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Pump Incidents

Pump Related Incidents

- Failures on pumps including breakdowns and physical breaks.

- Article 24 Incidents

- Years after the incident

- All evidence is destroyed

Introduction: The Purpose or Intension of the VARCA Model

- The VARCA Model is not intended to be a Root Cause Analysis, but a process to conduct a forensic investigation.

- It can be seen as a "strategy" to do an investigation.

- Although the Cause Map is part of the Model, it is not a Root Cause Analysis.

- The Model focus mainly on vibration analysis and the different levels of vibration analysis.

- Vibration Monitoring is not part of the Model – not part of Condition Monitoring.

- Specifications is not part of the Model due to the detail of the analysis.

- The Model is mainly tested on pump systems including motors and pumps. Some tests were also conducted on turbines, compressors and fans.

- The purpose of the model is to analyze and not to monitor.

Introduction - General

- Through the years vibration analysis was mainly used for condition monitoring.
  - Condition Monitoring is associated with the physical condition of the plant or industrial equipment.
  - According to the results of the condition monitoring, specific maintenance tasks will be performed on the equipment.
- It is also possible to use vibration data in failure investigations, due to the detailed data that is provided.
- By using the data correctly, it is possible to identify the root cause of an incident, or to give a clear direction to the root cause.

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What is the Problem?

- In the case of failure analysis where rotating equipment is involved, the same technique (used for monitoring) is used to conduct the analysis.

- There is a difference between Condition Monitoring and Forensic Vibration Analysis (FVA).

- It should also be used and applied differently.

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The Answer to the Problem

- The VARCA Model (Vibration Analysis in Root Cause Analysis) is the model of a specific process to conduct the correct forensic vibration analysis.

- It focus on the detail of Vibration Analysis.

- Make also provision for other forensic measurements and analysis.

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The Investigation Process

- Input – Event that happen
- Failures
  - Chain of critical events
  - Incident
- Know How
  - Data gathering
- Physical Investigation
  - Different analysis and results
- Formal Process
  - Root Cause Analysis
- Outcome
  - Different root causes

Chain and Sequence of Events

| Inputs | Failures | Know How | Physical Investigations | Formal Process | Outcome |
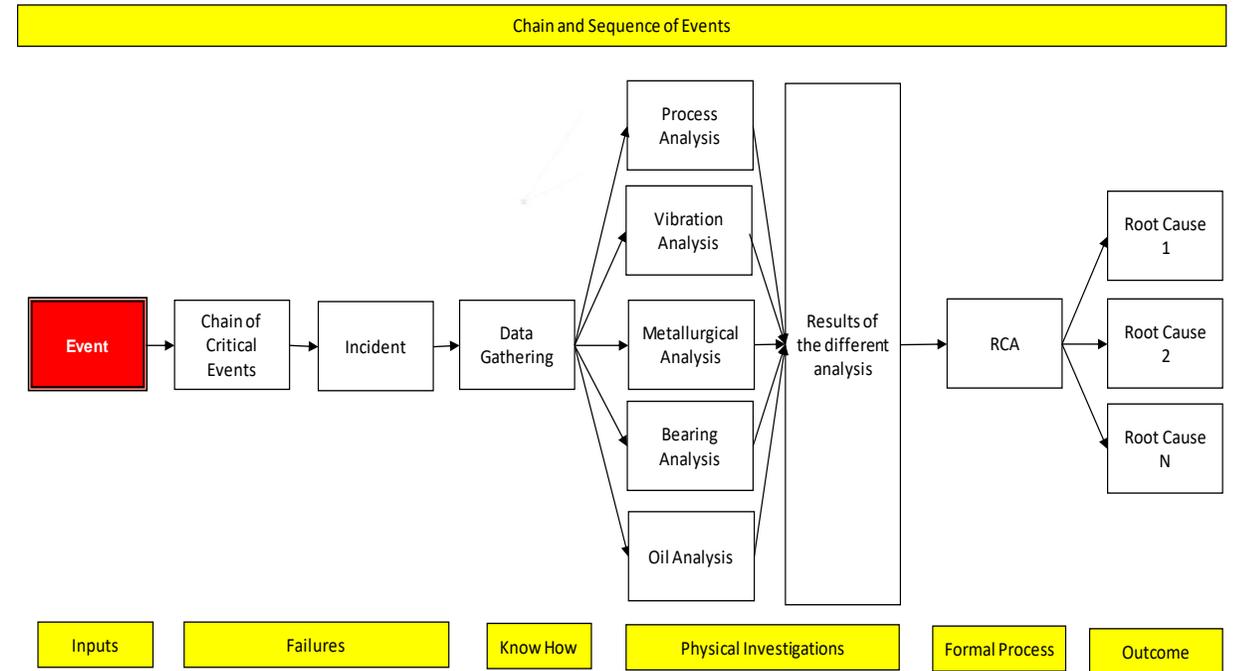
Vibration Analysis

- The best known type of vibration analysis is probably the Spectrum and Time Waveform.

- Figure also indicates the problems or defects that the vibration analysis will be able to identify.

- Different machine conditions are the most identified.

- This can again be classified in further detail.
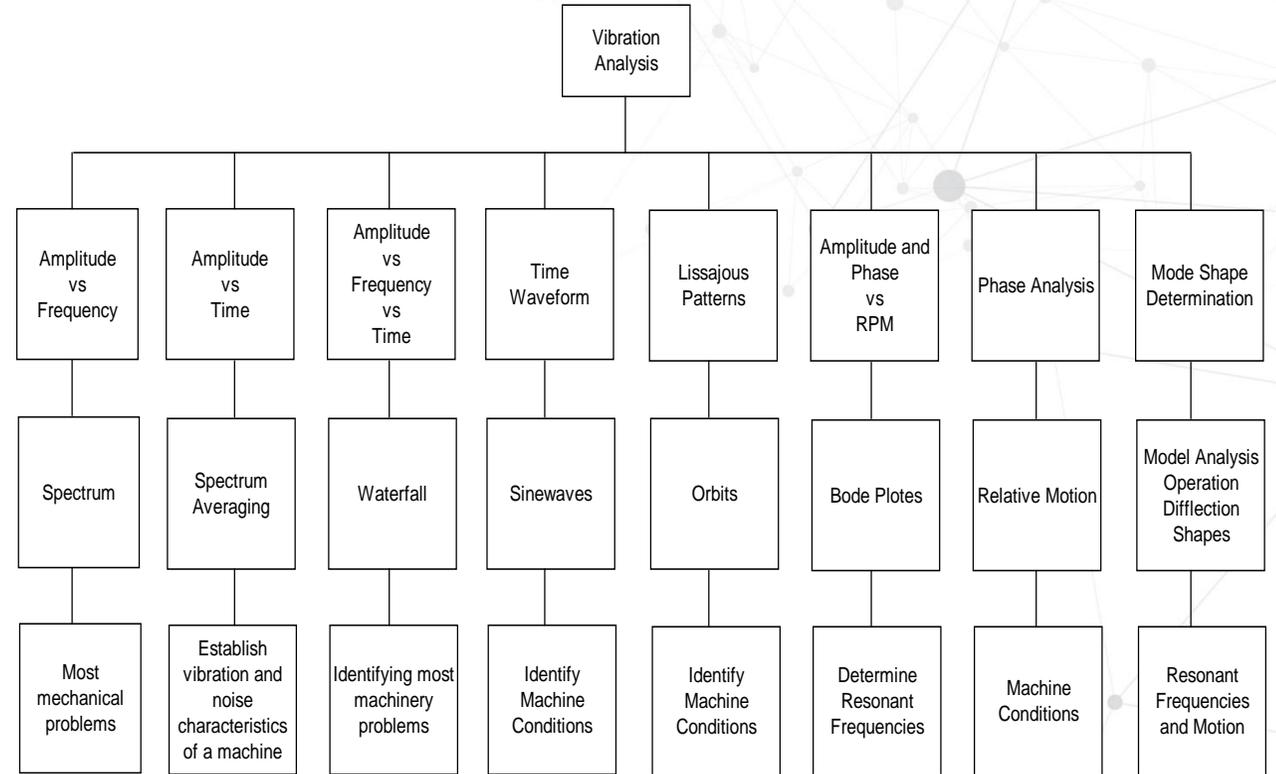
VARCA Model

- Results of the Model
  - Root cause or root causes of the incident.
    - The vibration data will give a clear indication of the physical condition of the piece of equipment.
    - It will also give an indication of the current defects present in the piece of equipment.
    - The use of a cause map at this stage of the investigation may provide the root cause or root causes of the incident.
  - Direction to the root cause.
    - If the process does not give an indication to the root cause or root causes of the incident, it will give a "direction" for further investigation, by means of a formal RCA.

- The Model consist of seven steps (indicated in red). Every step do have some actions (indicated in green).
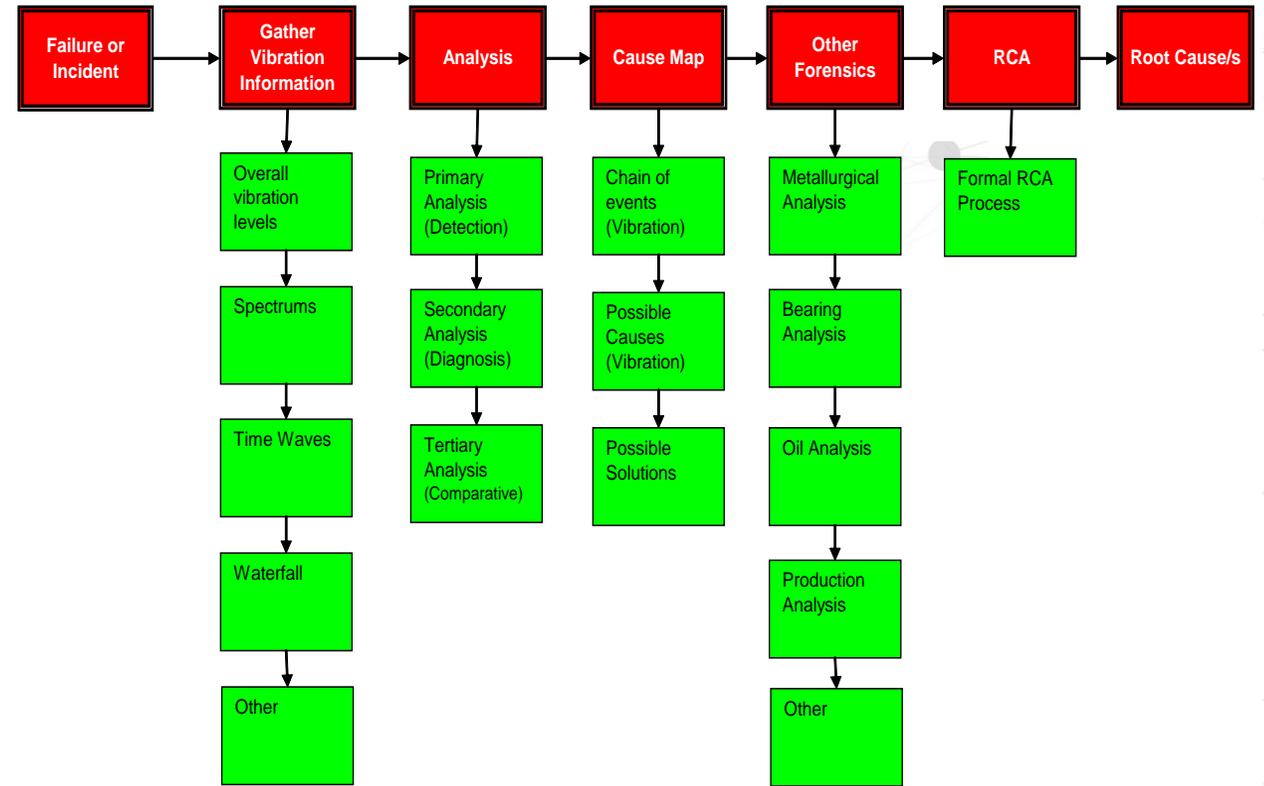
VARCA Model

Step 1: Failure or Incident

- Refers to the potential failure that may be a risk for the equipment or the functional failure that forced the equipment to a standstill.

Step 2: Vibration Information

- The mentioned information is gathered from the current vibration monitoring system.
- The data will include overall vibration data, spectrum data, time wave data, waterfall plots etc.

Step 3: Analysis

- The Model make provision for three levels of analysis.

Diagram (flowchart):

Failure or Incident → Gather Vibration Information → Analysis → Cause Map → Other Forensics → RCA → Root Cause/s

- Gather Vibration Information: Overall vibration levels → Spectrums → Time Waves → Waterfall → Other
- Analysis: Primary Analysis (Detection) → Secondary Analysis (Diagnosis) → Tertiary Analysis (Comparative)
- Cause Map: Chain of events (Vibration) → Possible Causes (Vibration) → Possible Solutions
- Other Forensics: Metallurgical Analysis → Bearing Analysis → Oil Analysis → Production Analysis → Other
- RCA: Formal RCA Process

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VARCA Model

Step 4: Other Forensics

- This relates to other investigations on the same incident.
  - Oil analysis and bearing analysis are examples of forensics. Both these types of analysis is very relevant in the cause of rotating equipment like pumps. These results can also give valuable information for the implementation of alarm levels and trips.

Step 5: Formal RCA

- Refers to the formal RCA session where a formal process is followed to determine the specific reason or reasons (or root causes) of the incident.

- This process will include all forensic data and investigative results.

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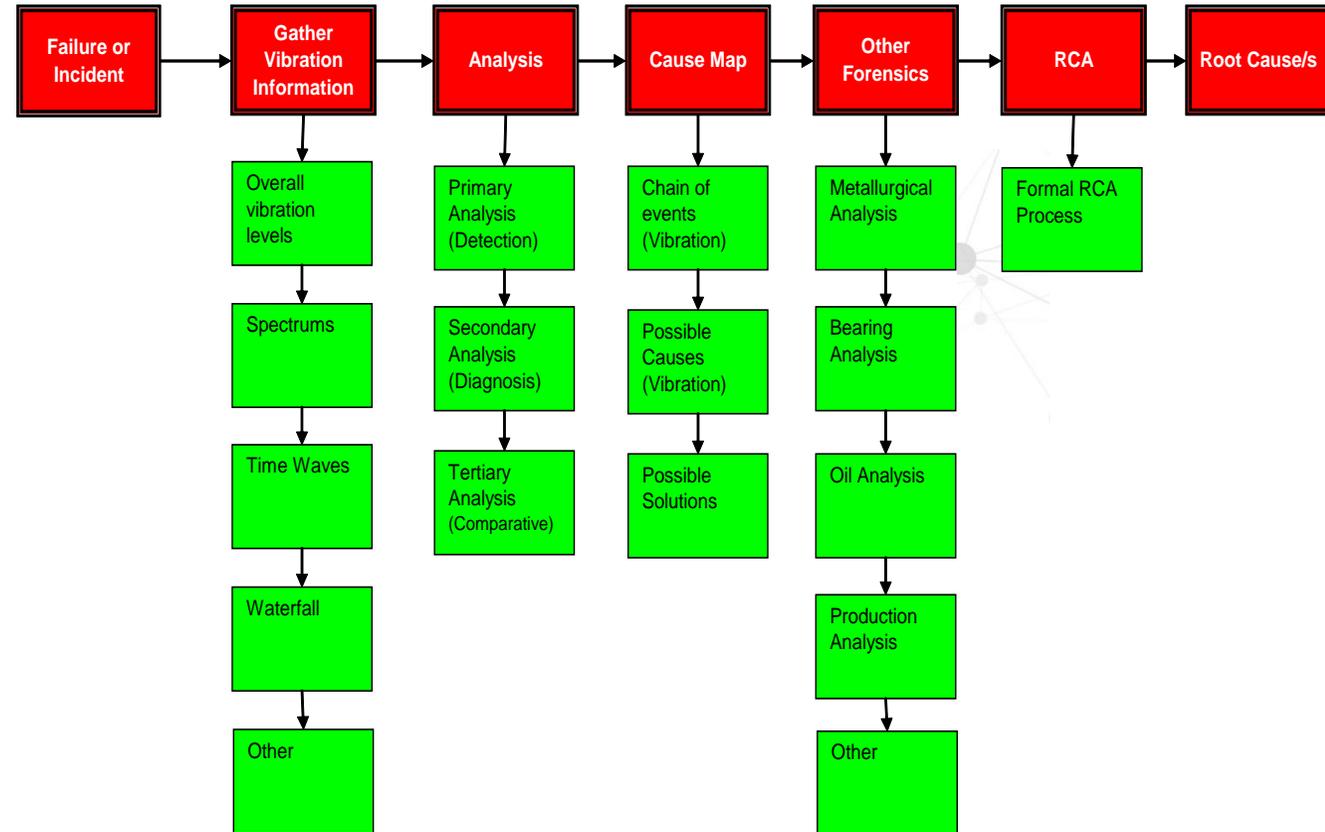
VARCA Model: Levels of Analysis

Primary Analysis (Detection)

- The purpose of normal vibration analysis is to determine the physical condition of the equipment at the time of vibration sampling and is based on the last measurement and time of the last measurement.

- The primary analysis is normal vibration analysis.
  - This is the normal way of defect detection.

Secondary Analysis (Diagnosis)

- Detailed analysis where the vibration spectrums and time waves are used to search for any signs of defects.

- The detailed analysis include techniques like Peak Trending, Profiling and Ratio Analysis.

- The secondary analysis is to diagnose what is wrong.

Tertiary Analysis (Comparative)

- Identifies the common factors in the equipment and compares it to each other.

- This is essential for the identification of problematic peaks and it may also give information were no measurements were taken.
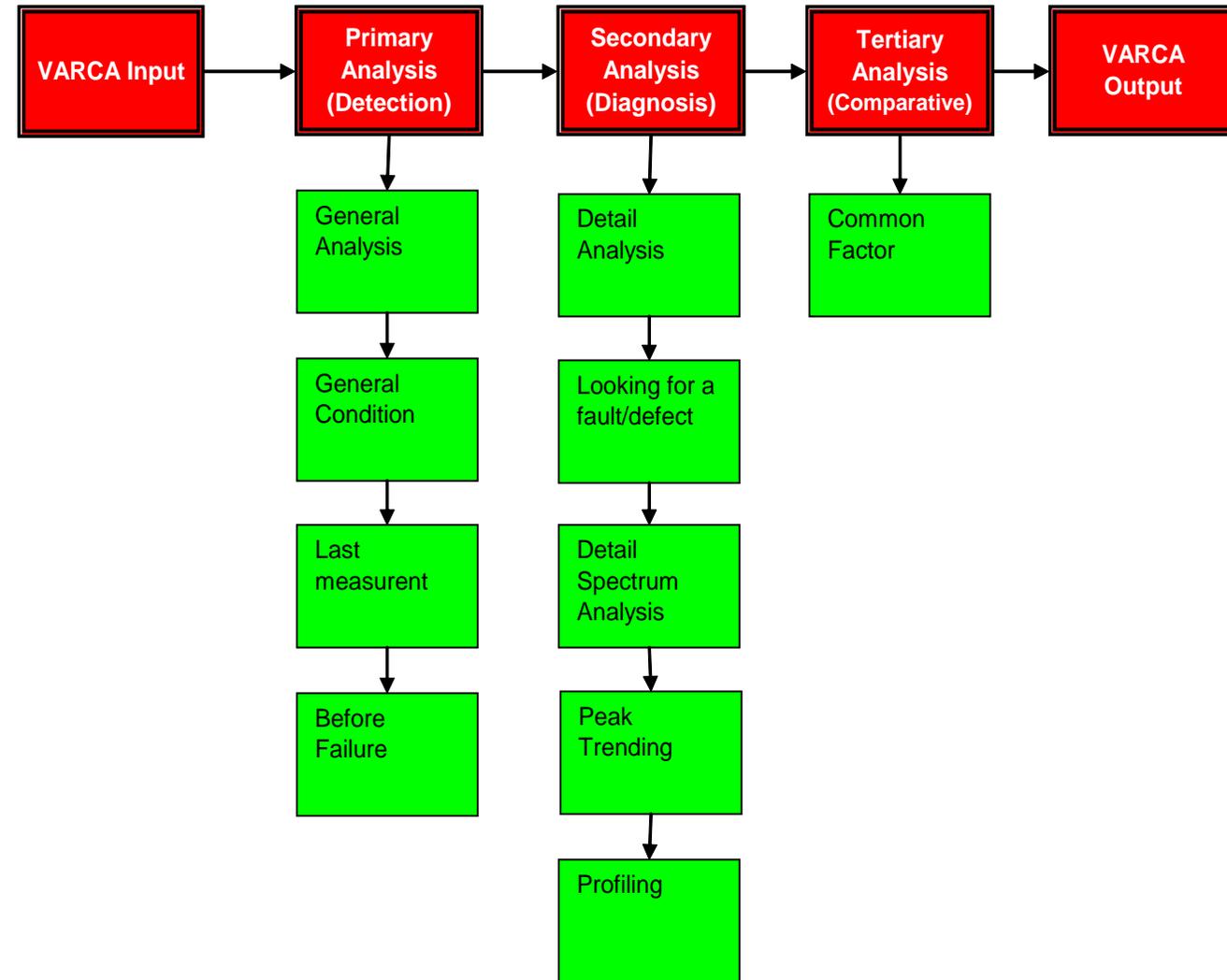
Cause Maps

- When conducting RCA's there is normally some sort of a logic tree, also known as a cause map.
- All known methods of conducting RCA's do have one thing in common: the cause and effect relationship.
- This is the fact that makes it possible to identify root causes.
- The use of a cause map means that data is collected and put into a logical format [6].
- A cause map will also "explain" the chain of critical events [4].
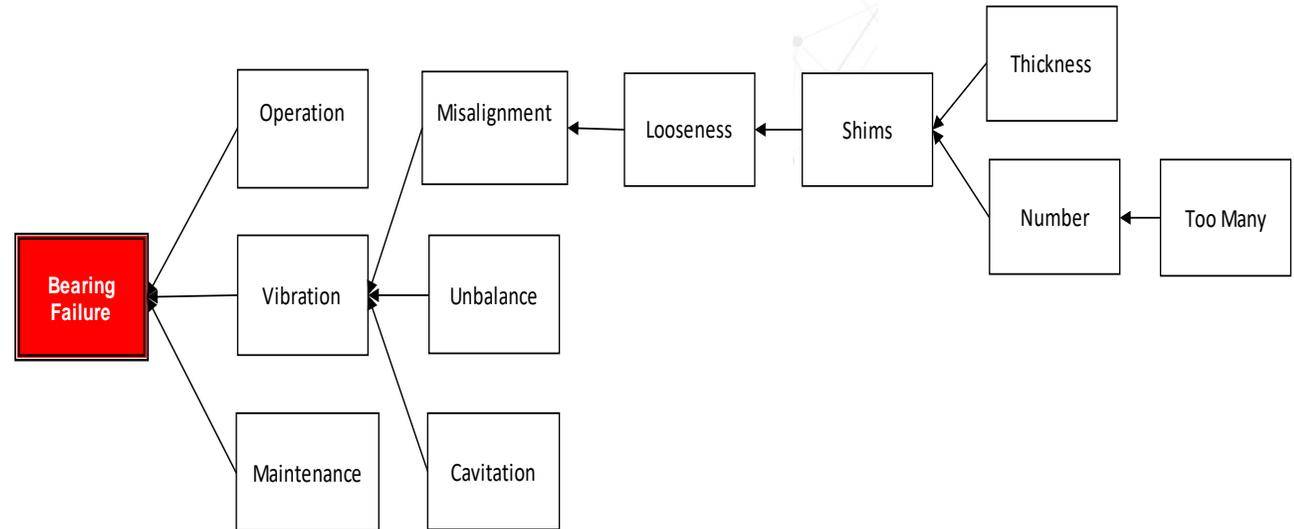
Lessons Learned

The lesson learned is from several case studies, some of them described in the original script

- It is important to have all the measurements of a system. If only certain measurement is available, it will be difficult to identify some defects.

- Normal vibration analysis, even when using spectrums, is not sufficient. Special techniques like peak trending, spectrum profiling and ratio analysis is necessary.

- In the case of normal condition monitoring, alarm levels is important. In the case of failure analysis profiles and ratios are more important. Very low vibration levels can already indicates a coming failure or defect.

- Detail vibration analysis will result in one of the following scenarios:
  - The root cause or root causes of the incident.
  - The results of the vibration analysis give direction to the root cause or root causes.
  - Combination of the two

- The trending of peaks may reveal some history of the equipment.

- Each analysis is an RCA on its own. It should also be treated as an RCA.

- Human intervention is still important with this type of failure analysis. Even with the use of expert systems, human intervention is necessary.

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Conclusion

- The normal way of vibration monitoring and the analysis associated with it will identify general defects like unbalance, misalignment, looseness etc.

- Vibration analysis can be a very efficient and effective tool to use for root cause analysis, if it is used in a specific way.

- Normal vibration analysis and the presented information from the vibration software program don't provide information for a detailed failure analysis or an RCA.

- The vibration information from the software can be used in special techniques to provide much better information regarding equipment failures.

- The outcome of such a vibration related investigation or failure analysis can be a valuable input to a formal RCA or Condition Based Maintenance (CBM) strategies

Advantages and Disadvantages

- Advantage
  - Detail vibration analysis may also identify hidden defects.
  - The VARCA Model give structure and direction to a vibration related analysis and investigation.
  - Vibration analysis will identify the dominant frequencies related to certain defects.
  - A detail vibration analysis can identify the root causes of an incident or it can give direction to the root causes of an incident.

- Disadvantages
  - The process of using vibration analysis for incident investigation is very time consuming. Normally not enough time is allowed for such an analysis.
  - All possible data should be used. This requires a large number of physical measurements.

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Technologies in the VARCA Model

- Why vibration data.
    - Vibration data contains detail information regarding the current condition of the specific equipment.
    - Vibration data can be manipulated to look at specific defects.
    - Vibration data do have a specific signature that is also related to specific defects.
    - Vibration data do have specific frequencies that is related to specific events and/or incidents.
    - Vibration data can be related to a specific time.
    - Vibration data can be stored for several years and still be used for data analysis.
    - Vibration data is digital, making it possible for digital data analysis.
    - There are different levels of vibration analysis, depending on the prescribed application.
- Other Forensic
    - This is for completeness of the RCA process
    - Other technologies may support the results of the outcome of the vibration analysis.
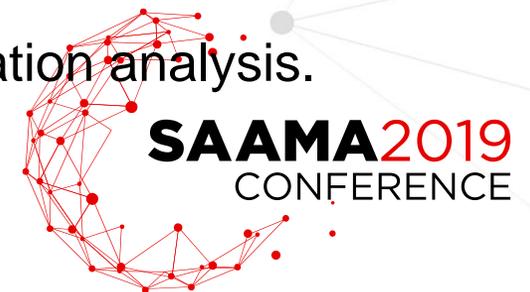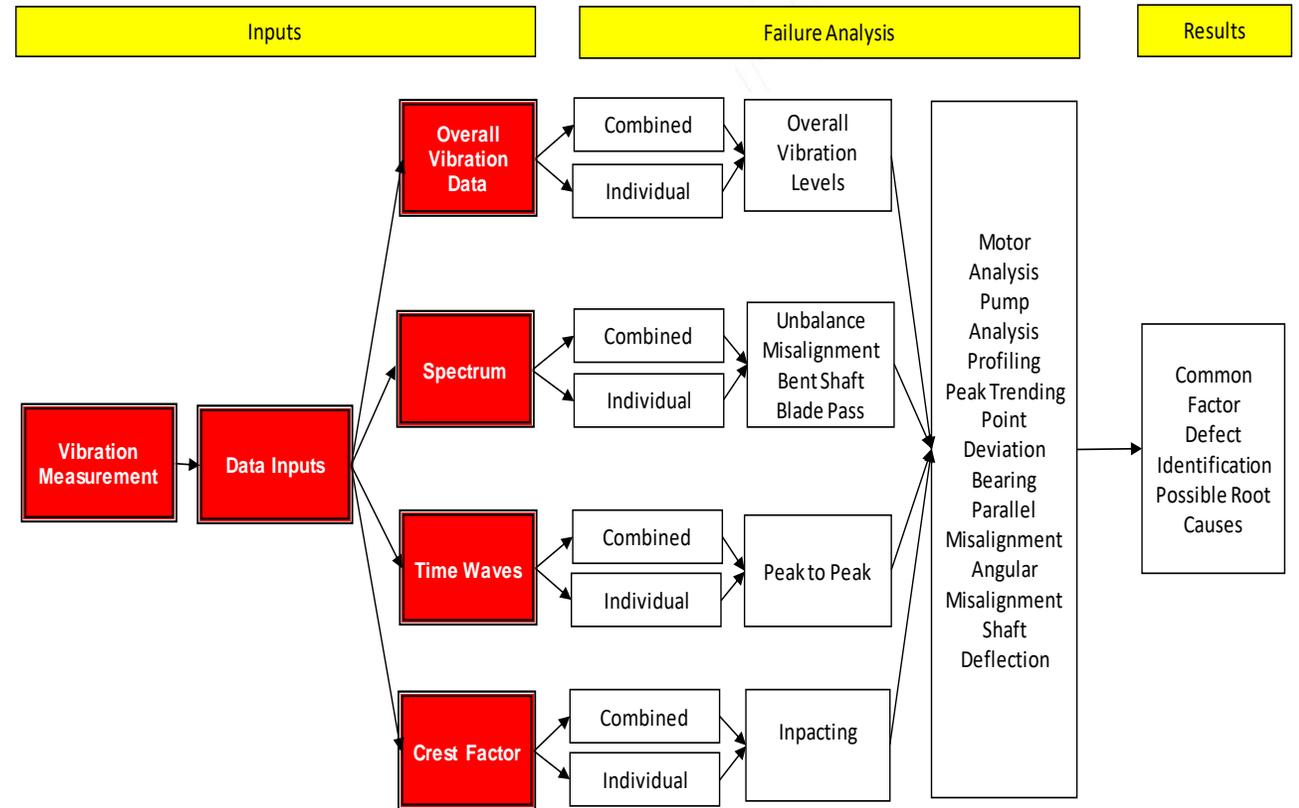
Prolizer AM

- Moubry mentioned in his book the following:
  - "The role of expert systems in vibration analysis is rapidly coming to age".
- This is true.
  - During recent years expert system became much more prominent.
  - Some of these systems even operate remotely.

  (RCM 2 – John Moubry)

Prolizer AM

- Prolizer AM is developed as an expert system and goes hand in hand with the VARCA Model.

- The system will perform most of it actions according to the VARCA Model
  - Provide the information regarding the secondary and tertiary analysis of the model.

- More features of Prolizer:
  - It will put measurements in three directions (horizontal, vertical and axial) on one graph, for comparative reasons [4].

- It also make use of mathematics to do some of the other detailed analysis.

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Thank You

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