotor and check lubricating system	Annually	Mechanic
25	Ν	Y	Y	Y	Ν	Ν	Y	Ν	Ν	N	(Schedule Discard Task) Conduct inspection on bearing and check lubricating system	Annually	Mechanic
26	N	Y	Y	Y	Y	N	Ν	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	Ν	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	Ν	N	N	N	(Scheduled On-Conditioned Task) Monitor temperature and rotational speed produced	Daily	Operator
		30	N	N	N	Y	Y	N	Ν	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	А	1	Y	Y	Y	Y	N	N	Ν	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	Ν	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	Ν	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	Ν	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	Ν	N	Ν	Y	N	Ν	(Failure Finding) Conduct inspection on emergency stop valve	Weekly	Mechanic
2	В	1	N	N	N	Y	Ν	N	Y	Ν	N	Ν	(Schedule Discard Task) Check speed sensor, check abnormalities on cables, measure current and do testing	Monthly	Electrician
		2	N	N	N	Y	Ν	Ν	Y	Ν	Ν	N	(Schedule Discard Task) Check signal processing unit, check abnormalities on cables, measure current and do testing	Monthly	Electrician
		3	N	N	N	Y	Ν	Ν	Y	Ν	Ν	N	(Schedule Discard Task) Check trip unit, check abnormalities on cables, measure current and do testing	Monthly	Electrician
2	С	1	Y	Y	Y	Y	Ν	N	Ν	Ν	N	Ν	(Failure Finding) Check speed sensor, check abnormalities on cables, measure current and do testing	Weekly	Electrician
		2	Y	Y	Y	Y	Ν	N	Ν	Y	N	Ν	(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	Ν	Ν	Y	Ν	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						

- 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

Maintenance Schedule							
HIGH PRESSURE TURBINE (MAA)							
Interval Done by							
ANNUALLY	MECHANIC						
These are lists of recommended action turbine: 1. Check condition of seal, contro 2. Check lubricating system of th 3. Analyse damage mechanism o 4. Check condition of speed sens 5. Run a test to check functionali 6. Run a test to check accuracy o 7. Clean built-up deposit on those 8. Repair or replace if it is needed	that can reduce potential failure of steam ol valve, rotor, stator, and shaft iose equipment or ty of those equipment f speed sensor e equipment d						

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

- Check physical condition of speed sensor
 Run a test to check functionality of speed sensor
- 3. Run a test to check accuracy of speed sensor
- Clean built-up deposit on speed sensor
 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:								
 Check physical condition of sp Run a test to check functionali Run a test to check accuracy of Check abnormalities on all ele equipment Clean built-up deposit on thos Repair or replace if it is needed 	peed sensor, signal processing unit and trip unit ity of those equipment of those equipment ectrical component such as cables on those e equipment d							

Maintenance Schedule								
HIGH PRES	HIGH PRESSURE TURBINE (MAA)							
Interval Done by								
ANNUALLY	ELECTRICIAN							
These are lists of recommended action that can reduce potential failure of steam turbine:								
 Check physical condition of valve, control valve actuator Run a test to check functiona Run a test to check accuracy Clean built-up deposit on sp Repair or replace if it is need 	Thydraulic power supply, servo valve, solenoid and speed sensor ality of those equipment of those equipment eed sensor ded							

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 pactuator, control valve and 11. Monitor the electrical flow 12. Conduct visual inspection 13. Check water and steam put 14. Monitor operational speed 15. Monitor lubricating system contaminated 16. Monitor temperature and p range of operational design 17. Conduct inspection if there 18. Repair or replace if it is ne 	ower, servo valve, solenoid valve, control valve seal within those equipment on seal. Ensure there is no leakage rity. Ensure it is not contaminated of turbine. Ensure it is not overspeed h. Ensure it is flowed with no obstacles and not ressure of turbine. Ensure the temperature is at h e is abnormalities eded							

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

- 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						

- 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					

- Check physical condition of speed sensor
 Run a test to check functionality of speed sensor
- 3. Run a test to check accuracy of speed sensor
- Clean built-up deposit on speed sensor
 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:	
 These are lists of recommended action that can reduce potential failure of steam turbine: Check physical condition of speed sensor, signal processing unit and trip unit Run a test to check functionality of those equipment Run a test to check accuracy of those equipment Check abnormalities on all electrical component such as cables on those equipment Clean built-up deposit on those equipment 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:	
 These are lists of recommended action that can reduce potential failure of steam turbine: Check physical condition of hydraulic power supply, servo valve, solenoid valve, control valve actuator and speed sensor Run a test to check functionality of those equipment Run a test to check accuracy of those equipment Clean built-up deposit on speed sensor 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:	
 Monitor hydraulic supply power, servo valve, solenoid valve, control valve actuator, control valve and seal Monitor the electrical flow within those equipment Conduct visual inspection on seal. Ensure there is no leakage Check water and steam purity. Ensure it is not contaminated Monitor operational speed of turbine. Ensure it is not overspeed Monitor temperature and pressure of turbine. Ensure the temperature is at range of operational design Conduct inspection if there is abnormalities Repair or replace if it is needed 	

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

- 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

- 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

- 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:	
 Check physical condition of speed sensor Run a test to check functionality of speed sensor Run a test to check accuracy of speed sensor Clean built-up deposit on speed sensor 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:	
 These are lists of recommended action that can reduce potential failure of steam turbine: Conduct visual inspection on seal. Ensure there is no leakage Check water and steam purity. Ensure it is not contaminated Monitor operational speed of turbine. Ensure it is not overspeed Monitor lubricating system. Ensure it is flowed with no obstacles and not contaminated Monitor temperature and pressure of turbine. Ensure the temperature is at range of operational design Conduct inspection if there is abnormalities Repair or replace if it is needed 	