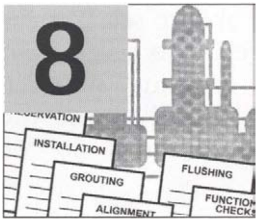


Site reliability assessment

- Site reliability audit form
- Reduction of data
- Identifying targets for improvement

Site reliability audit form

Included at the end of this chapter is a site reliability audit form that I have used successfully throughout my career to obtain input information for reliability assessment work. Readers are encouraged to use the information contained in this document as a guideline when obtaining field input information.

When obtaining input information, it is most important to understand that all input data must be checked for accuracy. If possible, only use recorded DCS trend data and if input information is obtained from site personnel, confirm the accuracy of this information. Accurate facts form the foundation for any site reliability improvement program and will assure that management support will be maintained throughout the program.

Reduction of data

In order to be most effective, the input reliability data from the site audit form must be separated, plotted, inputted into computer analysis, etc. In other words, it must be reduced. In this chapter we will present methods and relationships that have proven to be the most effective ways of analyzing and presenting reliability data. Each approach will first be introduced, defined and an example given. Readers are encouraged to use the information contained in this form to gather site information for reliability assessment work.

At the conclusion of this chapter, the reader will be able to select items that require reliability improvement based on the reliability assessment methods included in this chapter. This information, combined with the information contained in the site reliability audits will form the foundation for reliability improvement recommendations to be presented to management.

Life cycle graph

A life cycle graph, containing years from start-up to the present, plotted on the horizontal (x) axis can be very valuable in determining trends in reliability resulting from operations practices, maintenance practices, condition monitoring parameters, preventive and predictive maintenance procedures. A typical life cycle graph is presented in Figure 8.1 with significant procedural changes noted. Once this graph is developed, any chosen parameter can be plotted on the vertical (y) axis to show the influence of site practices on reliability. Typical (y) axis parameters are:

- Availability
- MTBF
- MTTR
- Cost of unreliability

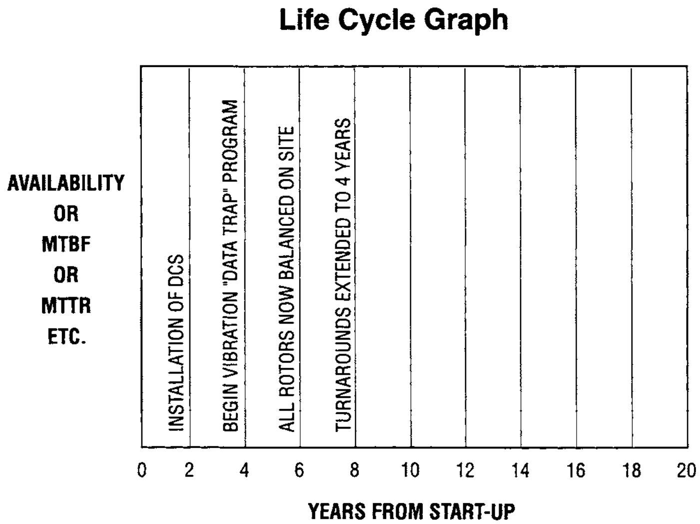


Figure 8.1 Life cycle graph

At the end of this chapter is a typical life cycle graph. Use this graph by noting the significant site changes obtained in sections 1, 3, 4, 5 and 6 of the site reliability audit form. Note these changes by drawing a vertical line and labeling. The vertical line should denote the year the practice started. If the practice was discontinued at a later time, please also note.

Preparation of Pareto Charts

Pareto charts present a clear picture of the major problem areas that reduce reliability. The representation is two dimensional and can plot any number of different parameters. A typical use of pareto charts would be to prepare the following charts from the reliability input data.

A. Number of major replacement parts for your reliability problem.

B. Number of forced outages for each major port.

C. Number of replacement *and* forced outage components for your reliability problem.

An example of a pareto chart for a gas turbine driven compressor unit is shown in Figure 8.2. This could be an example of item C.

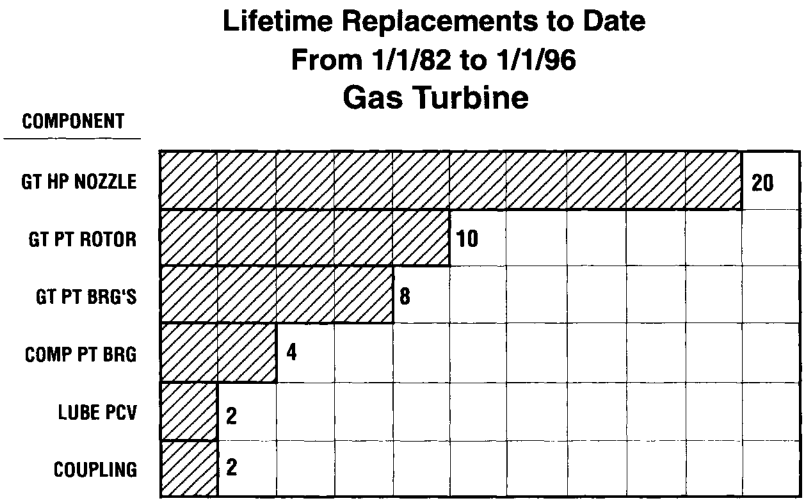


Figure 8.2 A pareto chart

Note the following characteristics:

- Parameters are noted on y axis (could be 'x' axis if required)
- Highest distribution is plotted first

- 'X' scale is direct

Included at the end of this chapter is a pareto chart format for use in assessing replacement components and forced outages.

Determining and measuring availability

Once information regarding failures and repair times is gathered and analyzed, MTBF (mean time between failure), failure rate, MTTR (mean time to repair) and availability can be determined.

MTBF

Mean time between failure is determined by dividing the total operating time for the period to be analyzed by the number of failures in that time period. MTBF can be determined for a unit, a specific piece of equipment or a component. The relationship is noted in Figure 8.3.

MTBF

Mean time between failure

$$\text{MTBF} = \frac{\text{Total operating hours}}{\text{Number of failures}}$$

Figure 8.3 MTBF

I have found that MTBF is most effectively utilized by first assessing data on a machine basis and then analyzed on a component basis (journal bearing, thrust bearing, seal etc) for the major machines ('bad actors') that fail. One should also consider separating MTBFs, machine or component based, into application categories if there is a significant difference between operating parameters (temperature, pressure and/or speed).

As an example, determine the MTBF for an LNG circulating pump given the following data:

1. Operating period 1990 – 1992
2. Operating data:

Year	*Operating hours*	*Failures*
1990	8600	2
1991	8000	4
1992	8500	1

$$\text{MTBF} = \frac{\text{25100 Hours}}{\text{7 Failures}}$$

MTBF = 3586 hours

Failure rate

Failure rate is the number of failures per machine hour. In other words, it is the reciprocal of MTBF. Figure 8.4 presents failure rate.

Failure rate

The number of failures per machine hour

$$\text{or failure rate} = \frac{1}{\text{MTBF}}$$

Figure 8.4 Failure rate

For the example on page 248, the failure rate for the LNG circulating pump is:

$$\text{F.R.} = \frac{1}{3586} = 2.789 \times 10^{-4} \text{ per hour}$$

MTTR

Mean time to repair is the total time to repair a unit, equipment item or component during a specific time period divided by the number of repairs.

MTTR

Mean time to repair

MTTR = Total number of repair hours for a specific

- Unit
- Equipment item
- Component

Divided by number of repairs

Figure 8.5 MTTR

As an example, determine the MTTR for a gas turbine during a 24 month period as noted below.

Repair	Date	Repair description	Total hrs*
1	1/1/93	Replace H.P.T. nozzles	96
2	4/8/93	Replace fuel nozzles	72
3	7/20/93	Replace No. 1 & 2 bearings	30
4	12/23/93	Replace P.T. rotor and bearings	36
5	5/6/94	Replace H.P.T. nozzles	80
6	11/15/94	Replace compressor (L.P.) rotor, stators and bearings	80

*Includes cool down time

Total maintenance hours = 394
Number of repairs = 6

$$\text{MTTR} = \frac{394 \text{ hours}}{6 \text{ repairs}}$$
=65.67 hours

Availability

Availability is a more effective measurement of reliability since availability is the percentage of time that a unit or equipment item operates compared to the time it is available to operate. Like reliability, it is normally used as a measurement for critical (unspared) equipment. Availability can be directly expressed as a function of time or as a function of MTBF and MTTR as shown in Figure 8.6.

Availability

$$\text{Availability} = \frac{\text{No. of operating hours/year}}{8760 - \text{planned downtimes (T\&I's or turnarounds)}}$$

$$\text{Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

Figure 8.6 Availability

As an example, if the MTBF for the gas turbine in the previous example is 2836 hours, what is this G.T.'s availability?

Given: MTBF = 2836 hours
MTTR = 65.67 hours

$$\text{Availability} = \frac{2836 \text{ hours}}{2836 + 65.67 \text{ hours}}$$

$$= 97.73\%$$

Included at the end of this chapter, is an availability factor worksheet that can be used to determine unit or component MTBF, failure rate, MTTR and availability.

Select the unit with the lowest reliability in your plant over the past two years and plot availability and MTTR for each year since the process unit startup on a life cycle graph.

Identifying targets for improvement

Once the site reliability audit data has been reduced, areas for reliability can be identified. In the previous section, the areas with the lowest availability were identified progressively as shown in Figure 8.7.

Identifying targets for reliability improvement

Train availability
↓
Unit availability
↓
Item availability
↓
Component availability

Figure 8.7 Identifying targets for reliability improvement

Normal component reliability comparison

Once low availability machinery items or components are identified, they must be compared to normal values to determine if a reliability improvement program is warranted. Normal availability data is available from company data bases, data obtained during Industry conferences and from personal experience. A suggested source for comparison is Table 4.3 from Machinery Reliability Assessment by Heinz P. Block and Fred K. Geitner, © 1990 by VanNortrand Reinhold. This table contains 'best' and 'worst' failure rates for a variety of components as well as basic failure modes. At this point, it is suggested that you list the component failure rates for your plant's lowest availability equipment item. Then compare the site actual to the normal failure rates and determine if corrective action is required. A component reliability comparison worksheet is included at the end of this chapter.

Cost of unreliability

At this point, the 'bad actors' or the 'hit list' has been identified and the specific availability measurements quantified. What remains is perhaps the most difficult task. See Figure 8.8.

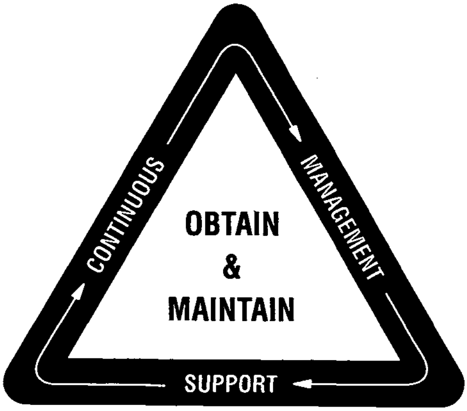


Figure 8.8 The most difficult task

Regardless of how great your salesmanship is, you will not succeed unless your plan is 'cost effective' in management's opinion.

Therefore, a 'cost' must be assessed for each bad actor. We define this cost as the **'cost of unreliability'**.

The cost factors are stated in Figure 8.9.

The cost of unreliability critical rotating equipment (per year)

- Lost product revenue x *days forced outage*
- Maintenance costs
- Replacement part cost
- Labor cost
- Unnecessary turnaround time*

*Assumes process unit start-up is delayed by activity

Figure 8.9 The cost of unreliability critical rotating equipment (per year)

Simply add the costs of unreliability for each component that does not meet the component reliability norms. Once these figures are obtained, the reliability assessment process is complete. We are now equipped with the data to proceed up the reliability pyramid to prepare reliability improvement plans. At this point, use the cost of reliability worksheet, included at the end of this chapter to tabulate the costs of unreliability for the components of your 'bad actor' list.

This completes the chapter on reliability assessment. The next chapter will address the preparation of a site reliability optimization plan.

Site rotating equipment reliability audit

Process unit: ______________________________

Included items: ______________________________

Study team member	Work discipline
1. ______________	______________
2. ______________	______________
3. ______________	______________
4. ______________	______________
5. ______________	______________
6. ______________	______________

It is recommended that the study team consist of the following disciplines as a minimum:

- Reliability
- Operations
- Process engineering
- Maintenance
- Control and instrumentation
- DCS specialist

I. General information

1. Daily revenue loss (local currency)

   A. If critical equipment (unspared) experiences a shutdown

   ____

   B Daily process unit production (tons/day) ______________

2. Contractor data

   A. Engineering contractor ______________

   B. Construction contractor ______________

   C. Start-up date ______________

3. Operations data

   A. Control room modernization

1. Changes and dates of change ____________________

____

____

B. Operator condition monitoring responsibility

Example	Responsibility	Date started
	Overall pump vibration (monthly)	1/1/90
	____________________	__________
	____________________	__________

4. Maintenance data

A. Proactive maintenance

1. Do maintenance personnel become involved with determination of root cause problems? Yes or No

B. Site maintenance

1. Since train start-up, have there been changes concerning the maintenance performed on site. Yes or No

2. If yes, what changes and when.

Example	Dates	Changes
	____________________	__________
	Started to balance on site __________	1/1/94
	____________________	__________
	____________________	__________

C. Hourly cost of maintenance labor ____________________

5. Condition monitoring data

A. Method (I.E. manual vs. 'data trap' vs. D.C.S.)

Example	Method	Years used
	Manual logs	1981–1988
	____________________	__________
	____________________	__________
	____________________	__________

B. Condition monitoring parameters. Please answer if the following parameters are condition monitored (see note)

1. Centrifugal compressor performance parameters (P_1, T_1, P_2, T_2, Flow, Speed, Gas Analysis) Yes No
2. Pump performance parameters (P_1, P_2, S.G., Flow & Speed) Yes No
3. Compressor seal fluid (gas or oil) supply flows (or valve position if oil system) (Gas) Yes No
   (Oil) Yes No
4. Centrifugal pump seal stuffing box pressures and temperatures Yes No
5. Centrifugal compressor balance line ΔP Yes No

Note: In the space provided between items, state item numbers of units where the answer is 'Yes'.

6. Preventive maintenance data

A. Please answer if the following items are changed on a preventive (time interval) basis. If the answer is Yes, please state the time between replacement time.

	Time		
1. Compressor rotors	____	Yes	No
2. Compressor bearings	____	Yes	No
3. Compressor seals	____	Yes	No
4. Compressor labyrinths	____	Yes	No
5. Gas turbine H.P. rotor	____	Yes	No
6. Pump bearings	____	Yes	No
7. Pump seals	____	Yes	No
8. Pump wear rings	____	Yes	No
9. Electrical switches	____	Yes	No
10. Accumulator bladders	____	Yes	No
11. Control valve diaphragms	____	Yes	No
12. Oil filter cartridges	____	Yes	No

B. Please answer if the following items are cleaned on a preventive basis.

	Time		
1. Oil reservoirs	____	Yes	No
2. Cooler tubes	____	Yes	No
3. Control valve pulsation dampeners	____	Yes	No
4. Seal oil drain traps	____	Yes	No
5. Seal oil degassing tanks	____	Yes	No

II. Turnaround activities

Please complete the following form for each noted equipment unit (this includes driver, driven, transmission device and auxiliary systems)

Plant ____________________

Process unit ________________

Compressors

Type and item no.	Turn-around dates	Major item replaced*	Reason†	Part cost	Labor time (hours)

* Major items: Rotors, coupling, bearings, seals, control valves

† Use following code

P.M. = Preventive maintenance

P.D.M. = Predictive maintenance indicated imminent failure

F.P. = Failed part

Plant ____________________
Process unit ________________
Pumps

Type and item no.	Turn-around dates	Major item replaced*	Reason†	Part cost	Labor time (hours)

* Major items: Rotors, coupling, bearings, seals, control valves
† Use following code
P.M. = Preventive maintenance
P.D.M. = Predictive maintenance indicated imminent failure
F.P. = Failed part

Plant ____________________
Process unit ________________

Equip. type and item no.	Date of event	Reason for outage	Parts affected	Process unit outage hrs.	Time to repair (hours)

Cost of parts	Suspected causes	Corrective action

III. Major rotating equipment forced outages

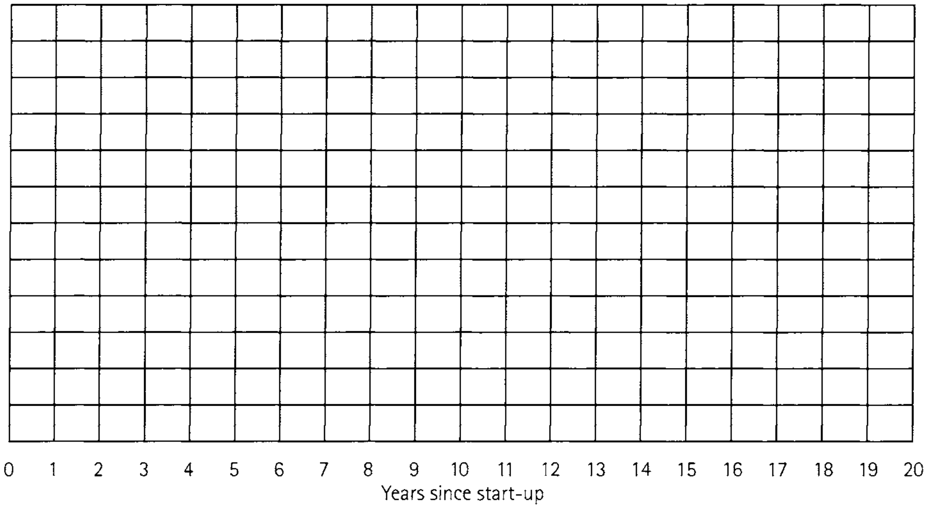
Please note the forced outages of major equipment, along with each item n umber for your group's assigned process unit.

IV. Rotating equipment documentation

Based on major forced outage events (occurring more than once) in section III, obtain the appropriate equipment data sheets, performance curves (if applicable), assembly drawings and P & ID's for these items.

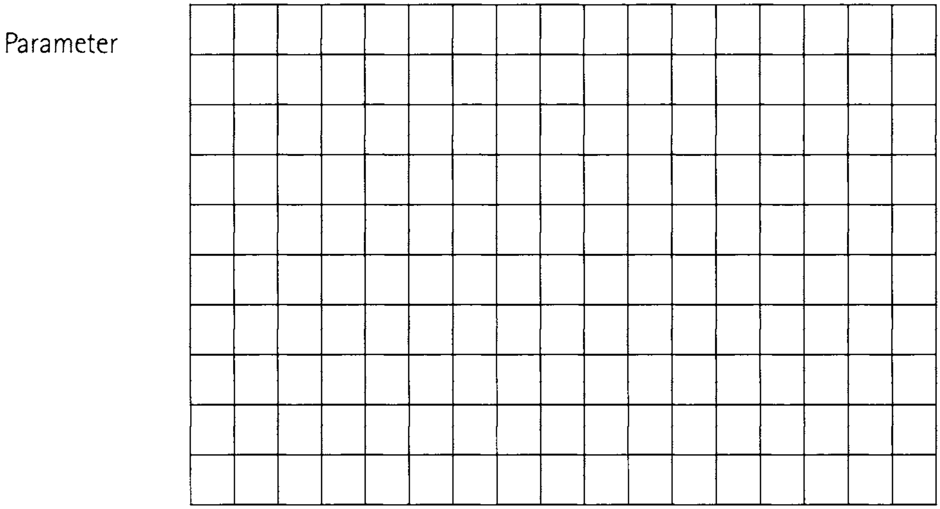
Life cycle graph

Date ________ Group ________ Train ________



Pareto chart

Chart title ____________________ Group ________________________
Time period ____________________ Train ________________________
Item ____________________ X Scale: 1 block = ___________items



Availability factor worksheet

Date ________ Group ________ Train

Unit/component	MTBF	Failure rate	MTTR	Availability

Component reliability comparison worksheet

Date ________ Group ________ Item ________

Component	Failure rate	Normal failure rate		Action required	
		Best	Worst	Yes	No

Cost of unreliability worksheet

Date ________ Group ________ Item ________

Component	Costs			
Labor	Material	Revenue	Unnecessary turnaround*	Total

*Unnecessary turnaround (ta) time assumes start-up is delayed by activity