(In the name of Allah the most Gracious, the most Merciful)

OMAINTEC 20 YEARS

Objectives

The Objective of RCA basic training:

❑ Learn Root Causes Analysis Methodologies.

❑ Be aware of RCA Management System

❑ Enhance RCA knowledge and Skills.

❑ Promote the Value of RCA.

RCA Consultant

Abdulaziz Al-Ghamdi

- ❑ Founder and President of Reliability Expert Center

- ❑ Bachelor Degree in Business Administration

- ❑ 42 Years of Working Experience with Aramco, SABIC & REC.

- ❑ Pioneer of Systematic RCA in Saudi Arabia

- ❑ Implemented Reliability Projects in major companies

- ❑ Trained more than 6,000 professionals.

- ❑ Expert in RCA, Reliability, Operation, and Management

RCA and Reliability Engineer

❑ General Manager of Reliability Expert Center

❑ Bachelor Degree in Mech. Eng. with first honor, PMU

❑ Certified MLT-1 from ICML

❑ Facilitated many RCA in Saudi Arabia

❑ Implemented Reliability Projects in major companies

❑ Expert in RCA and Reliability methodologies

Omar Al-Ghamdi

REC Products & Services

Reliability

Reliability software, and solution for industries to **manage assets** and **optimize** the **maintenance** and **reduce cost**

Lubrication

Lubrication consultancy, training and certification service to enable **reliability** through **lubrication**

Process Safety

Innovative consultancy & training to improve plant **Safety**, **PHA/HAZOP**, **PSSR**, **HAZAN**.

/OMAINTECConf

Root Cause Analysis

RCA consultancy, training and software solution to prevent problems from **re-occurrences** and **improve** overall plant **performance**

Sustainability

Innovative software, consultancy, training & certification solutions to Improve plant **Safety**, **PHA/HAZOP**, **Product Stewardship**, **Corporate Sustainability** and **Productivity**

Inspection & Asset Integrity

Managing inspection activities in industry. We focus on optimum **implementation**, **guidance** and **long-term effectiveness**, including RAM & LCC analyses

OMAINTEC 20 YEARS

THE 20TH INTERNATIONAL OPERATIONS & MAINTENANCE
CONFERENCE IN THE ARAB COUNTRIES

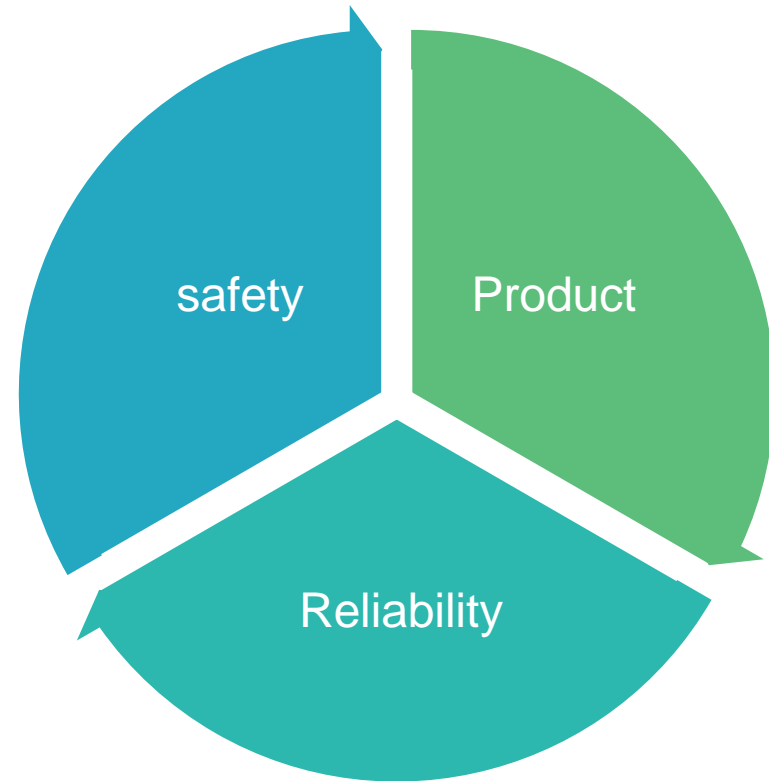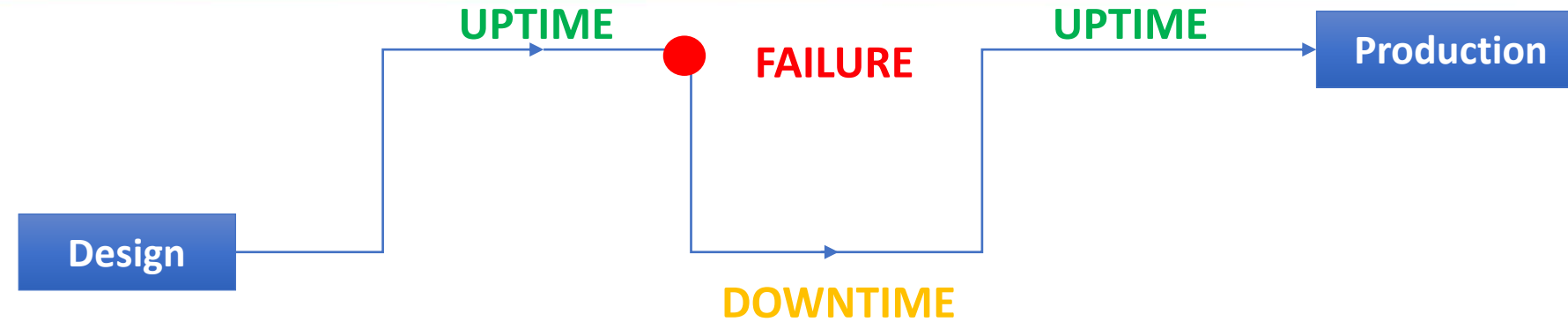# RCA & Reliability Overview

An Initiative by

Organized by

OMAINTEC
المجلس العربي للتشغيل والصيانة
Arab Operations & Maintenance Council

EXICON
International Group
مجموعة أكزيكون الدولية
International Business Unit

Top Priorities

Equipment → Management System → Human

safety

Product

Reliability

Failure Definition
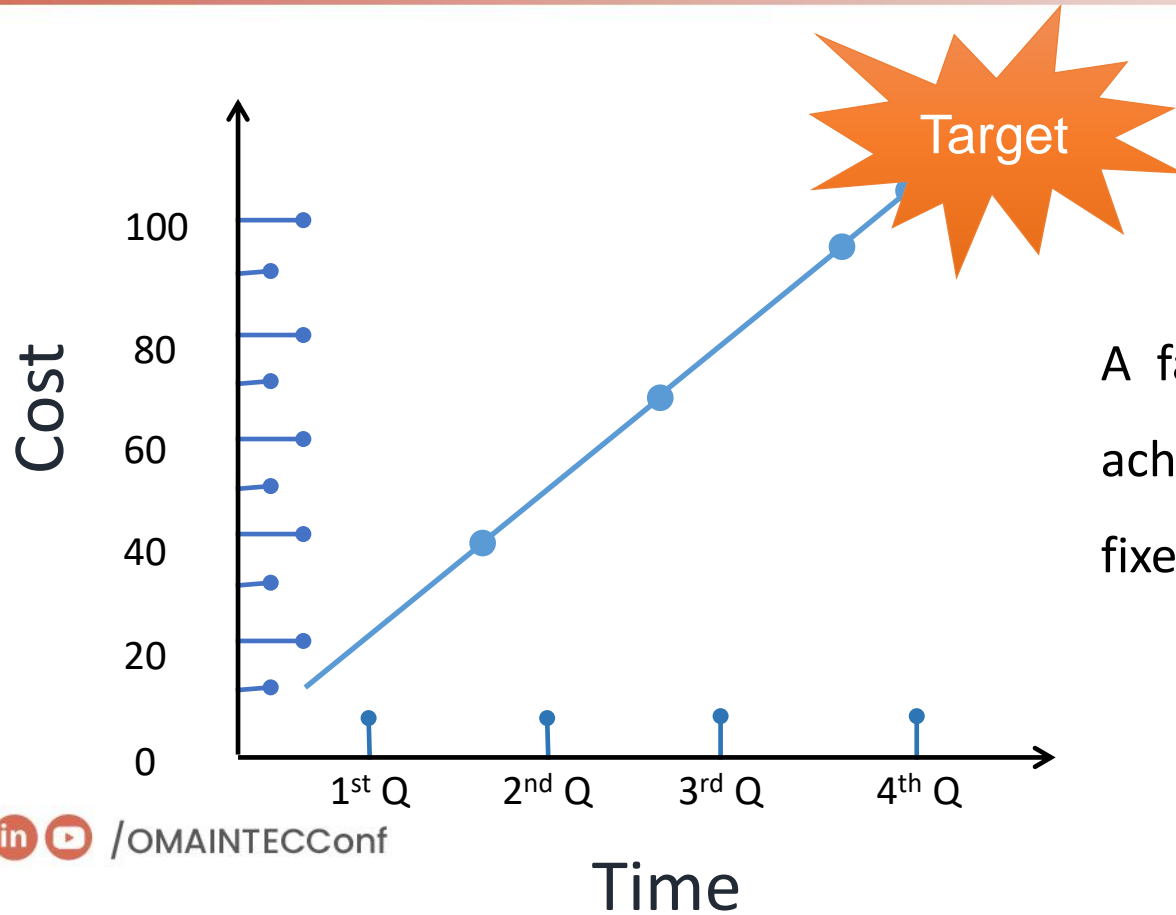
A failure occurs every time we do not achieve the <u>results</u> we anticipated, in a fixed <u>time</u>, at the <u>costs</u> we budgeted.

Reliability System

RCA Definition

Root Cause Analysis "RCA" is a problem-solving methodology. It is a systematic <u>process for identifying the fundamental causes of the failures</u> and <u>developing corrective actions</u> to prevent them from reoccurring.

RCA Main Process Flow

RCA is a systematic process designed to help investigators to:

- ❑ Describe **WHAT** happened.
- ❑ Determine **HOW** it happened.
- ❑ Understand **WHY** it happened.
- ❑ Act on the recommendation on **WHAT to do** about it.

WHAT

HOW

WHY

WHAT to do

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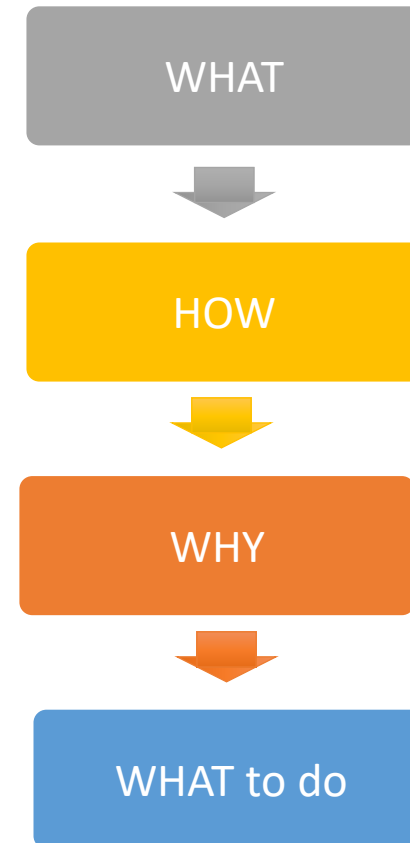
Problem, Symptom & Cause

Definitions:

❑ Problem is the difference between the actual situation and the desired situation. (Condition to be improved)

❑ Symptom is a sign or an indication for an abnormal condition.

❑ Cause is an action or condition that creates an effect or changed the situation.

Cause
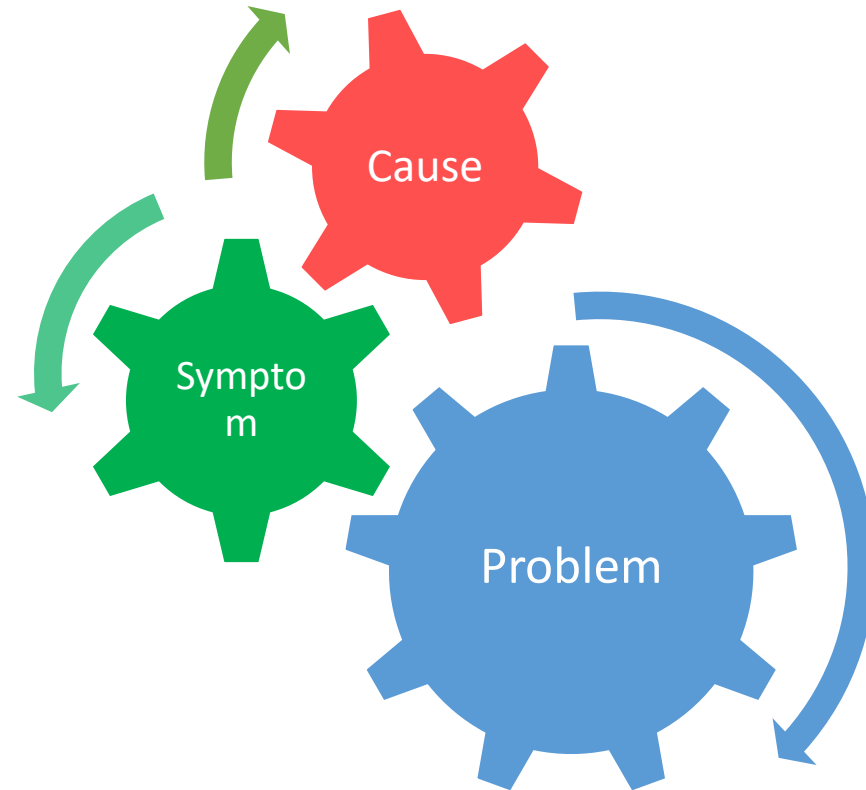
Symptom

Problem

Problem Exercise

If you only fix the symptoms, the problem will almost certainly happen again… which will lead you to fix it, again, and again, and again.

Problem → **Possible Causes** → **Analysis** → **Root Causes** → **Solutions**

When RCA is Used

HSE Incidents

- ❑ Fatality or Injury
- ❑ Fire or Explosion
- ❑ Release/spillage
- ❑ Near miss

Reliability Event

- ❑ Shutdown
- ❑ Production loss
- ❑ Equipment Failure
- ❑ Bad Actor

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Simple RCA

RCA Management System

RCA Management System normally contains:

- ❑ RCA Procedure & Methodology

- ❑ RCA Specialist

- ❑ RCA Sponsor

- ❑ Investigation Team Leader & Members

- ❑ Training & Qualification

- ❑ IR & RCA Software

/OMAINTECConf
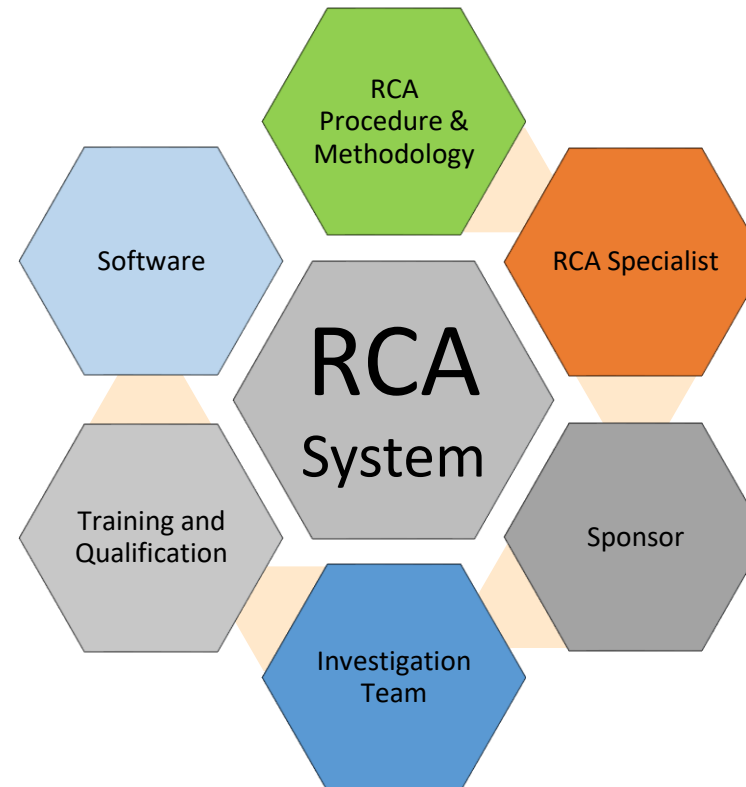
Incident Reporting

EHS Incident Reporting

❑ Refer to EHS procedure.

Reliability Incident Reporting

❑ Reliability Incident is reported in XFRACAS software.
❑ Refer to Reliability Procedure.
❑ Incident Report shall be initiated within 6 hours.
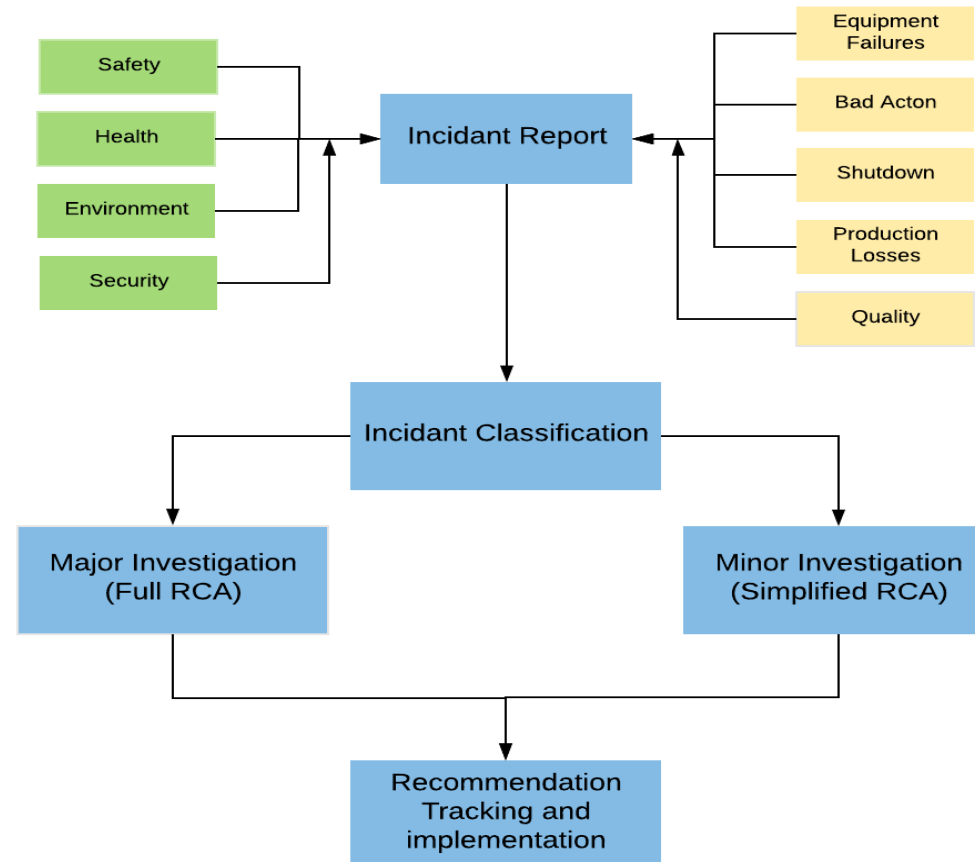
RCA & Reliability Software
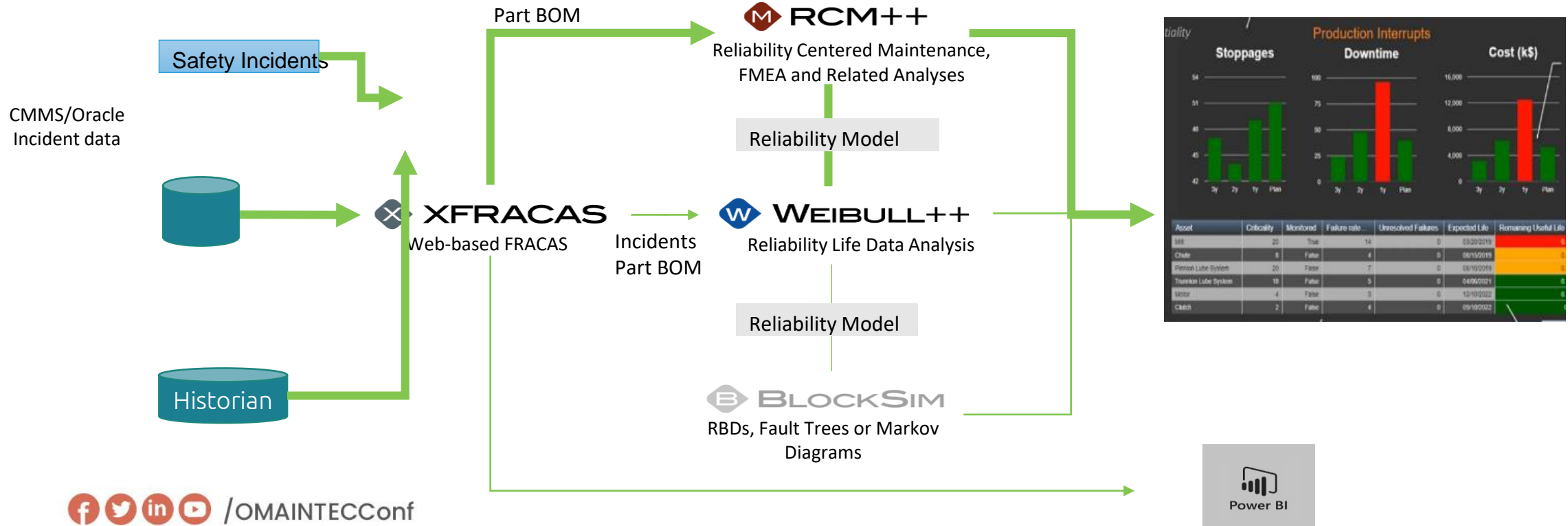
APM operations trends – BI Tool

Reliability Classification Matrix

OPERATIONS/PRODUCTION & FINANCIAL	CLASS	RCA TYPE
Event resulted in > 5 days of production OR Financial loss of > SAR 10M	**CLASS A**	MAJOR Investigation (RCA)
Event resulted in between 3 to 5 days of production loss OR Financial loss of SAR 5M – 10M	**CLASS B**	MAJOR Investigation (RCA)
Event resulted in between 1 to 3 days of production loss OR Financial loss of SAR 1M – 5M.	**CLASS C**	Major Investigation (RCA)
Event resulted in between 8 to 24 hours of production OR Financial loss of SAR 100,000 – 1M	CLASS D	MINOR Investigation (5 WHY)
Event resulted in less than 8 hours of production loss OR Financial loss of < SAR 100,000.	CLASS E	MINOR Investigation (5 WHY)

Investigation Type

There are three type of investigations:

Major Investigation (RCA)
Major investigation is conducted for Class A, B and C incidents.

Minor Investigation (5 WHY)
Minor Investigation (5 WHY) is conducted for Class D and E

Bad Actor
Bad Actors are repeating incidents. These are often the cause the most losses to an organization in terms of down time, equipment failure and maintenance expenses. Actor Matrix

/OMAINTECConf

CLASS	SPONSOR	TEAM LEADER	TEAM MEMBERS		FACILITATOR
			MIN	MAX	
A	President	Director	5	7	Full Time
B	Director	Manager	4	6	Full Time
C	Manager	Superintendent	3	4	Part Time
D	Superintendent	Senior Engineer or Supervisor	2	3	N/A
E	Superintendent	Senior Engineer or Supervisor	1	3	N/A

Investigation Quality

To Develop Quality Investigation:

- ❑ Qualified Investigation Team

- ❑ Available Data
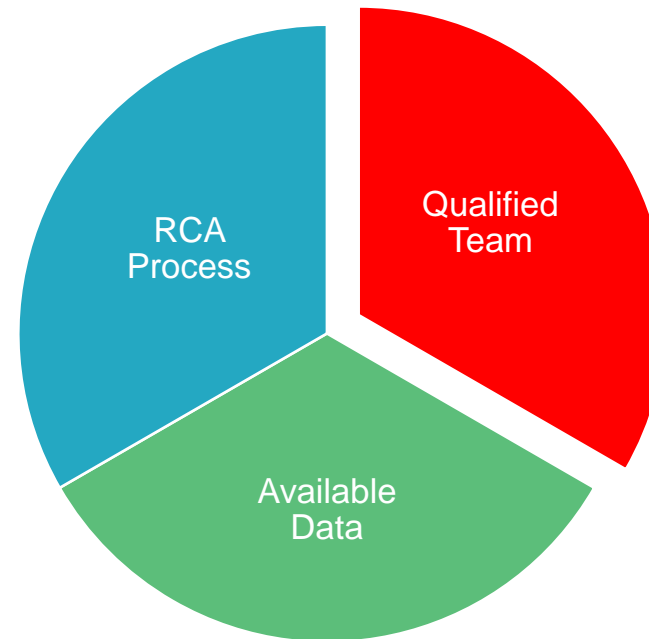
- ❑ RCA Process

RCA Benefits

Improve Profitability.

Increase Plant Safety and Reliability

Enhance Problem Solving

Enhance Management System

Enhance Quality
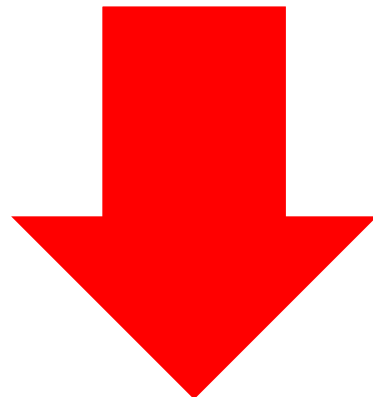
Eliminate Safety Incidents

Eliminate repeated Failures

Reduce Environmental Risk

Reduce Maintenance Cost
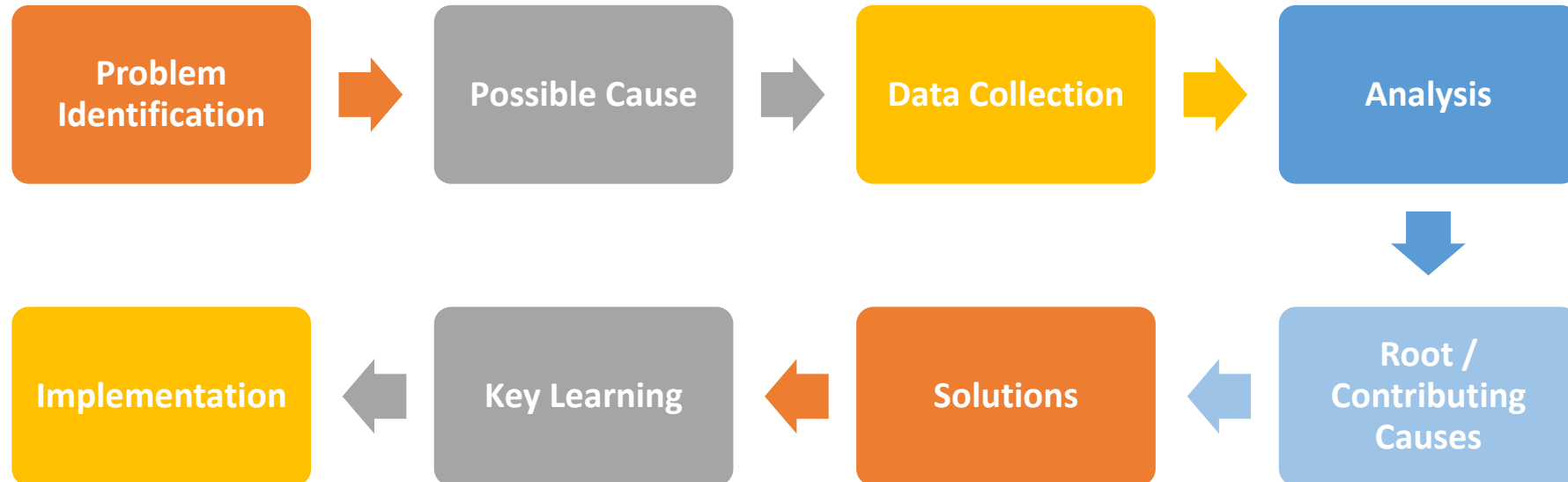
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RCA Process Flow

Reliability Expert Center
RCA Process Flow
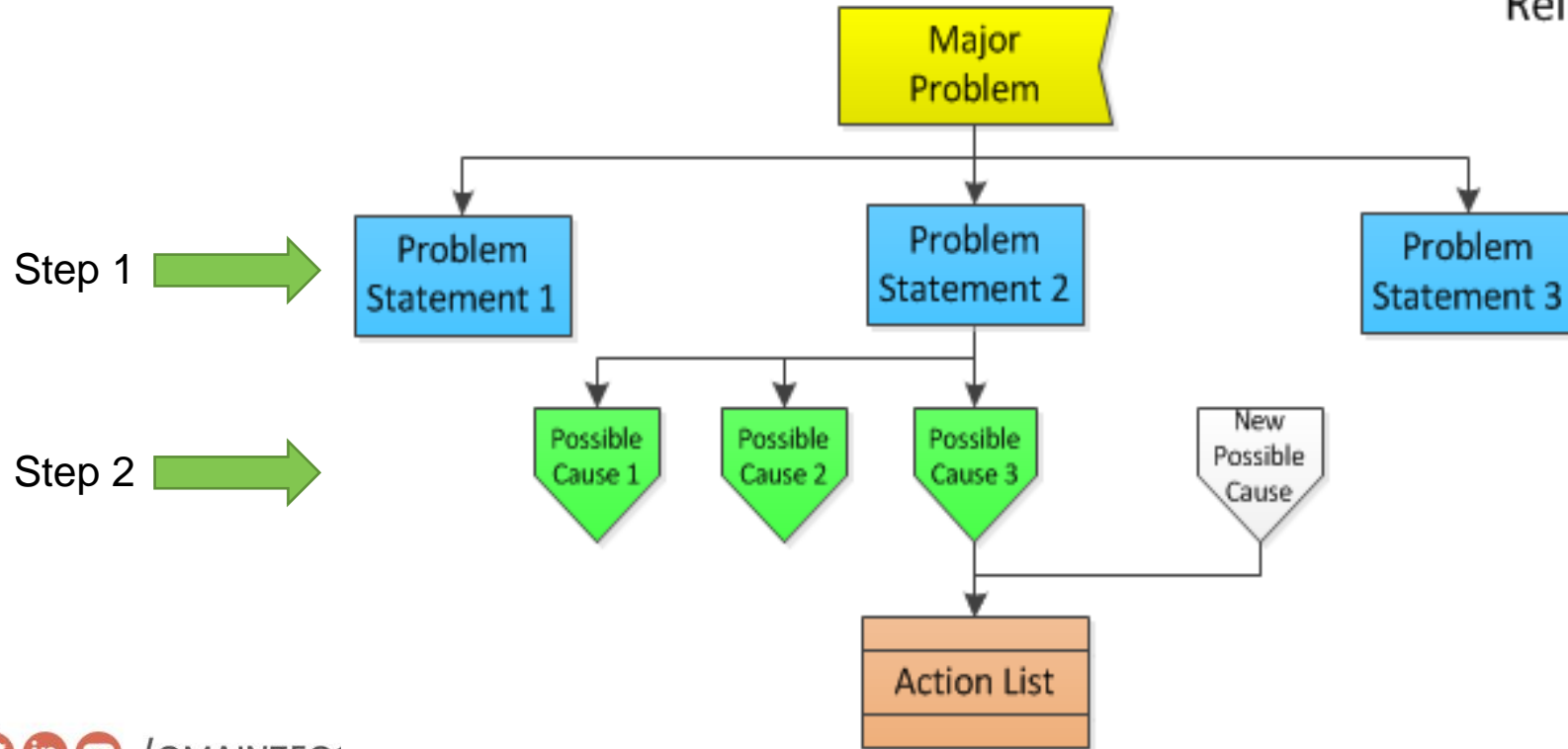
RCA Process Flow
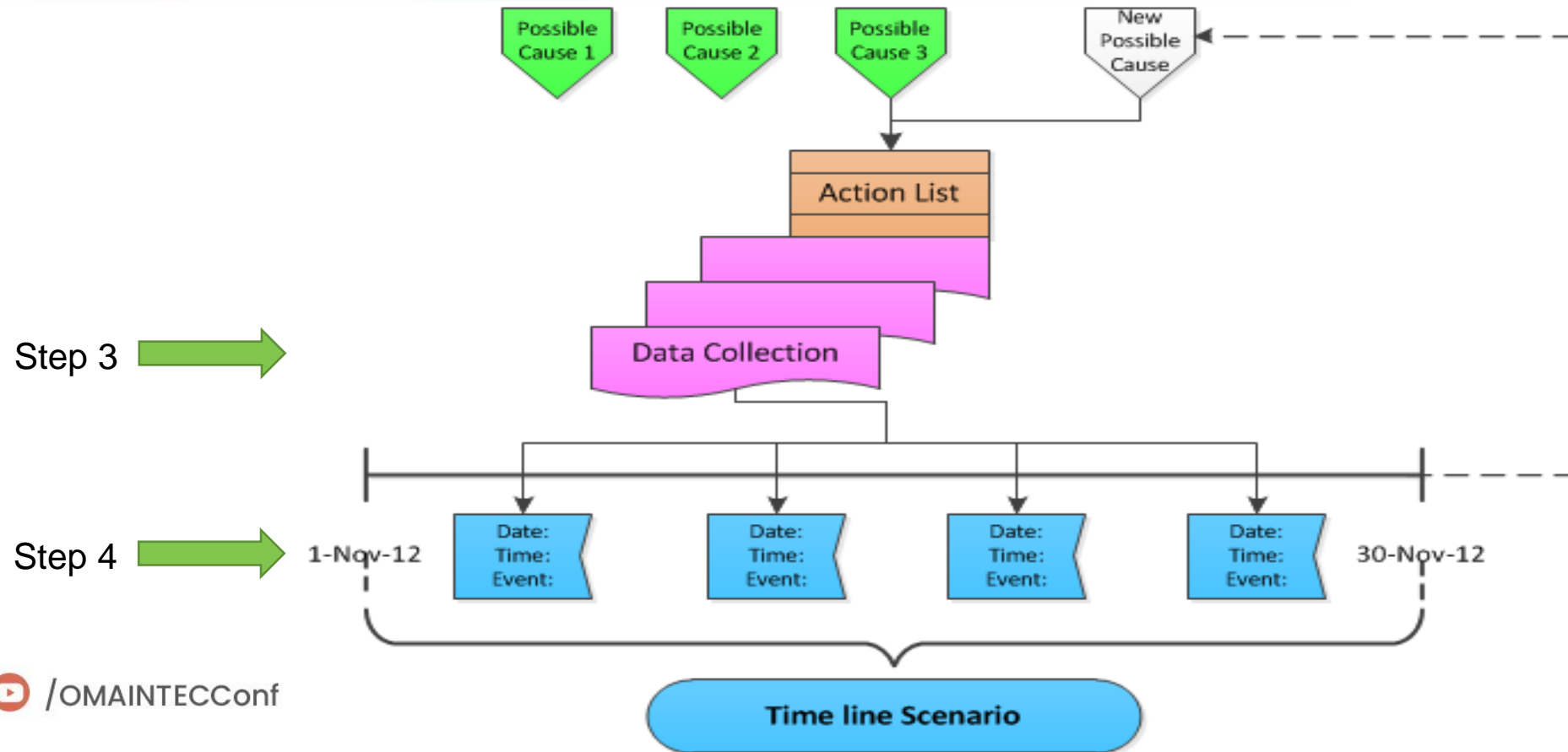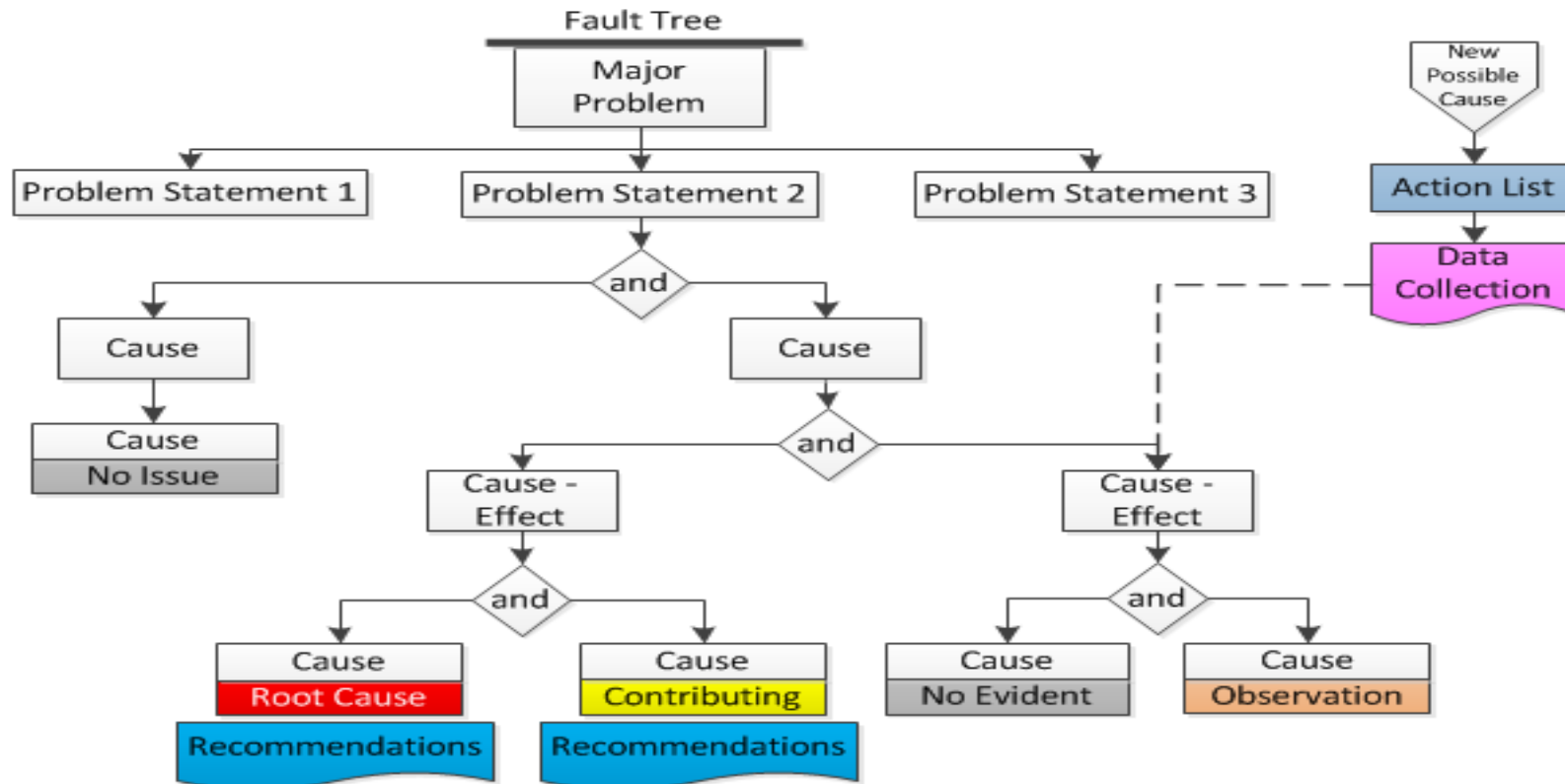
Problem Identification

A fire took place and lasted for 2 hours caused plant shutdown for one day, resulted in production loss and one man injured , he died at the hospital emergency room.

REQUIREMENTS:

❑ Identify Main Problem

❑ Identify problem main events

❑ Identify SME for each events

Fire   Extinguished

Injury   First Aid

Ambulance

Hospital   Fatality

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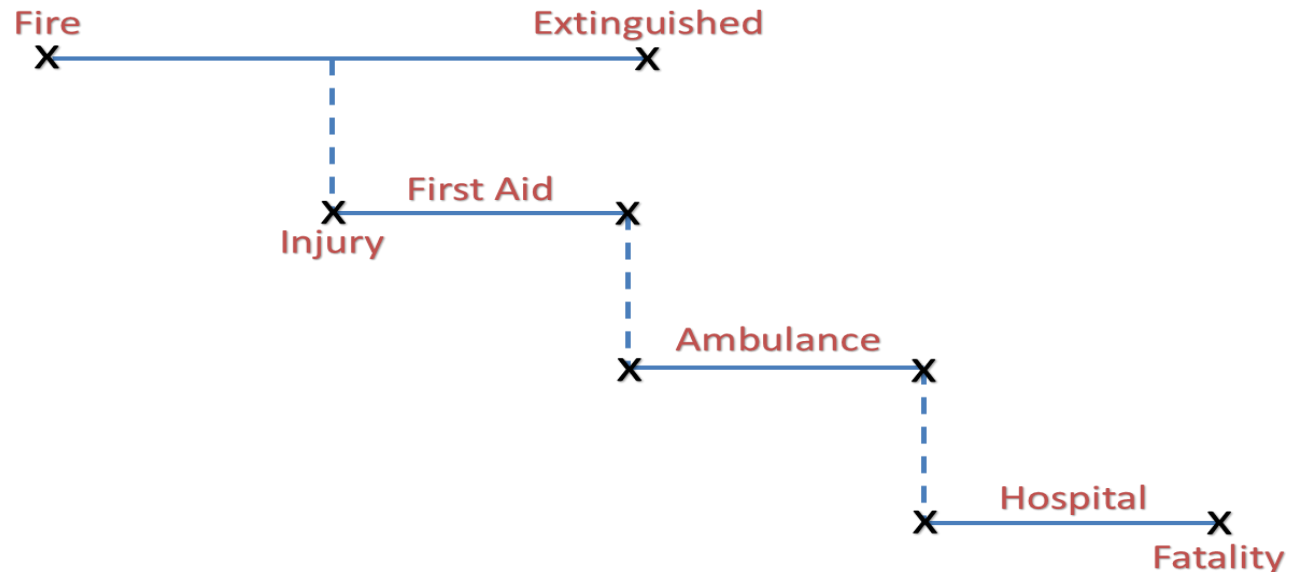
Data Collection Process

❑ Data gathering process is critical and time consuming.

❑ The purpose is to understand what and how the problem happened by creating an accurate and precise sequence of events.

❑ Data gathering starts with identifying;

    ❑ Possible cause/s

    ❑ Gathering data for each possible cause

    ❑ Analyzing all data

    ❑ Building Timeline with accurate causes supported by evidence.

Possible Causes

↓

Data Collection

↓

Data Analysis

↓

Time Line

Possible Causes

There are normally three basic types of causes:

Equipment Failure (Physical causes)
Tangible, material items failed
(for example, a car's brakes stopped working).

Management System Failure (Organizational causes)
Procedure, Training, or Software that people use to make a decision
or do their work, not available or not sufficient.

Human Error (Human causes)
People did something wrong; or did not do something that was
required.

Equipment

Management
System

Human
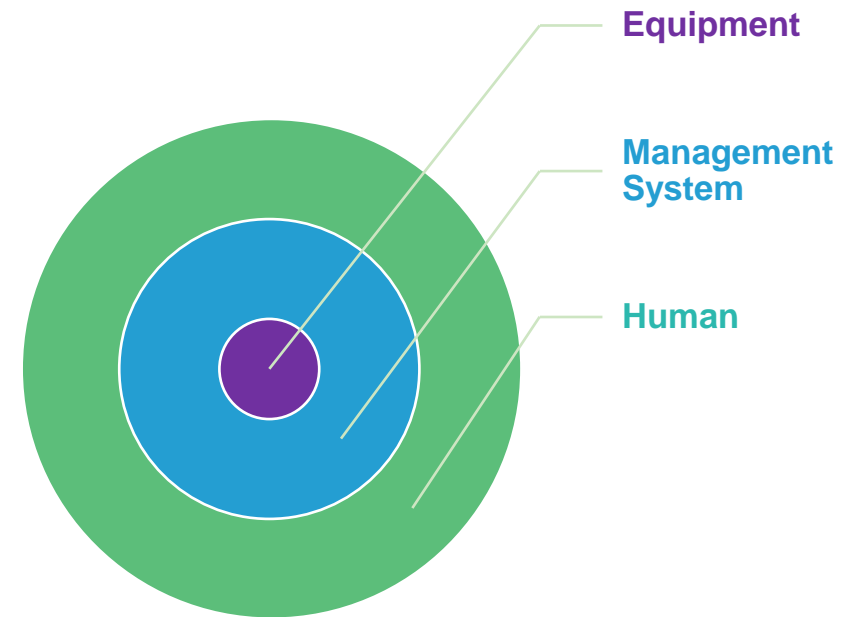
Possible Cause Action

The purpose of developing actions for possible cause are to gather data in order to proof or eliminate the possible causes.

❑ Start with identifying the standard.
❑ Create minimum one action and maximum three actions.
❑ All actions should be SMART.
❑ Team write the " What action" and SMT explain "How action shall be created"

Possible Cause

Standard

Actions

Finding

Analysis

Decision

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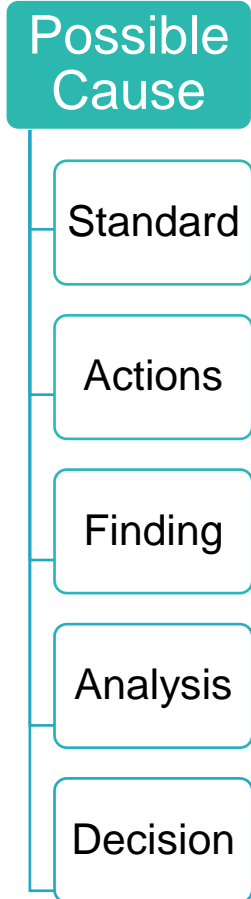
Possible Causes

❑ Identification of causes takes time & some causes can be ignored.

❑ The possible cause can identify multiple causes which, if true and relevant, would explain what happened.

❑ It provides paths to follow in collecting data.

❑ Looks for changes

❑ Some possible causes will be proven, and some may be eliminated.
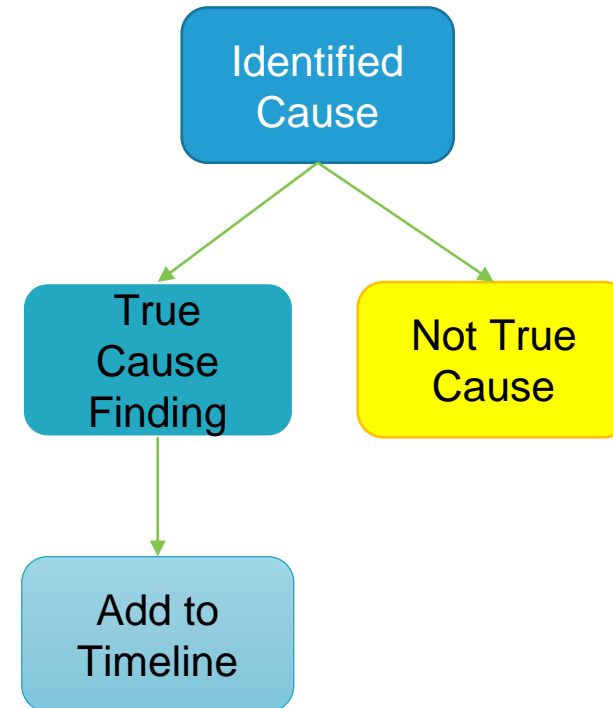
Identified Cause

True Cause Finding

Not True Cause

Add to Timeline

Data Collection Area

Data Collection

Equipment	People Interview	Management System

The intent of data collection is to prove or eliminate the identified possible causes. The data collection will be:

❑ Through developed action list.
❑ Collected from Equipment, People, or Management Systems

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Interview

The purpose of the interview is to collect factual data and not to blame the persons involved in incident directly or indirectly.

- ❑ Interview questions can be extracted from possible cause actions.
- ❑ Questions can be sent to interviewee prior to the meeting .
- ❑ Identify all people directly involved in the incident.
- ❑ Use one to one meetings only.
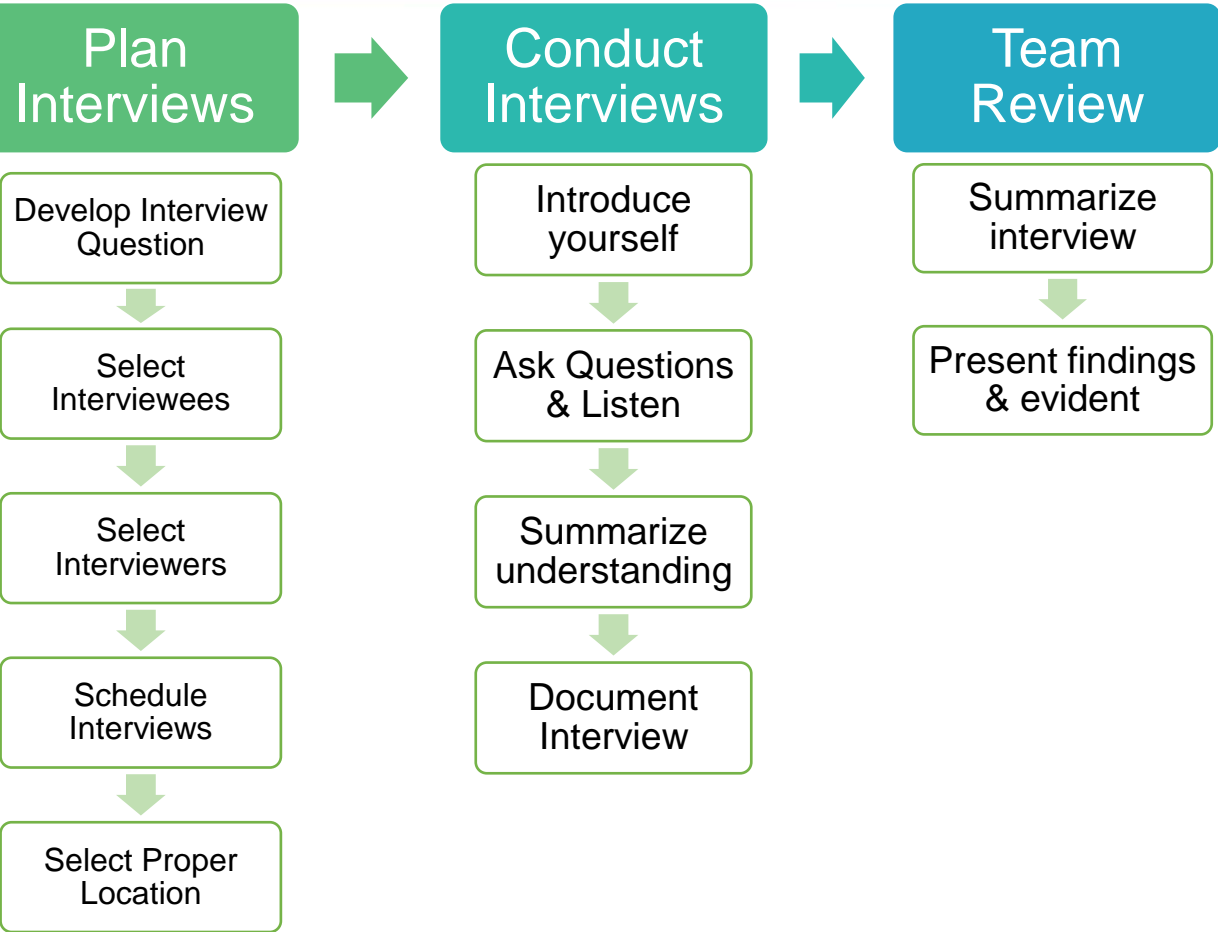
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Plan Interviews
- Develop Interview Question
- Select Interviewees
- Select Interviewers
- Schedule Interviews
- Select Proper Location

Conduct Interviews
- Introduce yourself
- Ask Questions & Listen
- Summarize understanding
- Document Interview

Team Review
- Summarize interview
- Present findings & evident

Data Collection Example

#	Possible Cause	#	Actions	Action By	Date	Finding
2	Hi Moisture air to EP from Air Blower	2.1	Identify design temperature of air conveyor system	Omar	4/8/2019	Design temperature is 200 degrees C
		2.2	Identify actual temp of air conveyor system.	Ali	4/8/2019	184 F
		2.3	Test performance of condensate trap	Ali	4/8/2019	No condensate trap
3	Low Air Flow to Drive the Ash	3.1	Identify actual air flow	Hamza	4/8/2019	Air pressure design is 1.26 Kg, and actual is 1.1 Kg.
4	Rotary Feeder not working	4.1	Test condition during operation	Osama	4/8/2019	Vibration test performed during operation and found OK

Case Study (Damages)

Hole and impact damage on blades
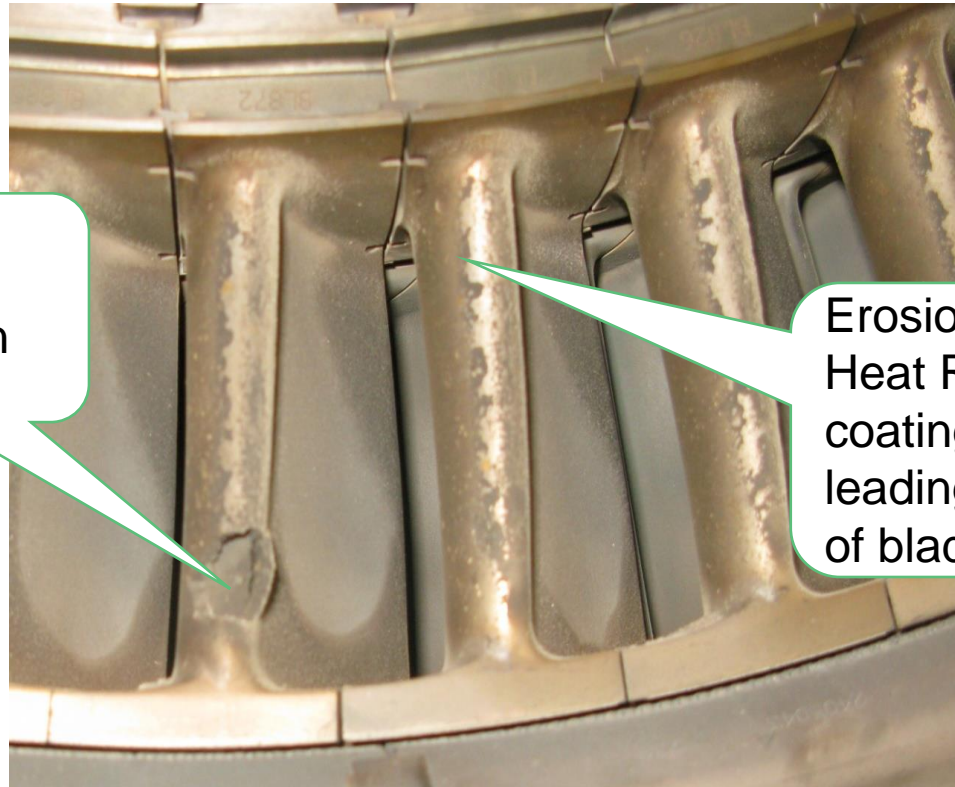
Erosion of Heat Resistant coating on the leading edges of blades

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Data Quality

Collected Data can be rated for quality as follow:

Qualities of Data	Definition
Facts	Precise, Accurate, Verifiable, Measurable
Inference	Logical deduction based on facts
Hypothesis	Causal theory (if true) could explain the facts
Assumption Opinion	Individual perception
Common Belief	Shared perceptions
Hearsay	2nd, 3rd, or 4th-hand information
Guess	Educated or wild deduction
Fantasy	No basis, distortion

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Only data with proven evident rated "Facts, Inference & Hypothesis" can be used during investigation.

Timeline

Accurate Timeline is based on an Accurate result of:

- ❑ Selecting the right **Problem**
- ❑ Determining the right **Event**
- ❑ Identifying all **Possible Causes**
- ❑ Collecting the right **Data**

- ❑ Conducting the right **Analysis**
- ❑ Determining the right **Evident**
- ❑ Pinpointing the **True Causes**
- ❑ Building the right **Timeline**

Problem → Event → Possible Cause → Collected Data → Analysis → Evident → True Cause → Time Line

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Timeline (Example 1)

Oil Type Changed	K1 Hi Vibration	K1 Hi Hi Vibration	K1 Compressor Trip
5 Feb. 2020	8 Feb. 2020	10 Feb. 2020	10 Feb. 2020
08:00	01:20	14:30:30	14:30:40

Lost off 100 Tone of
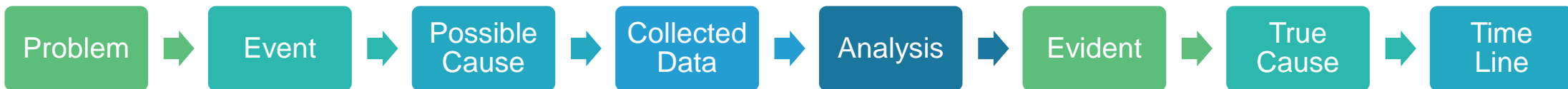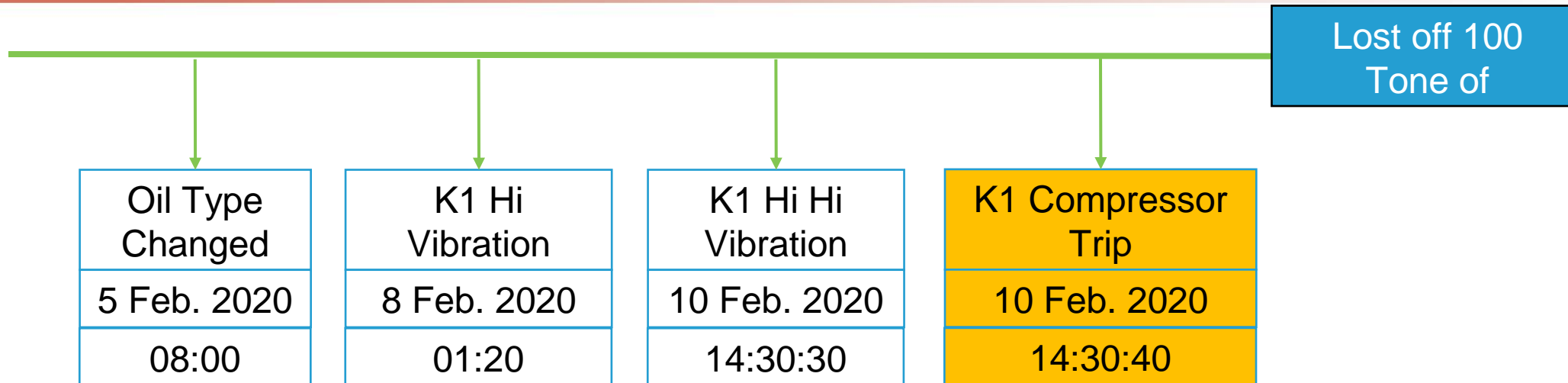
- ❑ Timeline follows backward direction. It starts from the time incident happened and ends with the first event or action that cause or contributed to the incident.

- ❑ The time scale on a timeline can be based on years, months, days, weeks, hours, minutes, or even seconds. Normally more than one timeline is created for one incident

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Fault Tree Analysis

Fault Tree Analysis is a method for analyzing causes, effect and the relationship between them. It defines the root and contributing causes of the problem.
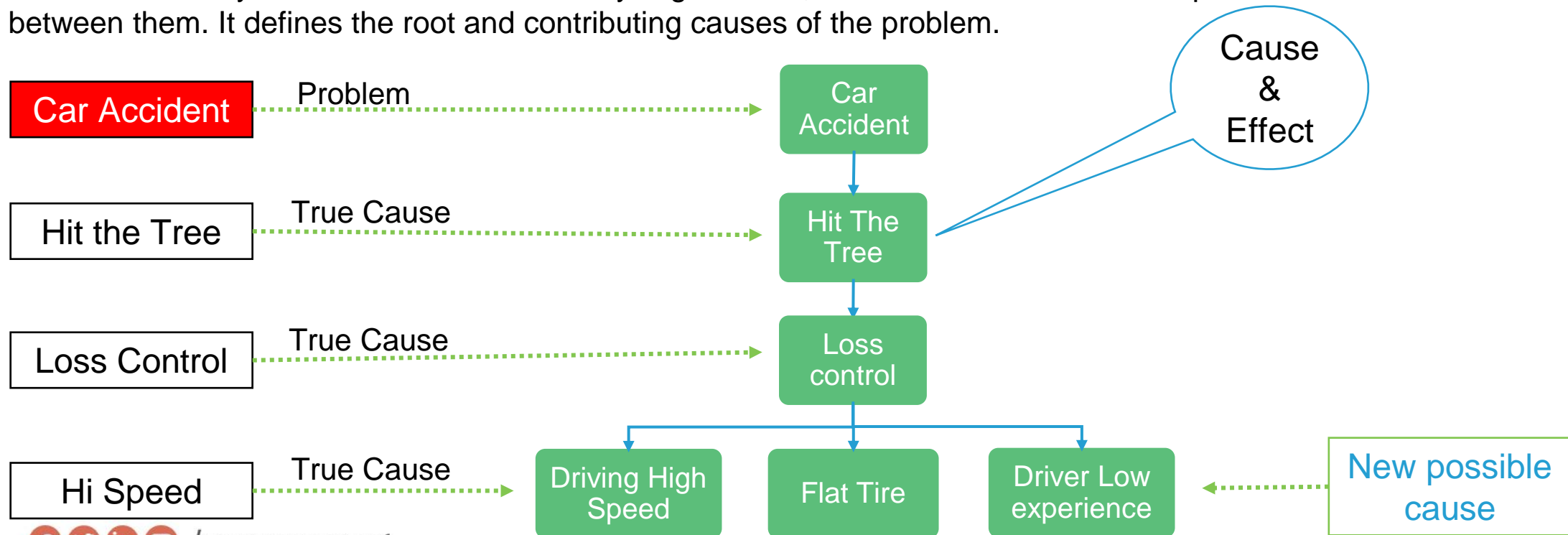
5 Why

5 Why is a question-ask technique used to explore the cause and effect relationship for one single small problem.

Car did not start. (the problem)
- ❑ *Why?* - Battery is dead.
- ❑ *Why?* - Alternator is not functioning.
- ❑ *Why?* - Alternator belt has broken.
- ❑ *Why?* - Belt was not replaced on time.
- ❑ *Why?* - No maintained as required.

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Problem
Why

Cause
Why

Cause
Why

Cause
Why

Cause
Why

Root Cause
Solutions
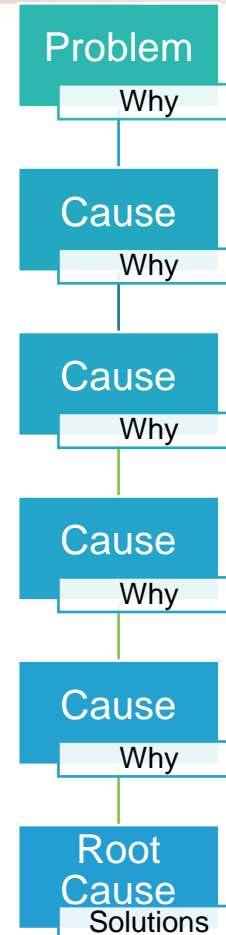
Fish Bone Diagram

The Fishbone diagram is a tool often used together with brainstorming. It provides a pre-defined set ais in looking for the root causes.

❑ Ishikawa diagrams were proposed by Ishikawa in the 1960s.

❑ It shows the cause/s of a certain event.

❑ Best to use for identifying possible causes.
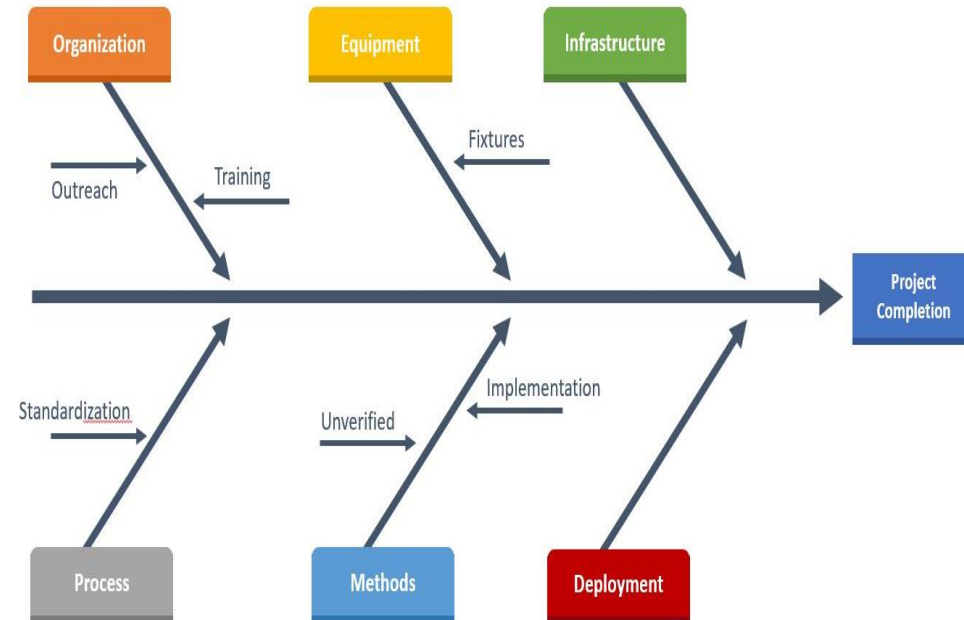
Fault Tree (Single Line)

❑ A Fault tree is built based on cause and effect relationship.

❑ It starts with problem statement.

❑ Use the WHY process to find the right effect

❑ Each cause/effect box must have a proven evidence

❑ 2nd box normally is a direct cause.

❑ End boxes are defined as root causes and contributing causes.

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| Ali Hand Injured |
| Problem |

| He Slipped |
| Cause |

| Oil Spillage in floor |
| Cause |

| Pump Leaked Oil |
| Cause |

| Pump Seal Failure |
| Cause |

| No PM System |
| Root Cause |

Logic Tree (Example)

```
         ┌──────────────┐
         │     Pump     │  Event
         │   Failure    │
         └──────┬───────┘
                │
         ┌──────▼───────┐
         │   Bearing    │  Failure Mode
         │   Failure    │
         └──────┬───────┘
       ┌────────┼────────┐
       │        │        │
┌──────────┐ ┌──────────┐ ┌──────────┐
│ Erosion  │ │ Fatigue  │ │ Corrosion│   Physical
│ Not True │ │  True    │ │ Not True │
└──────────┘ └────┬─────┘ └──────────┘
                  │
            ┌─────▼──────┐
            │Misalignment│  Human Error
            └─────┬──────┘
                  │
            ┌─────▼──────┐
            │No Effective│
            │  Training  │
            └────────────┘
```

Hypothesis
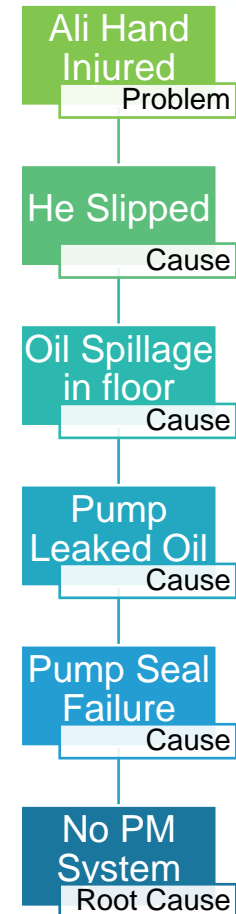
Latent Root Cause
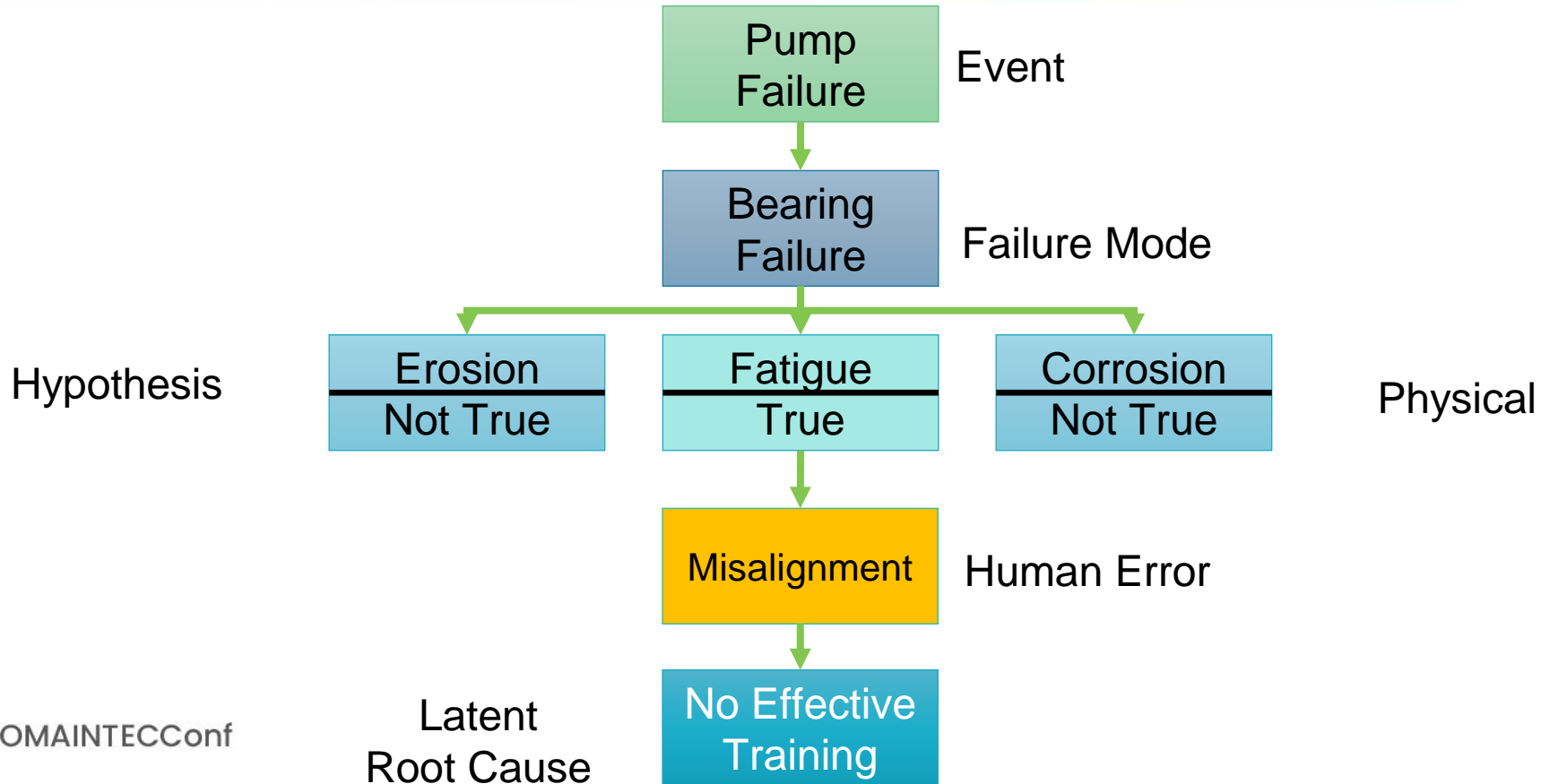
Root Cause

The root cause is the main cause of the problem, which is the one that we can prevent from recurring. It is the absence of effective management system or lack of compliance.

السبب الجذري هو السبب الرئيسي لحدوث المشكلة وهو الذي بإمكاننا منعة من التكرار, ويحث عادتا لغياب الممارسات الصحيحة لإدارة العمل من ناحية الأنظمة أو عدم الالتزام بها.

On average, there are two or three root causes per Incident

Fault Tree Example

Two phase flow in the 1st stage case cause Pump vibrated (ammonia gas from seal flush system) (I)

AND

40 High seal flush ammonia temperature (reached >32°C, normally < 10°C) (F)

49 Interlock is out of service since 1990 (High seal flush temperature, TSHH 8283) (F)

AND

41 Not enough ammonia cooling flow to seal flush cooler, I-2026 C from battery limit (I)

46 Seal cooler outlet temperature indicator, TI 8267 B is not reliable (I)

50 Spare is not available as it is obsolete model

Root Cause

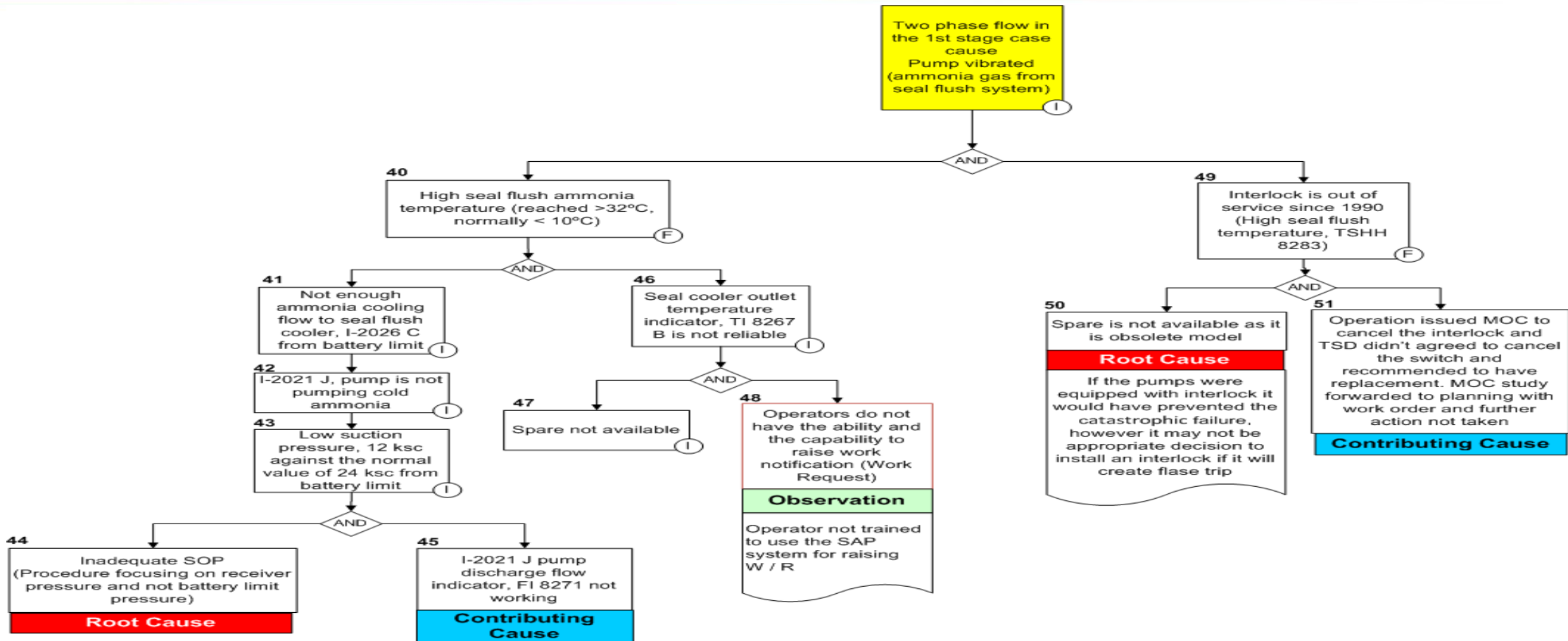If the pumps were equipped with interlock it would have prevented the catastrophic failure, however it may not be appropriate decision to install an interlock if it will create flase trip

51 Operation issued MOC to cancel the interlock and TSD didn't agreed to cancel the switch and recommended to have replacement. MOC study forwarded to planning with work order and further action not taken

Contributing Cause

42 I-2021 J, pump is not pumping cold ammonia (I)

AND

47 Spare not available (I)

48 Operators do not have the ability and the capability to raise work notification (Work Request)

Observation

Operator not trained to use the SAP system for raising W / R

43 Low suction pressure, 12 ksc against the normal value of 24 ksc from battery limit (I)

AND

44 Inadequate SOP (Procedure focusing on receiver pressure and not battery limit pressure)

Root Cause

45 I-2021 J pump discharge flow indicator, FI 8271 not working

Contributing Cause

Determining Root Cause

Method for Determining Root Cause:

- ❑ All Root causes are Human Error

- ❑ All Root causes are Management System Failure

- ❑ Root Causes can be:
  - ❑ Equipment Failure
  - ❑ Management System
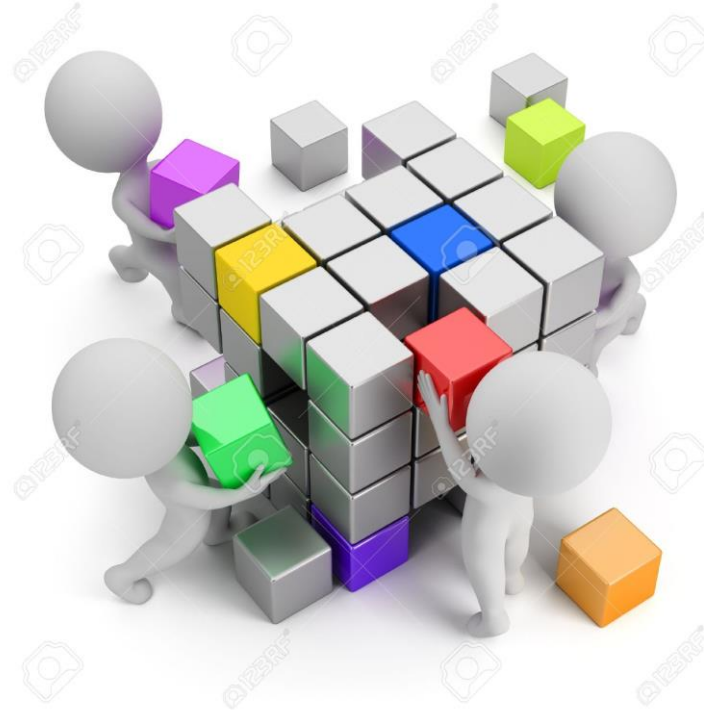 - ❑ Human Error

Human Error

Management System Failure

Equipment Failure	Management System Failure	Human Error

Contributing Cause

Contributing cause is the cause that helps to create the problem, cannot make the problem by itself. For example ineffective procedure.

**On average, incidents had Five to ten contributing causes per Incident**

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Human Error

Intentional: Action committed because it is believed, he believe it's quicker, easier, safer etc.

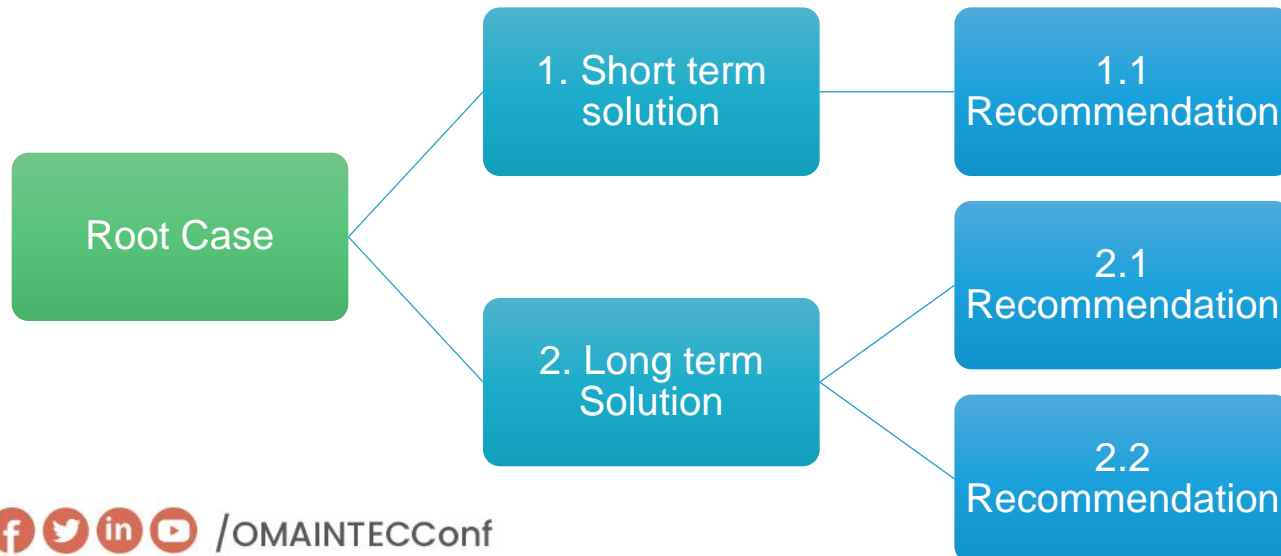For Example. Walking on top of the pipe rack without safety belt

Unintentional : Action committed without prior thought or intent.

For Example. Pushing a wrong switch – No label on the switch

Human Error → Intentional → Violation
Human Error → Unintentional → Inadequate Management System
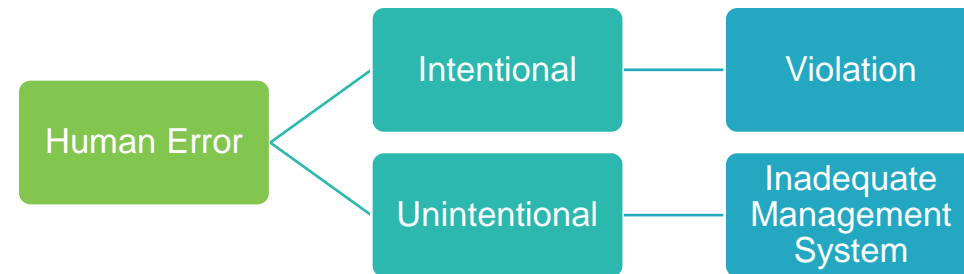
Effective Solution

The purpose of conducting investigation is to develop and implement effective solutions that will prevent incident from recurring

```
                        ┌─────────────┐          ┌─────────────┐
                        │ 1. Short term│─────────│     1.1     │
                        │   solution   │          │Recommendation│
                        └─────────────┘          └─────────────┘
┌─────────────┐              /
│             │─────────────/           ┌─────────────┐
│  Root Case  │                         │     2.1     │
│             │             ┌──────────│Recommendation│
└─────────────┘             │           └─────────────┘
                    ┌─────────────┐
                    │ 2. Long term │
                    │   Solution   │     ┌─────────────┐
                    └─────────────┘─────│     2.2     │
                                        │Recommendation│
                                        └─────────────┘
```

❑ Solutions shall be SMART.

❑ Connected with Root & Contributing Causes.

❑ Prevent the causes from reoccurring.

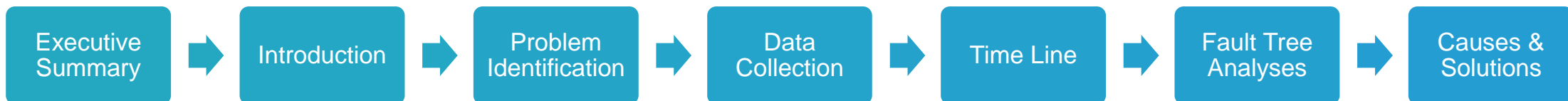❑ Can be implemented

❑ Not creating new risk

Final Report

The final investigation report consist of a presentation and a written report. The written report can be a generated from RCA software or hard copy document and the presentation can be developed in MS power point.

A typical outline of the Final Report shall be as per the following:

- ❑ Executive Summary
- ❑ Introduction
- ❑ Process Description
- ❑ Problem Identification and Description
- ❑ Cause Analysis
- ❑ Conclusions
- ❑ Key Learning
- ❑ Recommendations
- ❑ Other Observations
- ❑ Appendix

| Executive Summary | → | Introduction | → | Problem Identification | → | Data Collection | → | Time Line | → | Fault Tree Analyses | → | Causes & Solutions |

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Key Learning

A **Key Learning** is a high-level overview of the investigation final report, The intent is to share investigation results and encourager culture change to avoid repeated problem.

Statistical Analysis

Statistical analysis is the method for identifying the repeated root/contributing causes & measuring the effectiveness of the RCA system.
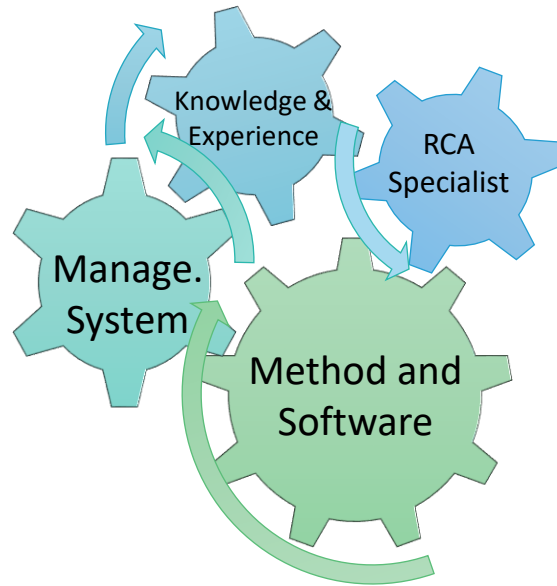
- ❑ Review all incidents & Investigations on quarterly basis

- ❑ Identify;
  - ❑ Repeated Causes relationships
  - ❑ System weaknesses
  - ❑ Performance issues

- ❑ Develop long term solutions

- ❑ Present finding & Solutions to Sr. Management
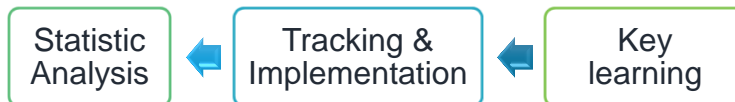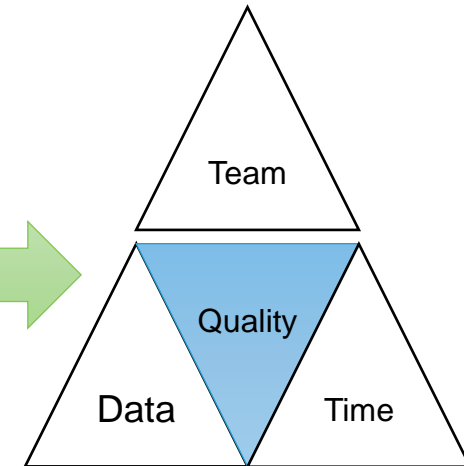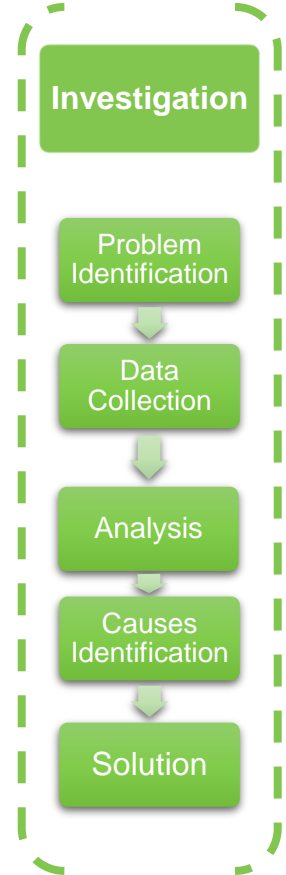
- ❑ Issue Statistical Report.
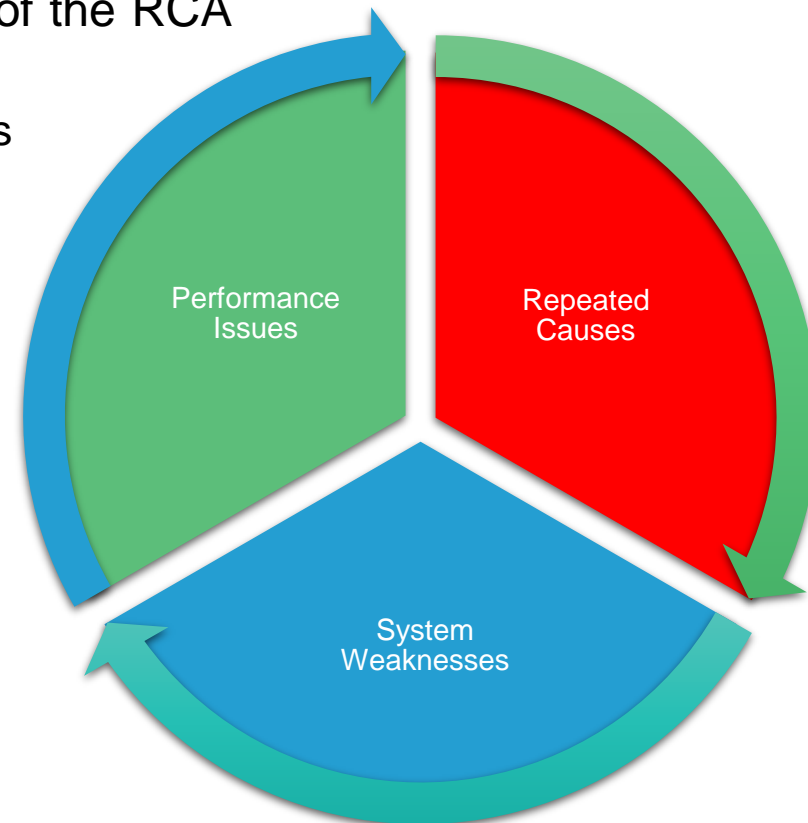
Performance Issues

Repeated Causes

System Weaknesses

Equipment Failure

Fish mouth opening in tube 21 along with a shot of other bulges and an earlier patch repair
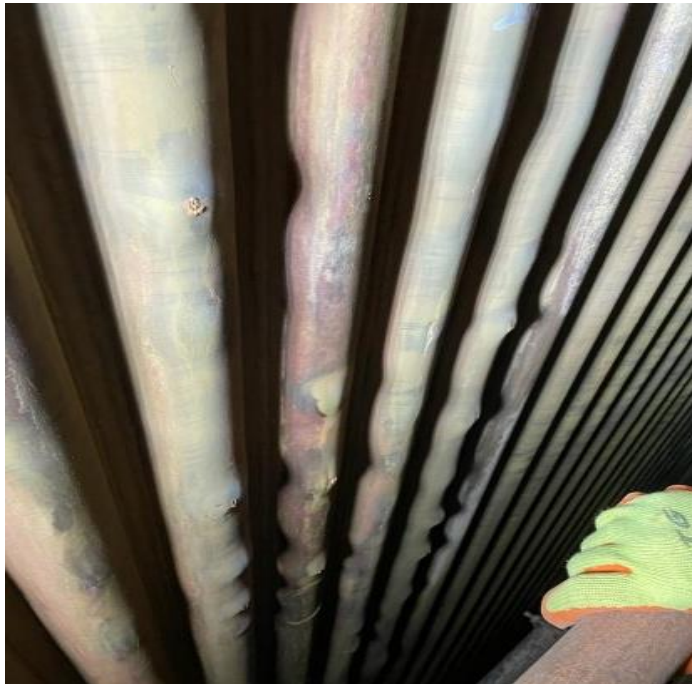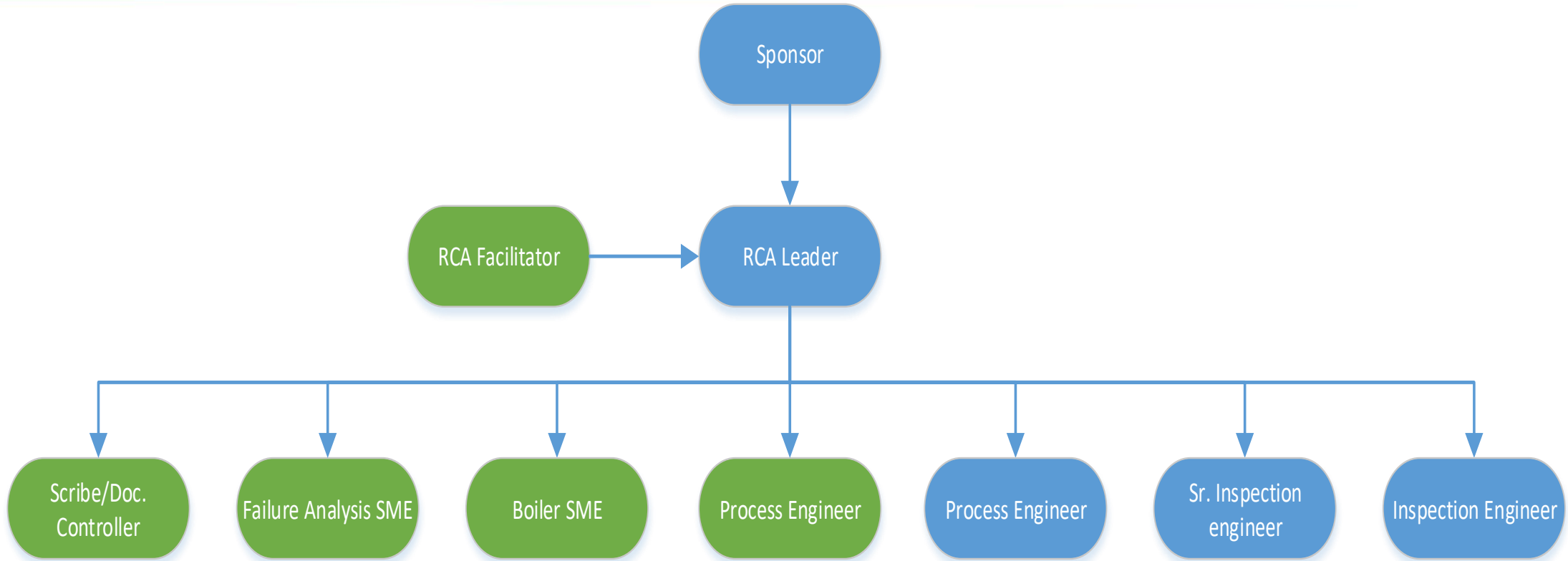
Problem Statement

On Saturday, December 26 at 01:05 AM, Boiler-4 has experienced an Emergency Shutdown after only 5 months of operation due to multiple Tubes Failures, leading to production loss, an increase in maintenance cost, and Severe business interruptions.

Possible Causes

1. Localized overheating due to localized scale buildup
2. Improper heat distribution from burners
3. Running boiler at a temperature higher than design spec (about 410C Vs 390C)
4. Burner & Flame shape
5. Not detect flame Impingement
6. Scale deposited below the failure tubes increasing the metal temp. more than the design leading to reduced yield strength (High heat flux area)
7. Burner angle problem - flame impingement more on dividing walls

8. Sudden temperature raised
9. Flame Impingement
10. Overload
11. Bad alignment of burners
12. Flame temperature more than the tube
13. During S/D the scale agglomerate than rap with heat
14. Improper water treatment causing abnormal scale buildup
15. Wrong thickness of the tube
16. Flame direction
17. Overheat
18. Burner controls, T & flam direction
19. Wrong selection of material
20. Improper water circulation

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What is Wrong ?

Flame Impingement

Boiler- 3 Video

Boiler- 1 Video

Flame Impingement

Burners

A C

B D

Most affected zones
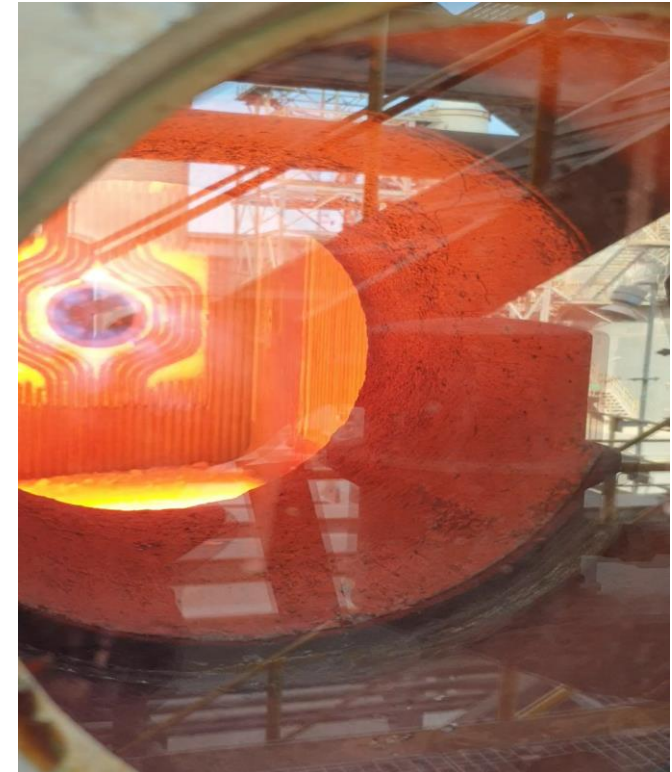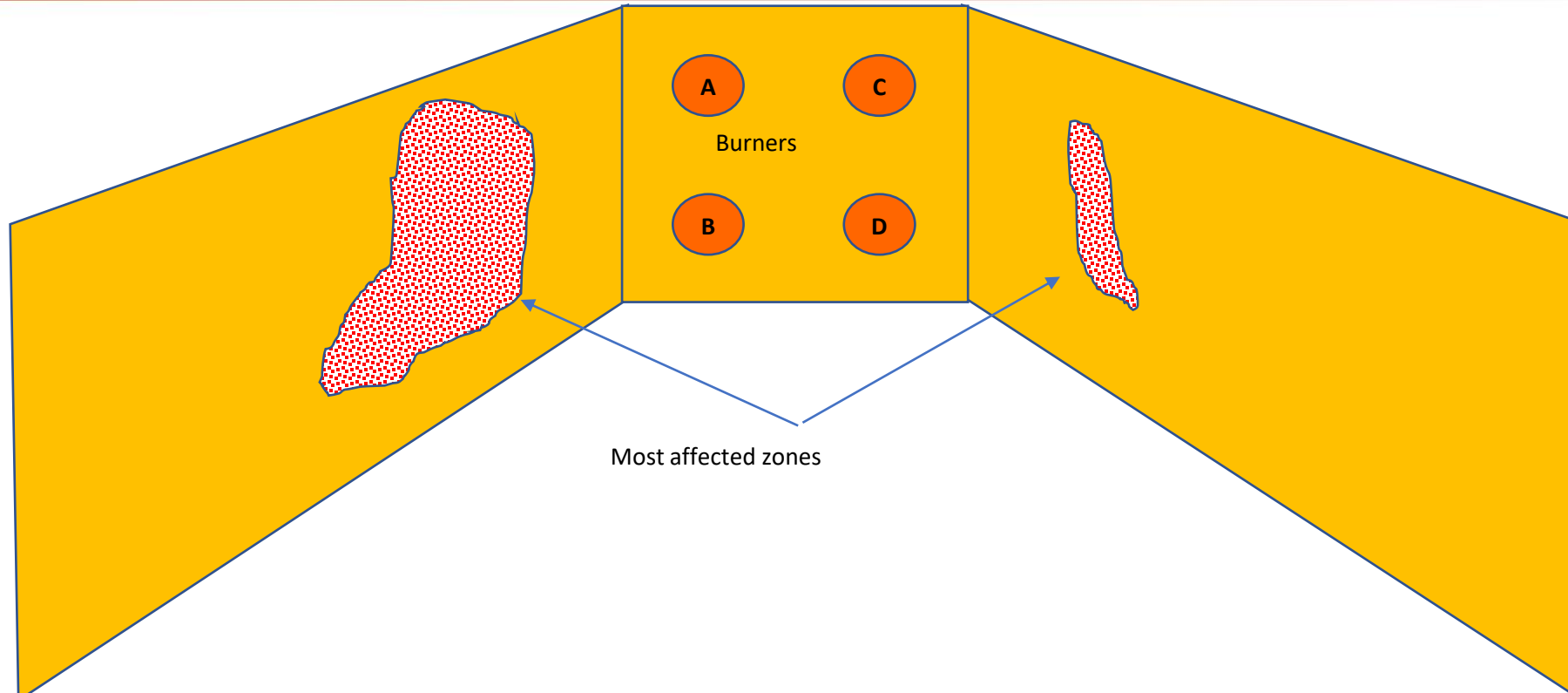
Metallurgical Failure Analysis

Figures shows boiler tubes as received for laboratory tests: (a) Cut piece of boiler tubes (tube, 21-2, 29-3 & 32-1) (b-d) sample after cross-sectional cutting details for further metallography analysis, (e) scale collected from the ID surface of the tube# 29-3 for SEM-EDS analysis.
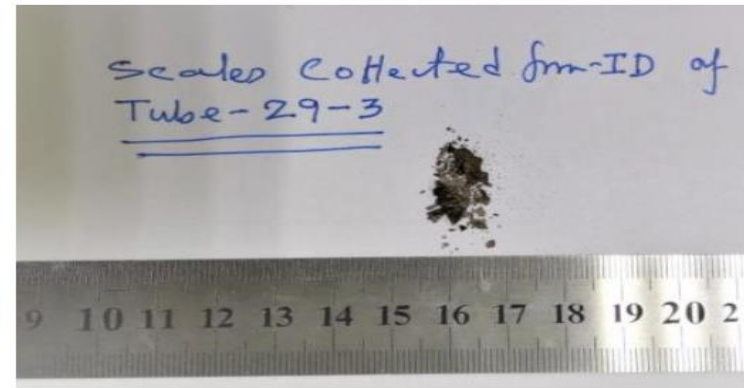
Metallurgical Failure Analysis – Lab Analysis

The possible findings observed based on the analysis & results as given samples–

a) Localized bulging observed on ## tube no. 29-3.

b) Longitudinal parallel fine cracks on the tube surface observed (## tube 21-2).

c) Microstructural analyses revealed pearlite disintegration / spherodized carbides microstructures at 424°C to 427°C clearly on (## tube no.29-3 (bulged) & 21-2 compare to intact (32-1) or initial bulging locations of the tube (29-3).

d) Creep voids / Fissure cracks found clearly with intergranular cracking nature on (## tube no.29-3 (bulged) & 21-2, The creep voids started in triply points of grain of the component which may agglomerate and forming cracks at high temperature.

e) The localized temperature may reach on the tube surface behind the design temp approximately above 500°C according to microstructure features for damaged one.

Water Quality Analysis – Sampling Points
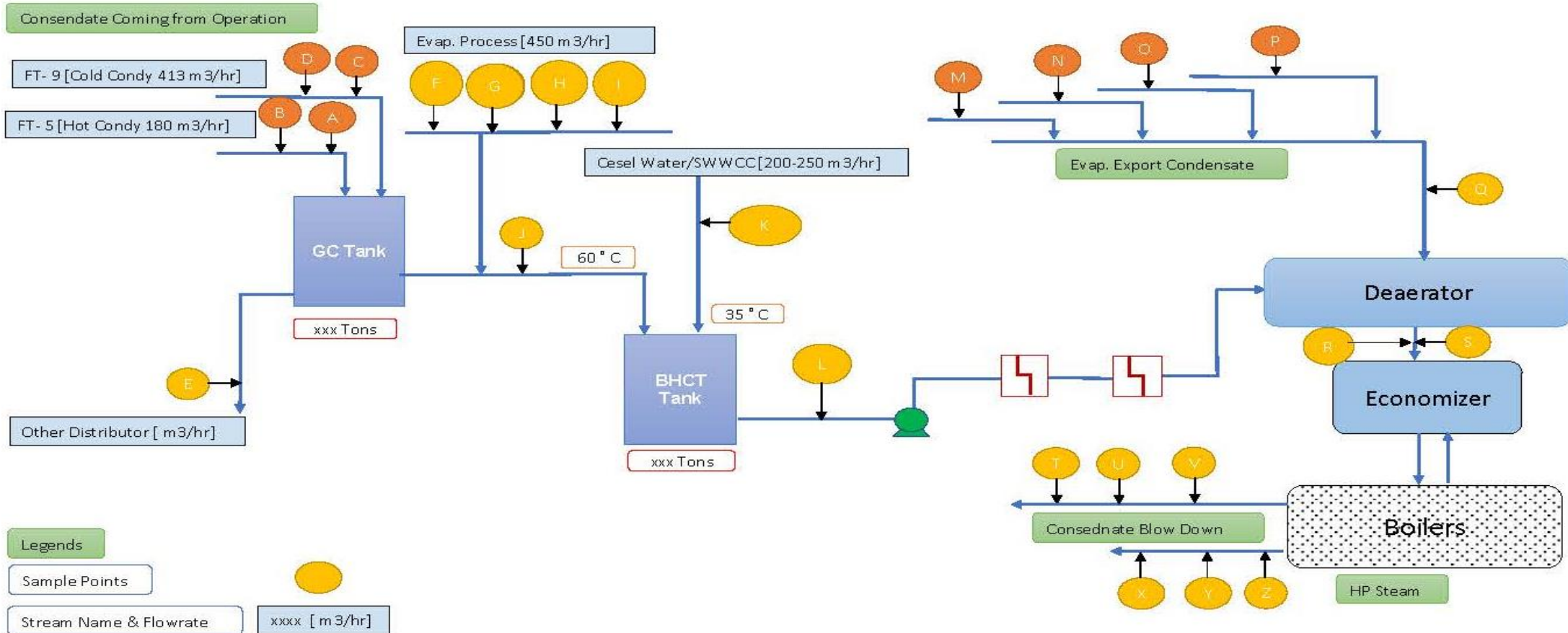
Water Quality Analysis – Sampling Point B

S . No	Item	Unit	Design		XYZ 2021	ASL 1st Sample	ASL 2nd Sample
1	PH Value (at 25°C)	-	9- 9.5		10.23	9.66	9.87
2	Total Hardness (as $CaCO_3$)	ppm	<0.01			<0.1	<1.0
3	Iron	ppm	0.01 - 0.03		0.061	<0.01	0.02
4	Total Alkalinity (as $CaCO_3$)	ppm	30			34	43
5	Oily matter	ppm	NIL			<5	<5
6	Total Dissolved Solids	ppm	30 - 50			26	31
7	Sodium phosphate as PO_4^{3-}	ppm	0.1			<0.01	<0.01
8	Silica SiO_2	ppm	0.04 - 0.08		1.16	<0.1	1.1
9	Aluminum	ppm	3 -- 5			1.34	5.16
10	Copper	ppm	0.004 - 0.01			<0.001	<0.001
11	Chloride	ppm	5 max.			<1	<1
13	Direct Conductivity	µS/cm	50 -100		51.51	45	54
14	Caustic Alkalinity (as $CaCO_3$)	ppm	40 - 50				
15	Ammonia (NH3)	ppm	3-- 5			7	4.75
16	Calcium (as CaCO3)	ppm	1.50		0.2	<1.0	<1.0
17	Magnesium (as CaCO3)	ppm	0.20			<1.0	<1.0
18	TSS	ppm	<0.03		4	<5	15
19	TOC -total organic carbon	ppm	<0.001			9.3	24.6
20	Total Phosphate	ppm	<10			<0.03	<0.03
21	Calcium Hardness (as $CaCO_3$)	ppm	<1.0			<0.1	<1.0
22	Hydroxide Alkalinity as CaCO3	ppm	<20			6	8
23	Dissolved Oxygen	ppm	<0.007			7.9	8.1

Fault Tree Analysis

On Saturday 26 December at 01:05 AM, Boiler 4 Went into Emergency Shutdown after only 5 months of operation due to repeated Tubes Failures, Leading to production loss, Increasing maintenance cost & severe business interruptions.

Rupture of Tube 21 (Fish Mouth) and Bulges in other tubes, mostly between tubes 9 and 67

AND

General Overheating of tubes in furnace side on dividing wall

Flame Impingement around tube No. 21 from burners

Improper Configuration of Boiler Burner

Improper Original Design by Samsung

Root Cause

Excessive amount of Internal Scale Deposit build-up inside the boiler tubes over a period of time

AND

Total suspended solid –TSS in boiler feed water off spec. reached to 72 ppm against the design of 0 ppm (Major contributor of scale build up)

Return condensate from the digestion stream & evaporation export condensate stream has high TSS

AND

No filtration system for TSS removal

Root Cause

No Online Monitoring system

Contributing Cause

Iron –in Boiler feed water off spec. reached to 0.4 ppm against the design <0.03 ppm (accelerate the scale formation and decrease thermal conductivity)

Return condensate from the digestion stream has high Iron in a dissolved state

AND

Not enough monitoring of Iron on the boiler feed water

Contributing Cause

No management system for removing Iron

Contributing Cause

PH, TOC, Oily Material, Ammonia and hydroxide alkalinity were off spec. Minor contribution to scale build up

Observation

Recommendation

S/N	Causes	TYPE	Recommendation	Sponsor	Target Date
1	Improper Original Design/configuration of burners.	Root Cause	Burners should be redesigned to ensure proper heat distribution that maximizes performance while not allowing flame impingement on tubes. As an intern resolution, flue gas temperature should be controlled below 400°C.		
2	No Filtration system for removal of impurities in the feed water, especially Total Suspended Solid (TSS).	Root Cause	Demineralized feed water should be considered. If not possible, an effective filtration system should be installed to limit ingress of impurities into feed water.		
3	No Online Monitoring System for TSS	Contrib. Cause	A proper online monitoring system for TSS should be installed.		
4	Not enough monitoring of Iron in the boiler feedwater	Contrib. Cause	A proper online monitoring system for iron should be installed.		