The RAM analysis 7 steps – Decommission Phase

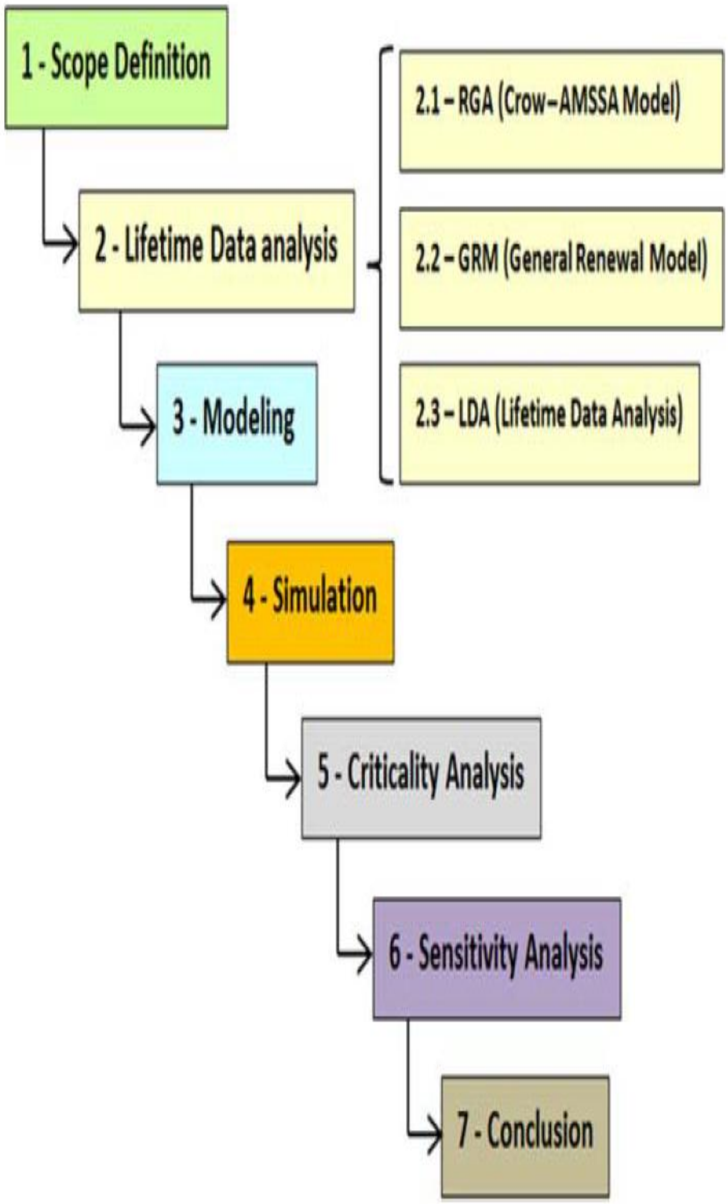

FIGURE 4.117

RAM methodology in the decommissioning phase.

Step one - Scope Definition: The boundaries of RAM analysis need to be defined as well as the source of data, the performance indexes target and the team to support the RAM analysis. The formal kick of meeting is the best practice to define the RAM analysis scope and it will be great if there will be a manager to sponsor the RAM analysis as well as the chronogram definition and project management concept application during the RAM analysis. The field data is a very important information and need to be from the current plant under assessment.

Step 2.1 – Reliability Growth Analysis (Crow AMSSA Model) : The effect of maintenance and operation conditions on aged equipment need to be taken into account to verify the trend of MTBF and predict future failures time for each equipment to define the next inspection time.

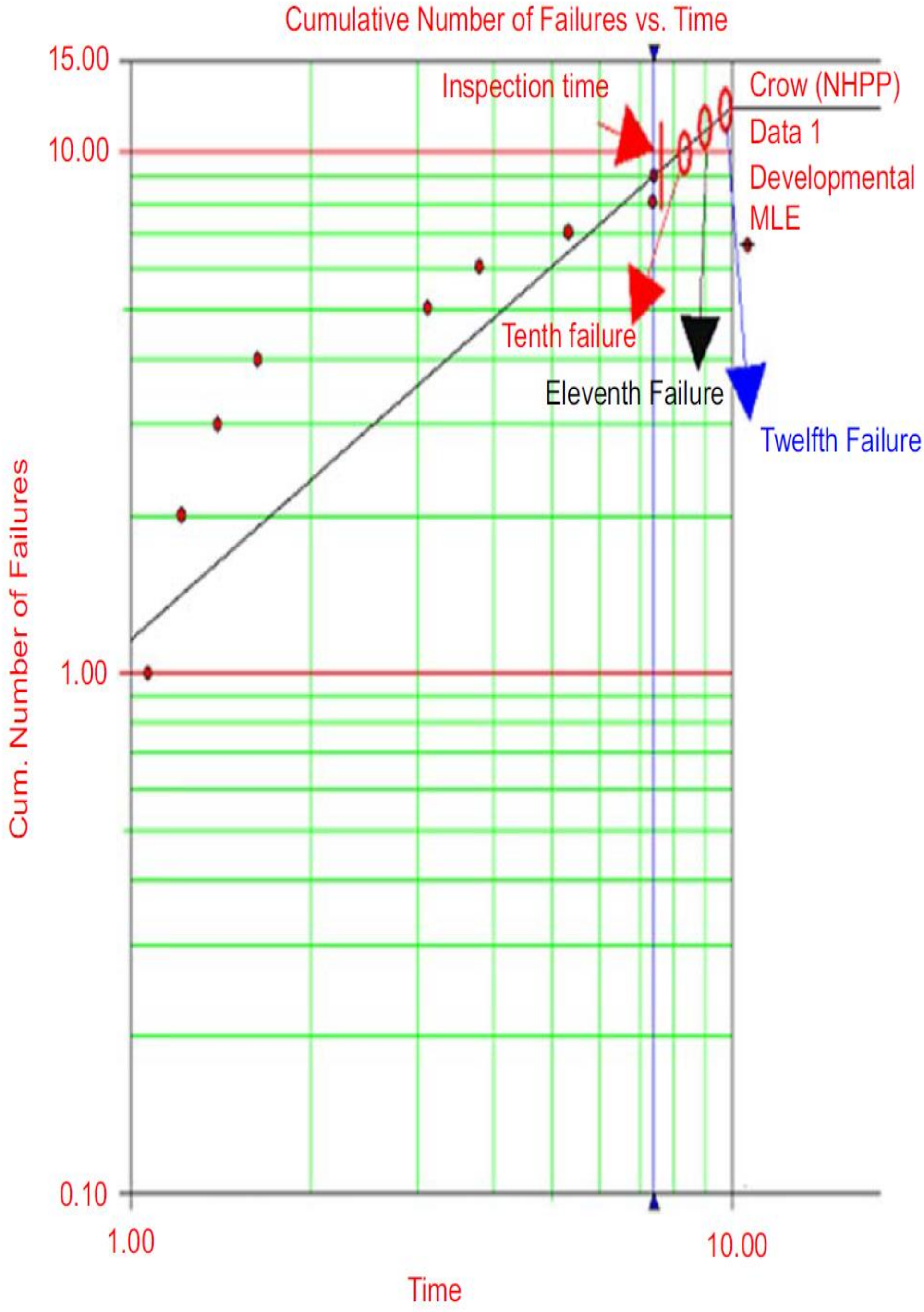

FIGURE 3.22

Inspection based on reliability growth (ReGBI).

Step 2.2 – General Renewal Model: The degradation factor needs to be predicted to be applied in RBD model in case of degradation

- Age reestablishment based on last intervention (Kijima I);
- Age reestablishment based on all interventions (Kijima II).

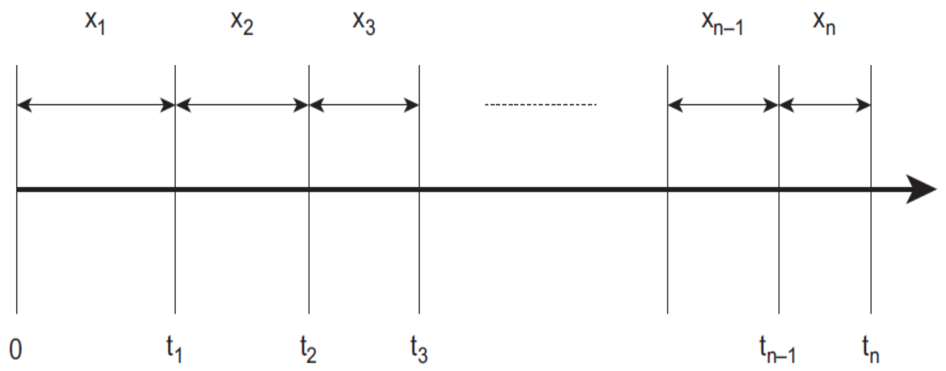

FIGURE 4.118

General Renewal Model.

Table 4.27 Reliability Database

Equipment	Failure				Repair			Kijima Factor			Crow-AMSAA Model	
Tank 1	PDF 2	Parameter (year)			PDF	Parameter (hours)		Type	q	RF	λ	β
	Gumbel	μ	σ		Normal	μ	σ					
		7.48	0.01			120	20					
Pump 2	PDF 2	Parameter (year)			PDF	Parameter (hours)		Type	q	RF	λ	β
	Weibull	β	η	γ	Constant	repair time						
		0.56	0.685	0.052		24		II	0	1	6.1044	1.0655
Pump 3	PDF 2	Parameter (year)			PDF	Parameter (hours)		Type	q	RF	λ	β
	Weibull	β	η	γ	Constant	repair time						
		0.47	0.46	1.35		24		I	0	1	0.6777	0.533
Pump 4	PDF 2	Parameter (year)			PDF	Parameter (hours)		Type	q	RF	λ	β
	Weibull	β	η		Constant	repair time						
		0.7285	0.564			24		II	0	1	0.6522	1.6522
Pump 5	PDF 2	Parameter (year)			PDF	Parameter (hours)		Type	q	RF	λ	β
	Weibull	β	η		Constant	repair time						
		0.6363	0.8888			24		I	0	1	1.4076	0.5716

Step 2.3 – Lifetime Data Analysis: Based on equipment historical data, it´s necessary to perform the lifetime data analysis. The specialist opinion is always important when no data is available and to validate the LDA results. The next step is to input the PDF parameter in the RBD model

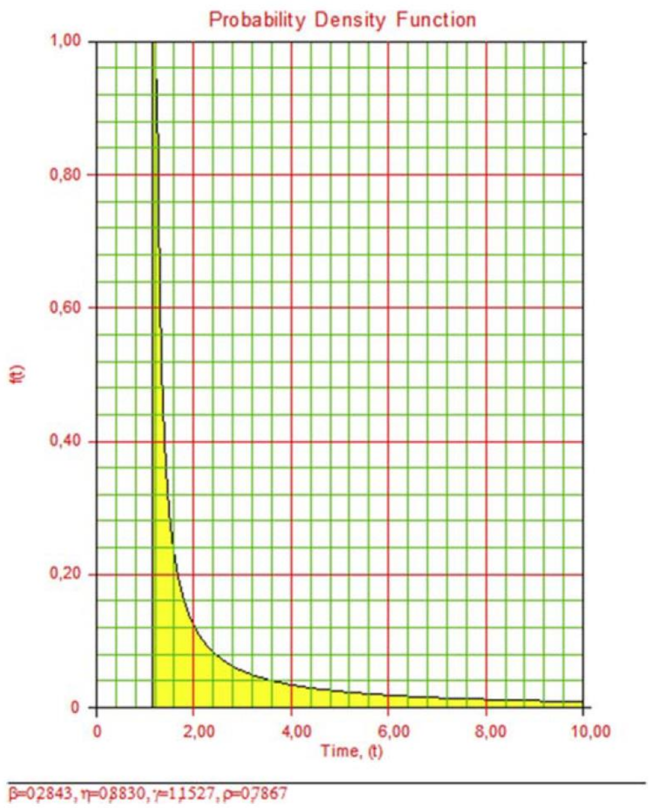

FIGURE 4.2

Furnace PDF.

Table 4.1 Quantitative Failure and Repair Data

TAG	Failure Mode	Failure Time (year) Variables (PDF)				Repair Time (hours) Variables (PDF)		
F-01 A	Coke formation	Normal		μ 4.95	ρ 2.66	Normal	μ 420	ρ 60
	Incrustation	Weibull	β 0.51	η 1.05	γ 4.05	Normal	μ 420	ρ 60
	Other failures	Exponential Bi p		λ 0.28	γ 3.22	Normal	μ 420	ρ 60
F-01 B	Coke formation	Normal		μ 5.23	ρ 2.55	Normal	μ 420	ρ 60
	Other failures	Exponential Bi p		λ 0.29	γ 4.07	Normal	μ 420	ρ 60

TAG, *used for equipment identification;* Bi p, *bi-parametric.*

Step 3 – Modelling: To perform RBD model including the degradation factor and compare with the RGA prediction to check the consistency

Table 4.28 RGA × MC

Equipment	10 Years		15 Years		20 Years	
Tank 1	MC 1	RGA	MC 1.99	RGA	MC 2	RGA
Pump 2	MC 9.7	RGA 8.89	MC 14.09	RGA 10.98	MC 18.3	RGA 12.76
Pump 3	MC 4.24	RGA 3.15	MC 6.44	RGA 4.28	MC 8.56	RGA 5.28
Pump 4	MC 15.37	RGA 12.88	MC 22.6	RGA 19.3	MC 29.91	RGA 25.27
Pump 5	MC 9.06	RGA 8.87	MC 13.23	RGA 12.13	MC 17.42	RGA 15.24

RGA, *reliability growth analysis;* MC, *Monte Carlo.*

Step 4 – Simulation: To define the simulation input such as lifetime, number of simulations, interval of results.

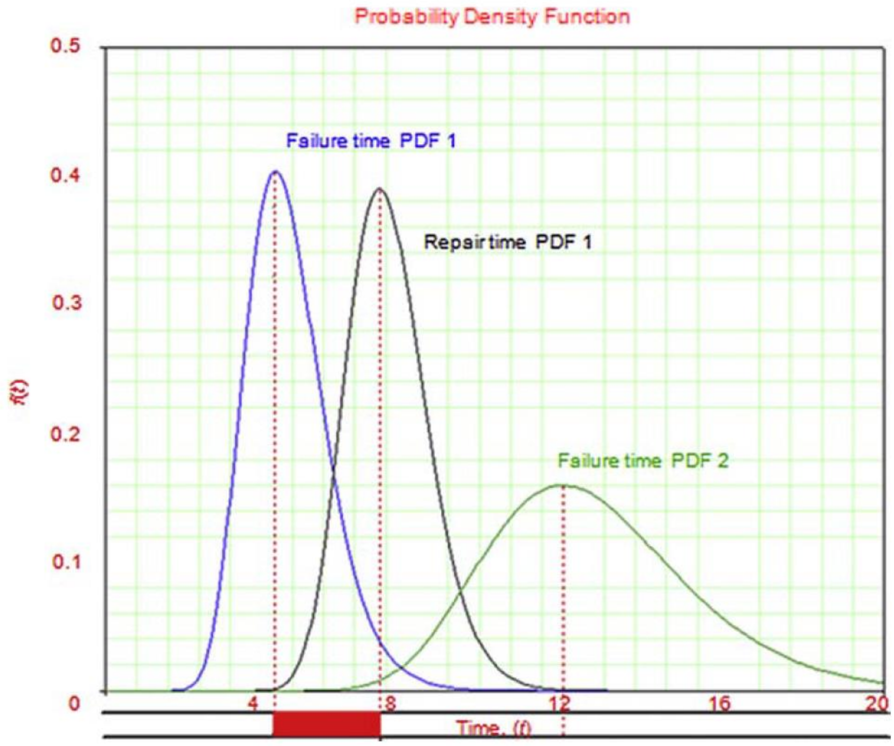

FIGURE 4.4

Block availability.

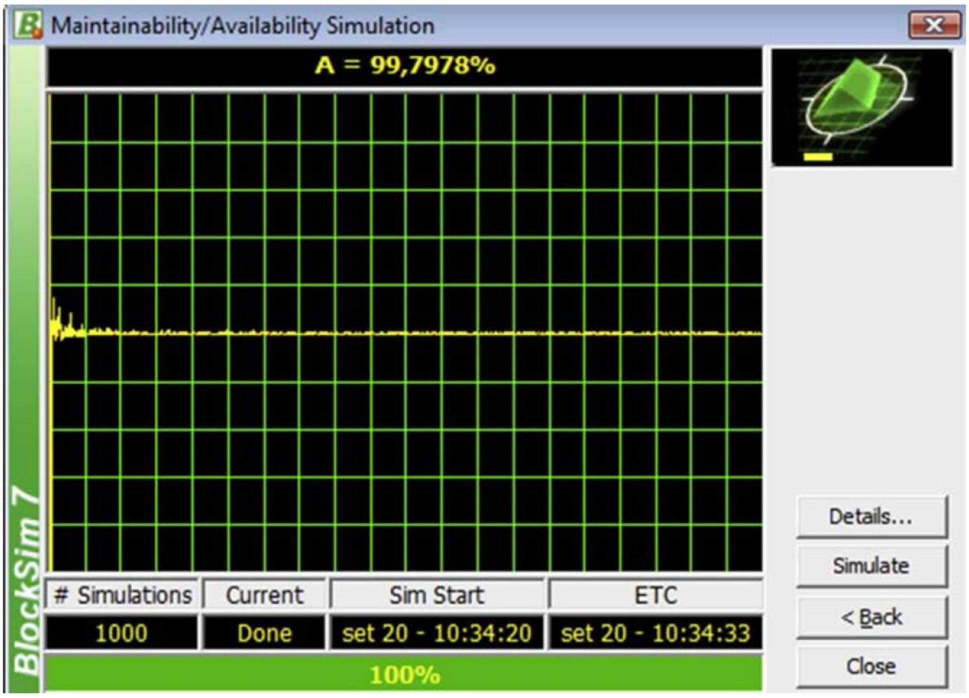

FIGURE 4.11

Simulation.

Step 5 – Simulation results (cont): To analyse the simulation result based on performance indexes achieved

Table 4.3 Simulation Result

System Overview	
General	
Mean availability (all events)	0.9683
Standard deviation (mean availability)	0.0092
Mean availability(w/o PM and inspection)	0.9683
Point availability (all events) at 26,280	0.971
Reliability (26,280)	0
Expected number of failures	12.52
Standard deviation (number of failures)	3.5168
MTTFF	1942.593
System Uptime/Downtime	
Uptime	25,446.98
CM downtime	833.02
Inspection downtime	0
PM downtime	0
Total downtime	833.02
System Downing Events	
Number of failures	12.519
Number of CMs	12.519
Number of inspections	0
Number of PMs	0
Total events	12.519
Costs	
Total costs	0
Throughput	
Total throughput	0

PM, *preventive maintenance;* CM, *corrective maintenance.*

Step 6 - Criticality Analysis: To define the quantitative impact of bad actor (low performance equipment) in the system considering the impact of operational availability, reliability, loss of production, number of downtimes, number of failure, and cost of failures.

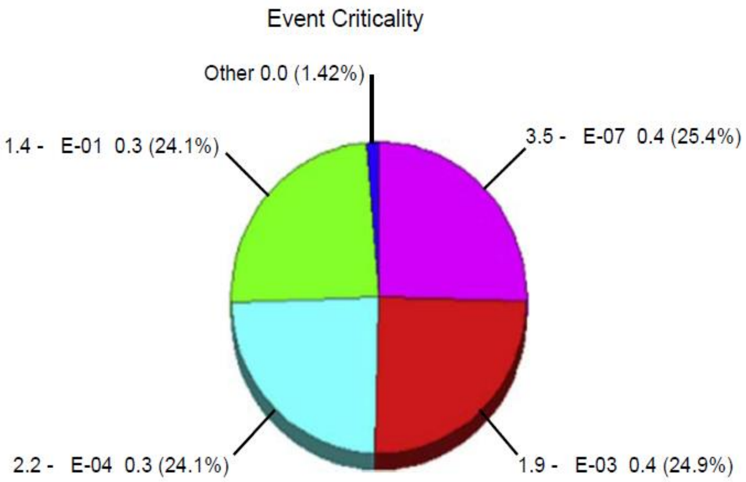

FIGURE 4.12

Percentage loss index.

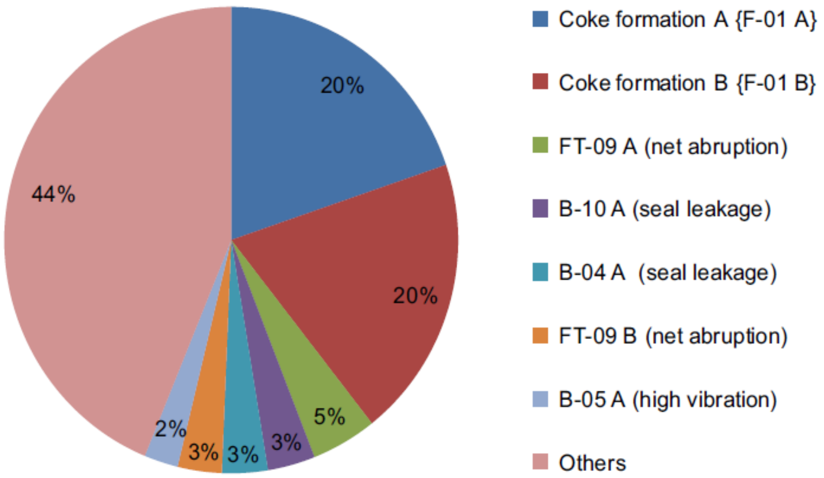

FIGURE 4.13

Failure index.

Availability Ranking	
Block Names	*Availability*
B-04 A (Seal leakage)	99.87%
Internal Corrosion (P-03)	99.52%
External Corrosion (P-03)	99.46%
Coke Formation B (F-01 B)	98.53%
Coke Formation A (F-01 A)	98.51%

FIGURE 4.15

Availability rank index.

Step 6 - Criticality Analysis (cont)

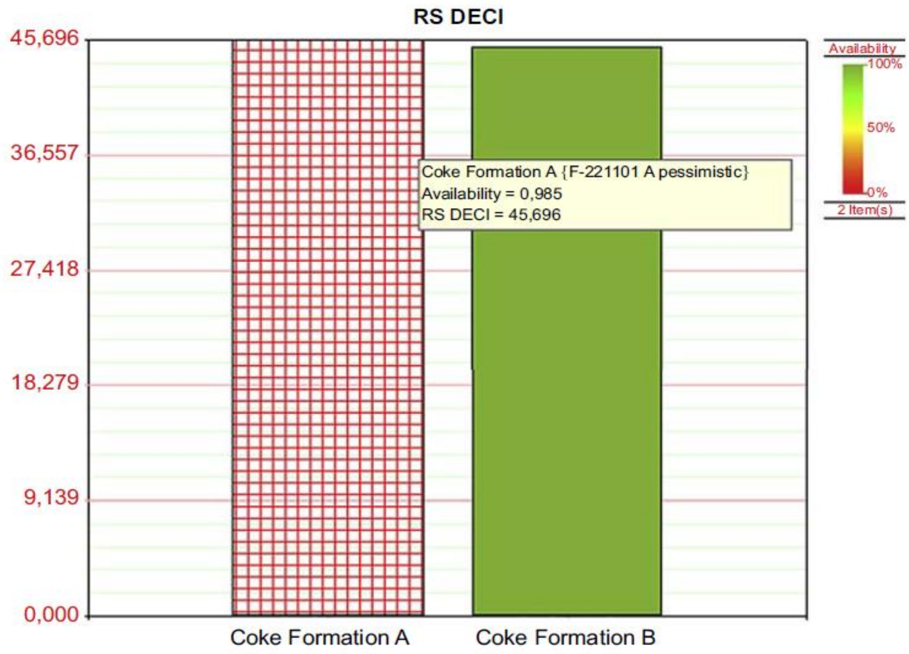

FIGURE 4.14

Downtime event criticality index.

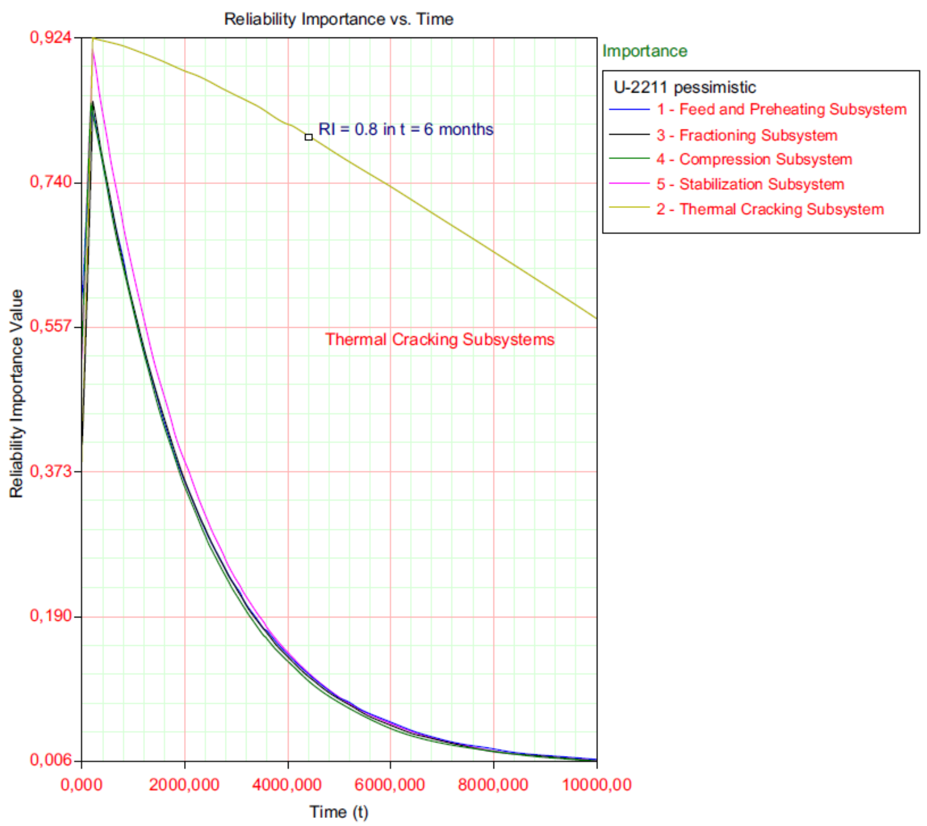

FIGURE 4.16

Reliability importance index.

Step 6 - Sensitivity Analysis: To define the impact of internal vulnerabilities that may affect the system performance such as spare part policies, preventive maintenance policy, redundancy configuration, impact on other facilities and LCC optimization.

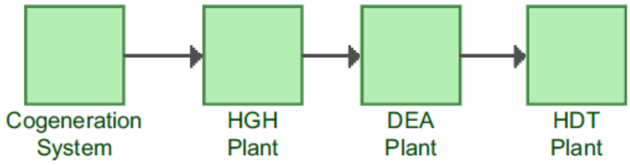

FIGURE 4.28

RBD (cogeneration system, HGH, Hydrogen generation Unit (UGH), Diethanolamine plant (DEA), and Hydrotreater Plant (HDT)).

Table 4.5 Turbine Stock Level

Equipment	Tag	Component	Minimum Stock Level	Maximum Restock Time (years)	Observation
Turbine	TG-01	Rotation part	1	0	Replace stock whenever stock achieves zero level. Random failure ($\lambda = 0.005$)
		Labyrinth	1	0	Replace stock whenever stock achieves zero level. Random failure ($\lambda = 0.004$)
		Shaft	0	7.5	The failure PDF is Gumbel with parameters $\mu = 10$, $\sigma = 2$. This means a low chance of failure occurring at the beginning of the life cycle. Thus 7.5 years would be the maximum replacement time, that is, 8 ($10 - 2 = 8$) years less 180 days
		Rotation axis	0	12.5	The failure PDF is Gumbel with parameters $\mu = 15$, $\sigma = 2$. This means a low chance of failure occurring at the beginning of the life cycle. Thus 12.5 years would be the maximum replacement time, that is, 13 ($15 - 2 = 13$) years less 180 days
		Coupling	1	7.5	The failure PDF is Gumbel with parameters $\mu = 10$, $\sigma = 2$. This means a low chance of failure occurring at the beginning of the life cycle. Thus 7.5 years would be the maximum replacement time

Step 7 – Conclusion: To prepare a formal presentation with all involved in the RAM analysis and prepare a final report. ***The formal presentation is crucial for the RAM analysis successful implementation of the recommendations because many engineers and manager will not understand the technical content of the RAM analysis report.*** The RAM analysis needs to be updated through out the Design phase and reviewed during operation phases when new data comes out.

Project Title: **Operational Assurance**
Document Title: **RAM Study Basis Report**
Document & Rev No: **REV-A**

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