

# **CORROSION MANAGEMENT TECHNOLOGY FOR ANALYZING AND SOLVING OF CORROSION PROBLEMS IN GEOTHERMAL FIELD**

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## **Abstract**

Industrial risk assessment is a careful examination of potential hazards that may affect the operation of a business; these may be risks associated with the safety and integrity of physical assets, risks to the environment, financial risk from various decisions and also risk from corrosion. Corrosion related failures of facilities are a major source of risk and a vital issue for the safety to geothermal installations. Corrosion can be a life-limiting cause of deterioration by general wastage, and/or pitting and/or environmentally assisted cracking to plant items which in turn can lead of containment of geothermal fluids. Management of corrosion is therefore a major driver to safety, environmental and economic issues within the industry.

Corrosion management technology is the integrated efforts to achieve the technique and method for handling and solving of corrosion problems based on the corrosion management and risk management analysis with adopting the optimal and efficient technology. The main aim is devised to enable it to act for the application of corrosion management techniques and methods in other hazardous area on the geothermal fields in terms of corrosion risk management guidance manual intended for use by both industry and HSE inspectors.

**Keywords:** Risk Management Analysis, Corrosion Management, Corrosion Management Technology, Identification Potential Risk

## **Introduction**

In this paper, corrosion at geothermal industry will be analyzed using Risk Management Analysis. The analysis will collect data and make prediction based on design, planning, prediction and potential risk identification. The data will be included initial data and advanced data gathering with offsite documentation and onsite inspection. the data and prediction achieved will be built in scenario to view problems, protection, prevention, handling and action to solve corrosion problems and effects such as damage and hazard. Based on data, prediction and scenario, the decision will be make using Corrosion Management such as Policy, Planning & Implementation and Review. The integrating of Risk Management Analysis and Corrosion Management will achieve Integrated System called Corrosion Management Technology. Corrosion Management Technology will be integrated with Corrosion Engineering to make best solving ways and methods, monitoring technique, inspection and reliability & maintenance begin at geothermal equipment and processing design, operational and maintenance.

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## **Risk Management Analysis**

Risk Management Analysis (RMA) is a new technique to determine and to find causes of risk mainly to detect possibility (predict) of failure and damage in an operating system. Kusumo, A.L.P, (2001) has introduced this technique at first time. Functions of the Risk Management Analysis are:

- As the tools to obtain all data and information needed for predicting risk potential nodes, which causes failure and damage.
- As the tools to investigate the possibility of risk and hazard occurred.

The area of interest on the utilization of Risk Management Analysis consists of equipment design and operating system, equipment operation and all activities (including at time that the equipment deliver from the factory, installation until the equipment in full operation condition) and conducted maintenance process (including monitoring, inspection, special maintenance, advance maintenance, replace the equipment, installing the new equipment, auditing and recommendations).

The objective of Risk Management Analysis activity is to obtain the integrated system, start from design, operational, maintenance, prevent and handling of a potential risk and hazard, and the action that should be take if the unlike condition occurred. This Risk Management Analysis activity will perform on the scenarios based on initial and advance predictions as the results from off-site and on-site inspections. Risk Management Analysis will identified the problems at the operation process to obtain risk potential nodes which will be occurred risk and hazardous. These risk potential nodes including:

1. Human and their activities
2. Equipments, material, process/operation and maintenance including technology
3. Environment

**Data.** Data can be determine into two types, initial data and advance data.

**Initial Data.** The method to find these data based on the specification, material choices, standard and procedure of the fabrication and equipment function. Re-checking of obtained data needed and compare with the International or national standard, quality and reliability, HS&E, technical and non-technical factors, and the history of the equipment. Furthermore, make a possibilities of occurring failure and damage, also the possibility which will causes a risk and hazard, including prevent and handling, and the actions if the unlike conditions happened. All the process results performed on the scenarios as an initial prediction, including risk potential nodes mapping together with preventing and handling actions.

**Objectives:** Historical of field, Reservoir Character, Fluids Characters and Compositions, Pressure and Temperature, Material Composition and Character of Facilities, Location, Wide and Range of Facilities, Environmental Data, Equipment history, Operational (load/cycle), Design and developing, Fabrication/assembling/post-assembling (Coating or re-heating, etc), Packing planning and transportation, Inventory planning, Installing and post installing planning, Human resources, Community, Culture, and Management (benefit and profit).

**Advance Data.** The advance data obtained by off-site and on-site techniques.

- **Off-site Data**, is a data obtain based on the reports (daily, monthly, annual, etc) without doing inspection in the fields where the equipment operated. From of the some anomaly found, can get the solution to prevent and handling if the risk and hazard occurred, of course, with conducting some tests and observation. This data is quite representative, but not too accurate due to field condition that has dynamic property.
- **On-site Data**, is the same with off-site data, but the different is we conducted inspection in the field. Time and cost needed for inspection are more expensive than off-site data, but the accuracy gave a positive indication than the off-site data.

**Objectives:** Monitoring and Inspection Data, Monitoring planning, Development planning, Inspection planning, Special/advance maintenance planning, Operational report, Environment

surround report, Monitoring report, Inspection report, Treatment report, Special/advance maintenance report, Reliability and Auditing Report.

**Causes of Failure and Damage.** Failure is malfunctions/un-working/un-operation of a system as well as due to certain causes. Failure can be caused by: Design and construction failure, Material and fabrication failure, Installation or set-up failure, Maintenance failure, Observation during operation failure, Human resources failure, Situation and condition predictions failure. Damage defined as malfunctions/un-working/un-operation of a system, which will affect the overall system. Damage can be caused by: Physical, Mechanical, Chemical, Thermodynamic and Biological Process.

**Identification Potential Risk Nodes Techniques.** Identification potential risk is also will observe all the data to obtain the accurate of potential risk nodes based on:

1. Equipment identification
2. Identification of the place assembling located
3. Identification of the facility/equipment relate with the equipment which will installed
4. Identification of assembling/installation
5. Identification of operating procedure and maintenance
6. Identification of procedures and inspection equipment and monitoring

**Scenario.** Scenario which made divided into two types, i.e.,

1. Initial Scenario with Initial Prediction, based on initial data
2. Advance Scenario with Advance Prediction, this scenario will use Initial Scenario basis and will add with advanced data based on offsite/onsite inspection and monitoring.

These scenarios was made based on the possibilities of risk occurred, hazard, failure and damage of the operational, so, with this scenarios we could be knew the preventing and handling technique as early as possible. The objectives of scenarios made into prevent and handling of risks, are as follows: Cost and time efficiency which needed for inspection, review, recommendation and re-auditing, Minimize risk of equipment/operational failure and damage, To make a program if the hazard occurred, as a basic for SOP making; Maintenance production continuity, Prevention and handling of risk and hazard early, quickly and accurately and Maintenance the equipment life cycle and facilities and must be combines between risk potential identification methods with the other factors (HS&E, Quality, Technique/Non-Technique, Prevention and Handling). The scenario will be made if the hazard occurred and to make an actions later, including investigating and determination of material loss, immaterial, management, human resources, technology, environment and financing.

This prediction will used to make a scenario to achieve an effective and optimally action of prevention and handling problems. Beside that, These scenario could be divided into three stages, are Pre-condition, On-condition and Post-condition.

### **Corrosion Management**

The function of the Corrosion Management is a part of policy making in order to handle the corrosion problems, including development, implementation, review and maintenance. In the operation of an geothermal industry, the management of corrosion lies within the function of many parts of the duty holder's organization. It is therefore important that corrosion management activities are carried out within a structured framework that visible, understood by all parties and where roles and responsibilities are clearly defined.

The key elements of such a framework are being use in the context of managing corrosion, and discussed the key points, which can be considered as best industry practice. The key elements are: Policy, Organizing, Planning and Implementation, Measuring Performance, Reviewing Performance and Auditing.

A structured approach such as this typically adopted, for instance, by Total Quality Management (TQM) and used to control risks within organizations. The successful operation of such procedures is often indicative of management commitment to continuous improvement in performance. The approach adopted by operators to the management of risks associated with corrosion and/or installation integrity is generally similar to that adopted for management of safety risks, as required by legislation for the safety case. The interface is the corrosion management strategy with output as implementation through documentation. Weaknesses in management systems tend to occur not with the front-end steps (the strategies/policies/planning/data gathering/review) but towards the later steps of the process (recommendations or actions).

The practical means of achieving specified objectives (minimum leakage and downtime) requires guidelines, codes and standards for specification of the works (the tactics) plus suitable management procedures and systems (the strategic means). The linking of strategy and tactics as part of a Corrosion Risk Assessment is important because responsibility for the day-to-day management of corrosion may be split between groups or individuals, hence procedures must be in place to ensure that overall control and responsibility are both measurable and effective.

Corrosion management also covers other integrity risks, including those from stress corrosion cracking, embrittlement, erosion, etc., as well as “simple corrosion” (i.e. general, pitting and crevice corrosion). It was recognized that there are many ways to organize and operate successful corrosion management systems, each of which is asset specific depending on factors such as: Design, Stage in life cycle, Process conditions, and Operational history.

The corrosion policy provides a structured framework for identification of risks associated with corrosion, and the development and operation of suitable risk control measures. That is, employers should have effective plans and organizations to control, monitor and review preventative and protective measures to secure the health and safety of employees.

### **Corrosion Management Technology**

Corrosion Management Technology (CMT) is the integrated efforts to achieve the technique and method for handling of the corrosion problems based on the Corrosion Management and Risk Management Analysis with adopting the optimal and efficient technology. It has been developed by Kusumo, A.L.P., Kristanto, D., and Harryawan, members of Indonesian Corrosion Association (INDOCOR). Target of this system are to integrate decision tools, reliability strategy to perform capital rationing, and life cycle planning as integrated enabling tool into performance management.

Corrosion Management Technology is an advance of corrosion management system, which consists of risk management system, in this case this system using Risk Management Analysis. This tool has a progressive framework that is compatible with the requirements of risk, safety and reliability management system concerned with ensuring the integrity of operating and processing equipments. Corrosion problems in geothermal industries can be eliminated and predicted for production, processing and plant facilities which are of interest in design, installation, operation and maintenance and as integrity management process also covers other integrity risks and causes of failure and damage that may occur as hazards.

Additional techniques in Reliability and Maintenance that will be conducted and adopted in this system are as follows: Optimum Potential Risk Mapping, Optimum Operational Strategy, Optimum Maintenance Strategy, Optimum Process Safety Management Strategy, Optimum Engineering Strategy, Optimum Spare Part Inventory, Optimum Configuration/Project Management System, Optimum Inspection and Monitoring System, Optimum Investigation System, Optimum Corrective Action, Computerized Operational and Maintenance

Management System, Total Productive Maintenance and/or Predictive Maintenance Program, Operator Activity Management System, Documentation/Configuration Management System, Training Strategy, Strategy Sourcing Strategy and Contract Management System. The policy that made will provide a structured framework for identification of risks associated with corrosion, and the development performance operating system including corrective actions with the target are optimization and efficiency for geothermal industries.

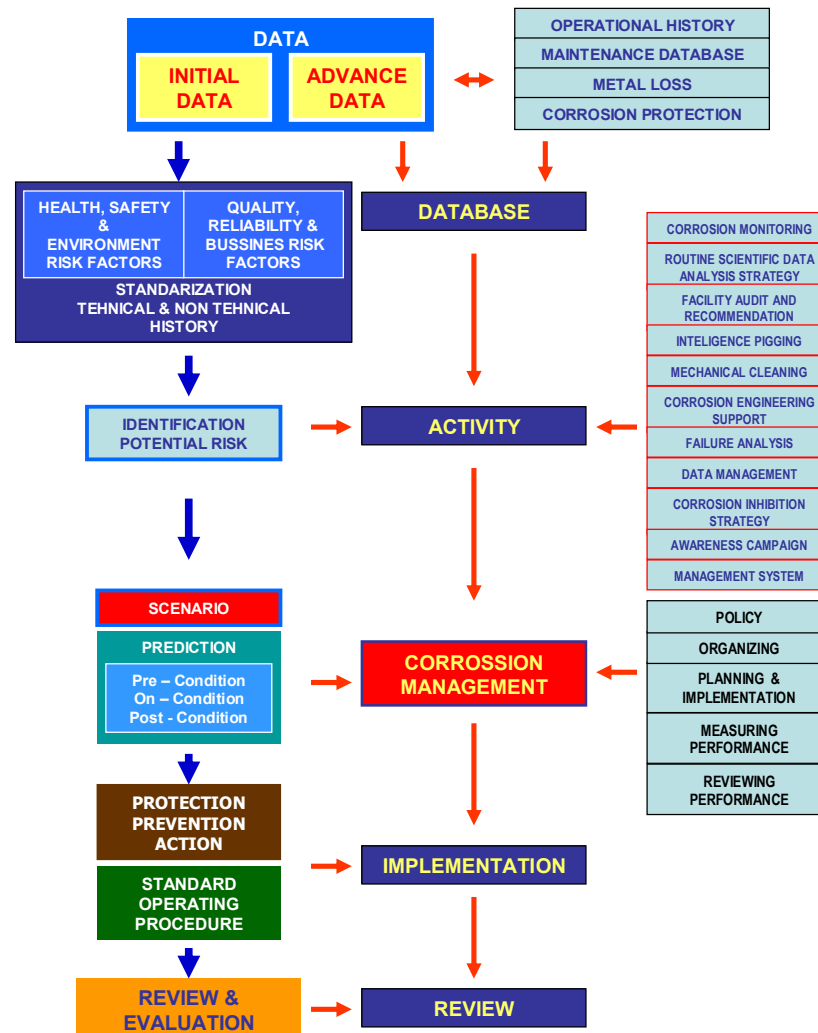


Figure 1 - Corrosion Management Technology  
(Image adapted from Kusumo, A. Lesto P., 2002)

### General Data of Geothermal Field in Indonesia

Indonesia currently produces about 589MW of geothermal electricity. The Indonesian islands are located on the boundary between the Eurasian and Australian plates, resulting in a very good geothermal resource. The first geothermal development was the dry steam resource at Kamojang in the 1920s, which now produces 140MW of electricity. Currently, the largest field is Gunung Salak which has an installed capacity of 330MW. In addition to large projects, 10 MW of small (35kW-1MW) "mini-geo" plants for isolated villages are scheduled for development in 1999. It is predicted that by the end of 1999, the installed capacity in Indonesia will have increased to 1,079MW. Kamojang field is located in Kampung Pangkalan West Java Region, Indonesia. The field is approximately 1500 m above sea level with environment temperature 15 – 20<sup>0</sup> C. The first well is built in 1926 by Dutch Government.

And in the current year is developed by Indonesian Government incorporate with New Zealand Geothermal Project. The potential reserve is 280 MWe, the development status until 1997 is produced 140 Mwe to supply the electricity in Java and Bali. The reservoir characteristic is vapour dominated system, pressure: 30-33 Bar, Temperature; 230-240 C, permeability; 5-120 mD, NCG 1 % in weight, enthalpy; 2800 kj./kg. Kamojang geothermal Field has 10 exploration wells, 14 monitoring well 34 production wells. Water produced is re-injected approximately 3650 ton/ day in 3 injection wells.

### Power Plant System for Geothermal Industries in Indonesia

**Flash Steam Power Plant.** Single flash steam technology is used where the hydrothermal resource is in a liquid form. The fluid is sprayed into a flash tank, which is held at a much lower pressure than the fluid, causing it to vaporized (or flash) rapidly to steam. The steam is then passed through a turbine coupled to a generator as for dry steam plants. To prevent the geothermal fluid flashing inside the well, the well is kept under high pressure. Flash steam plant generators range in size from 10MW to 55MW, but a standard size of 20MW is used in some countries.

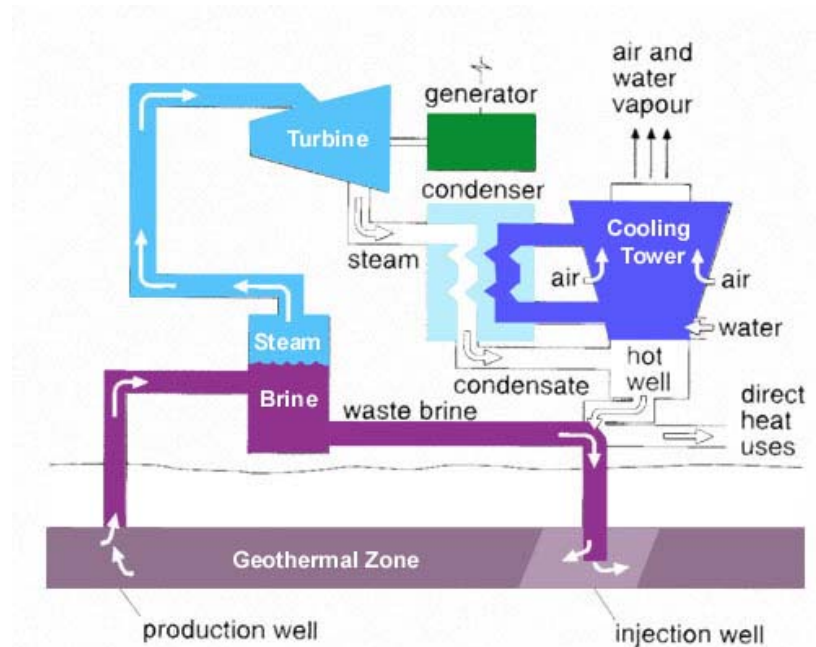


Figure 2 - Single Flash Steam Power Plant[17]

**Binary Cycle Power Plant.** Binary cycle power plants are used where the geothermal resource is insufficiently hot to efficiently produce steam, or where the resource contains too many chemical impurities to allow flashing. In addition, the fluid remaining in the tank of flash steam plants can be utilized in binary cycle plants. The unit sizes are typically in the range of 1MW to 3MW, and these are used in a modular arrangement. In the binary cycle process, the geothermal fluid is passed through a heat exchanger. The secondary fluid, which has a lower boiling point than water (eg isobutane or pentane), is vaporised, and expanded through a turbine to generate electricity. The working fluid is condensed and recycled for another cycle. All of the geothermal fluid is reinjected into the ground in a closed-cycle system. Binary cycle power plants can achieve higher efficiencies than flash steam plants, and they allow the utilization of lower temperature resources.

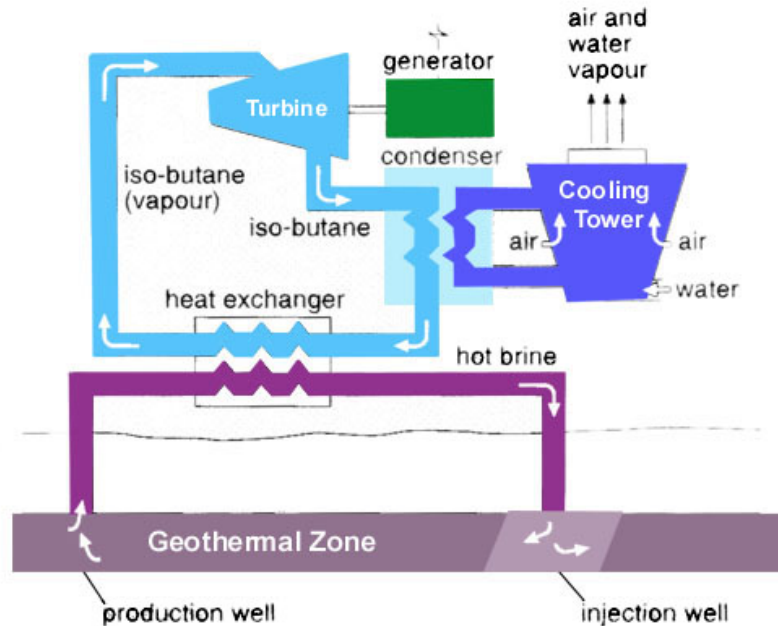


Figure 3 - Binary Cycle Power Plant[17]

### **Approaching Corrosion Management Technology in Geothermal Industry**

Production/Deliverability/Processing, and Water Injection to reservoir in Geothermal Industry are important to see possibility and to protect this industry from the corrosion problem. In this case we use the approaching result based on Kamojang Field at West Java, Indonesia. Kamojang is prospect to use Single Flash Power Plant and Binary Cycle Power Plant.

#### ***Task 1 - Analyzing Risk using Risk Management Analysis***

*Identification Potential Risk (general condition):* Possibility problem in this field can be occur at well, transportation pipe, heat exchanger, separator, turbine, generator and condenser, cooling tower, and transportation pipe to injection well.

*Scenario for Protection, Prevention and Action:* Material Selection, Coating, Barrier, Cathodic Protection, Impressed Current System, Inhibitor, Reheating, Monitoring, Inspection, Repairing, Change Material/Equipment and Reliability/Maintenance.

#### ***Task 2 - Approaching of Decision using Corrosion Management***

*Data-Based on Result Data from Risk Management Analysis:* This data will use to process the decision to make a concrete Policy, Planning and Implementation and Review to handling the management and problem that probably occur in geothermal operation.

#### ***Task 3 – Implementation Integrated System using Corrosion Management Technology and Problem Solving***

*Corrosion Engineering :* The corrosion engineering will be considering selection appropriate material, chemical treatment, coating and lining, Cathodic protection, process control and design detailing. For filed application the corrosion engineering will be held in some activities including corrosion monitoring, routine scientific data analysis strategy, facility audit and recommendation, intelligence pigging, mechanical cleaning, corrosion engineering support, failure analysis, data management, corrosion inhibition strategy, awareness campaign and management system.

*Monitoring and Inspection:* To check that corrosion engineering method and strategy run well and also to know corrosion growth should be done proactive and reactive monitoring and periodic inspection.

*Reliability and Maintenance:* To keep the performance of equipments and facilities in the best condition and to make sure that the productivity can run as well as target.

*Review:* To ensure that Operation Performance are consistent with the changing business plan and changing production requirements. The processes are Assessment of the effectiveness process and procedure in terms of improving operation, Ensuring that the procedures and processes in place will not be compromised by planed changes from business plan and by changing production requirements, and Carry out review of measured parameters covering both proactive and reactive measures.

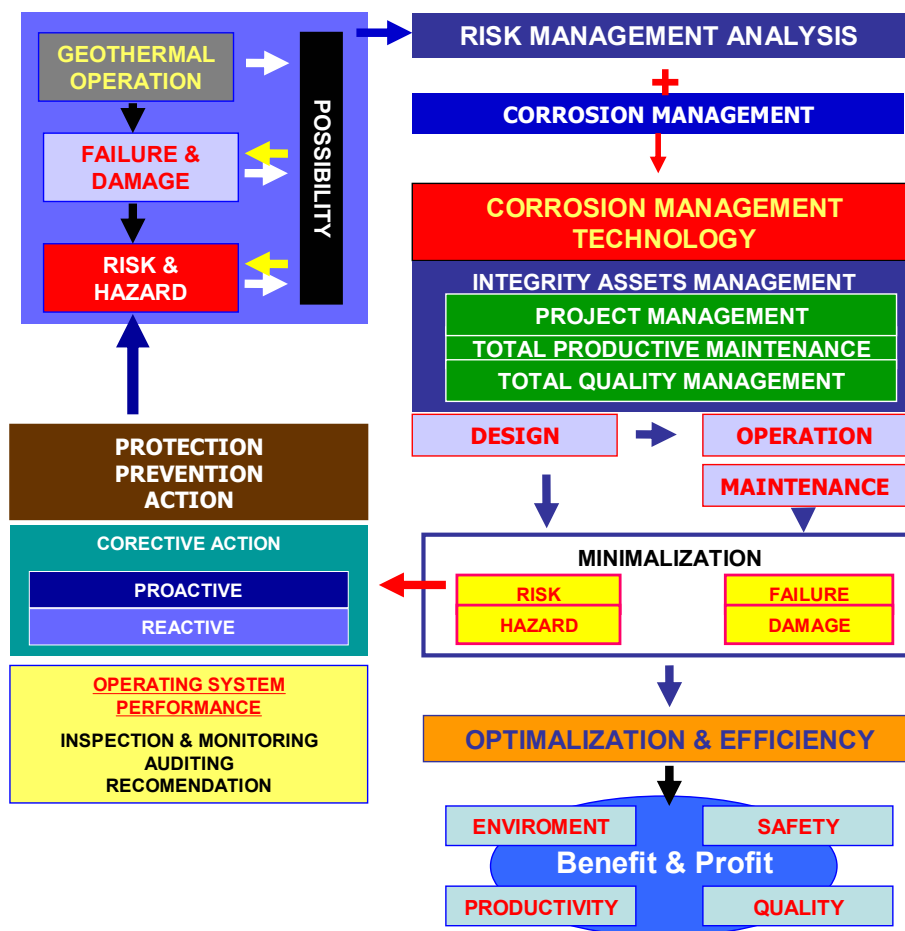


Figure 4 - Application of Corrosion Management Technology  
(Image adapted from Kusumo, A. Lesto P., 2002)

## Conclusion

1. Corrosion is the biggest problem for all equipment and facilities that using metal component in geothermal equipment and processing especially well, transportation pipeline, separator, turbine, generator, heat exchanger, condenser, cooling tower and transportation pipeline to injection well.
2. In geothermal field corrosion will occur cause dynamic condition, after that before the



equipment will failure and damage. Factors affecting corrosion in dynamic condition including the characteristics of internal and external system like fluid flow, temperature, pressure, reservoir fluid composition, human, environment condition, weather, etc can be analyzing use Risk Management Analysis, mainly to determine Potential Risk Nodes.

3. The Corrosion Management Technology as integrated system to analyze and solve the problem caused by corrosion, can be proposed for achieving optimal equipment and processing performance in geothermal field resulting quality, safety, productivity and environment will be very important for geothermal company to make decision prior to company benefit and profit.

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