



# COMPREHENSIVE DATA COLLECTION FOR ROOT CAUSE FAILURE ANALYSIS IN OIL AND GAS INDUSTRIES

Umair Ahmed, Hilmi Hussin and Masdi Muhammad

Department of Mechanical Engineering, Universiti Teknologi Petronas, Bandar Seri Iskandar, Perak, Malaysia

E-Mail: [umair\\_sfc84@hotmail.com](mailto:umair_sfc84@hotmail.com)

## ABSTRACT

Equipment failure that affects plant operations is a major issue in industries. When equipment fails it causes immense loss to industries in terms of resources and time, increased maintenance cost and equipment stoppage. The priority of reliability/maintenance team is to overcome these failures as soon as possible to avoid further losses. Root cause failure analysis (RCFA) process is used to identify and stop recurrence of these failures and data collection is most significant part of this process. Comprehensive and relevant failure data is crucial to identify and understand the root causes of a failure accurately. Unavailability of correct, adequate and sufficient data can lead to undesired results of RCFA. The purpose of this study is to propose a comprehensive approach of data collection for equipment failure in oil & gas/process industries for successful identification and elimination of root causes. Furthermore, this study has also proposed a template for comprehensive data collection that can be used to gather sufficient data for equipment failure investigation.

**Keywords:** root cause failure analysis, RCFA, data collection, failure, recurrence, interview.

## INTRODUCTION

Root cause failure analysis (RCFA) is part of reliability program and the objectives of RCFA process are to identify and eliminate root causes of the failure to avoid recurrence of similar failure in future. It is a structured approach of failure analysis and based on four main phases including failure reporting and investigation, data collection, root cause identification and solution. Each phase of RCFA is critical and carried out carefully by failure investigation team to identify root causes of failure.

First phase of RCFA involved failure reporting and investigation regarding incident which includes details of failure time, place, nature of failure and failure impacts on organization, second phase of RCFA is based on data collection and analysis related to the failure, in third phase immediate, contributory and root causes of failure are identified based on collected and analysed data and final is solution phase that concludes recommendation to the failure. The critical part of RCFA is the collection of failure data. Data collection is the second and important phase of RCFA process. Acquiring, gathering or collecting the failure data regarding the incident is a key for getting the valuable results of RCFA investigation. Accurate and relevant data is the primary source for identifying and eliminating causes of the failure of any part, equipment, machinery, process, system or plant. It is important to collect data immediately after occurrence of failure for accurate information and evidence collection before the data is lost.

Comprehensive data is needed for conducting the effective and successful RCFA for equipment failure in oil & gas/process industries. Affonso [1] insisted to avoid making the conclusion without proper analysis of data and evidence collection. Data for any failure could include the previous failure reports, maintenance and operations data, process data, drawings, design, physical evidences, failed part of equipment and any other necessary information

related to the particular failure. It is not necessary that every failure required comprehensive data but sometimes data could be missing and gathered data is not sufficient to identify actual causes of the failure. So it is necessary that collected data must be accurate and relevant. Failure can't be investigated properly without availability of correct and related data. Usually data collection consumes more time as compare to other steps of RCFA process so data must be precise and meaningful for identifying the exact causes of failure. Information collected from gathered data is significant for making recommendation and conclusions.

The objective of this paper is to propose a comprehensive data collection approach for failure investigation. This study will identify important data elements and categorize it to have comprehensive data for conducting RCFA. A data collection template will also be proposed based on identified categories that will guide investigator to collect maximum data for equipment failure in oil and gas industries.

## LITERATURE REVIEW

Various criteria and approaches are used for collecting equipment failure data in RCFA process. Heuvel, *et al.* [2] and Cassidy [3] discussed the different P elements of data can be collected for analyzing and identifying the root causes of the failure. Further US department of energy, DoE [4] provided the guidelines of data collection for conducting effective RCFA. These guidelines discussed the data collection of failure condition, environmental factors, evidence collection, conducting interviews, reviewing records and drawing reviews of the failed part or equipment. Perez [5] and Tahan, *et al.* [6] discussed the data collection of rotating equipment failure similarly Pinna, *et al.* [7] discussed the data collection for fusion machine component failure. Sutton [8] described the necessary data collection elements for equipment failure in process industry. Moreover Mobley [9] and Martinez [10] also provided instructions



for collecting the data for equipment failure. Likewise data collection for machinery failures is suggested by Affonso [1] and for forced draft fan failure in petrochemical industry discussed by Valyakala, *et al.* [11]. Details of various data collection found in literature have been summarized and shown in Table-1.

**Table-1.** Types of data collection identified based on literature review.

S. No.	Equipment/ Failure type	Types of data collection
1	Guidelines for RCFA data collection US department of energy (DOE) DoE [4]	Physical evidence collection (photographs, failed parts, failed equipment, etc). Conducting interviews (involved person, witness, experts and others) Reviewing records (maintenance records, equipment history records, operating logs, etc) Drawings review (technical, parts, equipment) Failure conditions (before, during and after occurrence). Environmental factors (temperature, wind, fire)
2	Rotating equipment failure data Perez [5]	Failure report Interview Equipment process data Evidences (photographs/ parts) Non-routine events
3	Fusion machine component failure Pinna, <i>et al.</i> [7]	Operation records, previous incident reports, maintenance records, plant personnel interview, failed components, operating life, design documents, drawings, etc.
4	Chemical process failure data collection Cassidy [3]	<b>People:</b> Witness statement, <b>Physical:</b> parts, equipment, raw material, <b>Position:</b> place of failure, equipment, or components. <b>Paper:</b> Procedure, operating log, test & maintenance records
5	Process industry RCA data collection Sutton [8]	Written statement (Initial failure report). Interviews (involved people, witness). Documents (previous failure reports, maintenance records). Field Information (location, equipment, parts). Tests, lab analysis
6	Incident investigation process Heuvel, <i>et al.</i> [2]	<b>People:</b> interviews with involved person and witnesses <b>Physical:</b> parts, chemical samples, raw material <b>Paper or Electronic:</b> Policies,

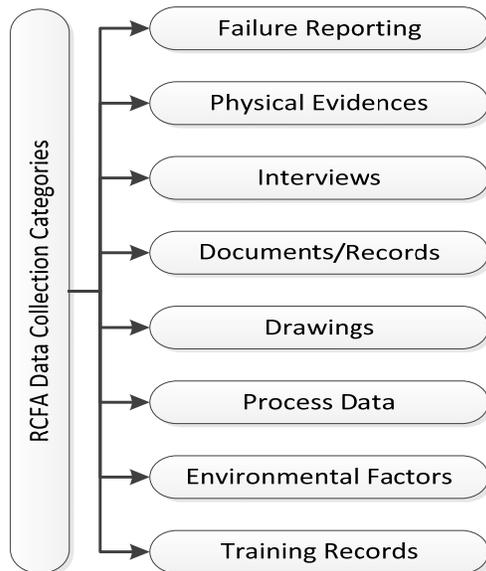
		procedures, drawings, sketches, operational data, <b>Position:</b> location of people and physical data (valves, switch positions, tank levels)
7	Data collection for equipment failure/ damage Mobley [9]	Interviews with involved person, manager or superior, witness, technical experts and others. Physical evidences (documents, photographs, sketches, instrumentation and control settings, electronic reports, videos) Information (Standard operating procedures (SOP), operating and process data, maintenance records, log books, work orders. Drawings, diagrams, technical specification, vendor manuals. Broken hardware (ruptured gasket, burned leads, blown fuses, failed bearings) Environmental conditions (temperature, wind, rain, dust, etc.) Similar incident report (previous failure reports)
8	Equipment failure Martinez [10]	Identify what happened? Review equipment failure history, previous records Interviews with operators, mechanics, shift personnel, anyone who has knowledge of equipment Check plant's system that tracks equipment failure Equipment inspection while disassembling Photographs Documents
9	Machinery Failure Data Affonso [1]	Maintenance records (previous failure, vibration analysis) Operation records (temperature, pressure, flow, fluid composition, Vibration data Manufacturing reports (inspection report, chemical analysis, manufacturing process, performance testing) Design data (dimensions, loads, stresses, natural frequency) Photographs Samples
10	Forced draft fan failure in petrochemical industry Valyakala, <i>et al.</i> [11]	Maintenance records Inspection records Previous records regarding similar failure.



As shown in Table-1, multiple types of data are being collected for different equipment and process failures in oil and gas/process industries. These data collection depends upon the nature of failure event and equipment involved. While searching for the root cause of the failure, it is essential to recognize various key data required for analysis.

### CATEGORIES OF FAILURE DATA COLLECTION

It has been identified from literature that list of data is being collected for RCFA investigation. These data has been analyzed and categorized into different groups. Generally, these data can be classified into the following categories; 1) Failure reporting, 2) Physical evidences, 3) Interviews, 4) Documents/records, 5) Drawings, 6) Process data, 7) Environmental factors, 8) Training records as shown in Figure-1. Each provided category has multiple elements of data that could be needed for conducting exhaustive RCFA investigation.



**Figure-1.** Categories of data collection for RCFA.

The detailed description of these categories is given in Table-2. A template based on these categories has been proposed and presented in Figure 2. In this template, various sources of data for each category have been listed to assist and guide investigator on gathering comprehensive and relevant information. Nevertheless, the investigator can opt not to collect all proposed items based on his judgment, expertise, experience and nature of the failure.

**Table-2.** Description of RCFA data collection categories.

S. No.	Categories	Descriptions
1	Failure Reporting	Failure report is the first report written and documented after the failure/ incident

		occurrence. Report consist detail of the failure including what happened? When did it happen? Where did it happen? Description of the failure, time, date, location, place, area, site, plant or facility and any other necessary detail.
2	Physical Evidences	Collection of physical data like failed equipment, failed parts, photographs, video, samples, material, tests, lab analysis and any other important data.
3	Interviews	Interviews from involved persons, witness, managers, superiors, experts, management, technicians, consultants and other people for detailed data collection regarding particular failure/ incident as necessary.
4	Documents/ Records	Documents and records like previous failure reports, similar failure, maintenance records, operating logs, standard operating procedure (SOP), inspection records, equipment manual, equipment history, safety manual, technical specifications, vendors manual/data and other relevant document or records .
5	Drawings	Review of drawings like technical, equipment, parts, plan layouts, process flow charts/diagrams, system network architecture, schematic diagrams and other necessary drawings.
6	Process data	Collection of process data like temperature, pressure, vibration, flow, voltage, event logs, PI trending and other data at the time failure/ incident occurrence.
7	Environmental Factors	Environmental factors at the time of failure/ incident like temperature, humidity, wind, rain, fire or any other environmental and natural condition.
8	Training records	Review of training records for operating equipment, safety trainings, maintenance skills and others to see whether the trainings are provided or not.



## INTERVIEWS

Among all categories of data collection, interview is identified as one of the most important part of investigation [12]. It is an essential part of gathering information to establish facts based on the incident [9, 13]. Before going to detailed data collection, initial interviews are necessary for understanding nature of the failure. Interviews need to be conducted from different people available at the time of failure. Plant personals both involved and those available at the time of incident (witnesses) must be interviewed for detailed data and information collection regarding the failure. Interviews can be conducted in different ways as Mobley [9] categorized interviews into following three types, 1) Individual interviews, 2) Two-on-one interviews, 3) Group interviews, details of each one can be seen in [9]. Any of these methods can be used while conducting the interviews. Sutton [8] pointed out that the persons required to be interviewed fall into three categories; 1) Directly or indirectly involved in the failure or incident, 2) Witness of the incident, and 3) Having knowledge regarding the incident like workers, compliance and safety personals, managers, supervisors, engineers, technicians, consultant and others depends upon circle of the failure.

Interviews should not be like police investigation to punish or blaming someone, it must be for the sake of investigation to control the recurrence of the similar failures in future. Before starting interview, interviewees must be taken into confidence that they are part of investigation and information collected will be used for controlling the future failure occurrence not to punish anyone [8, 9]. Investigator must be careful while conducting interview to extract the valuable information of the incident. Some important points should be kept in mind by interviewer before conducting interviews are:

- Let the witness feel relax and easy, avoid interruption during interview, don't ask many questions quickly, don't threaten the witness, explain the purpose of investigation and develop confidence not to punish.
- Respect witness and others involved in interview, ask open ended questions and don't blame anyone[14].
- After the incident, immediately interview the witness before evidences lost, concentrate on fact finding rather than fault finding [13].

- Provide sufficient time to witness to talk/listen, confirm statement of witness by asking again, note down the important things or ask someone to note.
- Never propose conclusions earlier until all investigation is done.
- Positively end the interview, don't promise to keep interview confidential and keep in contact all the persons interviewed for further investigation.

During the interview, it is better to ask flexible questions which should not be answered simply by yes or no. Interview questions may differ from failure to failure. Some examples of interview questions are 1) Where were you at the time of incident? 2) What did you see? 3) What were you doing? 4) What were the environmental conditions at the time of failure (temp, wind, fire, rain)? 5) As per your opinion, what cause the failure? 6) What are the preventions for future failure? Asking more questions regarding the failure will bring investigation in more depth and clear understanding about the incident [13-15].

## RESULTS and CONCLUSIONS

A comprehensive approach of RCFA data collection has been presented in this study. This study has identified and categorized failure data into 8 different categories required for conducting RCFA for equipment failure in oil & gas/process industries. Each category has a list of data that can be collected to identify and analyze the causes of the failure thoroughly. On the basis of this study a template can be seen in Figure-2 is also proposed to assist and guide investigator to collect comprehensive data for equipment failure. However, failure investigators can opt not to collect all proposed data included in template based on their experience, expertise, and nature of failure. Information extracted by analyzing the collected data can be used for making the effective recommendations to identify exact root causes of the failure instead of blind guesses. Furthermore, interview is identified as one of the key element of data collection to extract sensible and critical information of the failure.



Root Cause Failure Analysis (RCFA) Data Collection Template for Plant Equipment Failure							
1: Failure Reporting	2: Physical Evidences	3: Interviews	4: Documents/ Records	5: Drawings	6: Process Data	7: Environmental Factors	8: Training record
<input type="checkbox"/> Initial failure report <input type="checkbox"/> Previous RCFA reports <input type="checkbox"/> Others please specify	<input type="checkbox"/> Equipment location <input type="checkbox"/> Photographs/Videos <input type="checkbox"/> Failed parts <input type="checkbox"/> Samples <input type="checkbox"/> Material <input type="checkbox"/> Tests <input type="checkbox"/> Lab analysis <input type="checkbox"/> Non-Routine events <input type="checkbox"/> Others please specify	<input type="checkbox"/> Operators <input type="checkbox"/> Witness <input type="checkbox"/> Manager/ Superior <input type="checkbox"/> Experts <input type="checkbox"/> Management <input type="checkbox"/> Technicians <input type="checkbox"/> Consultant <input type="checkbox"/> Others please specify	<input type="checkbox"/> Previous failure reports <input type="checkbox"/> Maintenance records <input type="checkbox"/> Operating logs <input type="checkbox"/> Standard operating <input type="checkbox"/> Vendors manual <input type="checkbox"/> Equipment manual <input type="checkbox"/> Equipment history <input type="checkbox"/> Safety manual <input type="checkbox"/> Technical specification <input type="checkbox"/> Inspection records <input type="checkbox"/> Others please specify	<input type="checkbox"/> Plan layout <input type="checkbox"/> Process flow charts/diagrams <input type="checkbox"/> Equipment drawings <input type="checkbox"/> Parts drawings <input type="checkbox"/> System network architecture <input type="checkbox"/> Schematic diagrams <input type="checkbox"/> Others please specify	<input type="checkbox"/> Temperature <input type="checkbox"/> Pressure <input type="checkbox"/> Vibration <input type="checkbox"/> Flow <input type="checkbox"/> Voltage <input type="checkbox"/> Event log <input type="checkbox"/> PI trending <input type="checkbox"/> Others please specify	<input type="checkbox"/> Temperature <input type="checkbox"/> Wind <input type="checkbox"/> Rain <input type="checkbox"/> Humidity <input type="checkbox"/> Fire <input type="checkbox"/> Pressure <input type="checkbox"/> Others please specify	<input type="checkbox"/> Operating <input type="checkbox"/> Safety <input type="checkbox"/> Maintenance <input type="checkbox"/> Others please specify

Figure-2. RCFA data collection template for equipment failure [1-5, 7-11]

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