Reliability-Centered Maintenance Methodology for Compressed Air System

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Abstract:
Maintenance is the work which carried out keep or protect and assets to continuous use of apparatus in industrial application without failure or above a least acceptable level of performance and its design characteristics and service life without unforeseen renewable and major failure that cause stopping production. However, conventional maintenance strategy is commonly defined empirically based on personal experience. Due to this practice maintenance plans are not related to failure mode of equipment. Therefore company spend time, money and resources to maintain equipment. Be that as it may, there is no assurance of maintenance program viability.

This paper presents the new approach of maintenance called reliability cantered maintenance for compressed air system. Compressed air system consist of electric motor, compressed pump, pressure switch, receiver etc. RCM is a systematic risk based method for achieving cost effective maintenance task. RCM has aim to make sure that maintenance strategy result largest availability of equipment for operation and efficiency up to maximum operating life. By applying RCM it demonstrated that the essential time between failure for plant equipment and the chances of sudden equipment failure diminished.

***Idex terms*: RCM, Preventive Maintenance, FMEA, Criticality, Reliability**

1. Introduction

Compressed air system is an important part of many processing industry, application, maintenance, unwavering quality, , accessibility and aggregate maintenance dependability cost are some of most critical factor in Compressed air system. Compressed air system provide compressed air for various application in industrial process. This work mean to create maintenance program in light of the RCM technique for the Compressed air systemThis method should be able to cut the down time DT and enhance accessibility, and dependability of plant gear also, it should be advantages to diminish the unexpected failure and substitution of system components.

RCM is a deliberated way to find the maintenance requirement of plants and equipment in its proper operating[1].it is used advanced preventive maintenance (CP) technique. The developed preventive maintenance program limited equipment failure and gives industrial plant with effective equipments[2]. RCM is the outstanding among other know and most utilized device to safeguard the operation efficiently of the compressed air system.

RCM works by changing the high remedial maintenance cost with the cost of altered Preventive or prescient polices, thinking about the potential shortening of "useful life" of the equipment considered In some cases, it is hard to choose suitable maintenance strategy for each bit of equipment and each failure mode, for the great measure of equipment and dubious cause of maintenance strategy determination.

RCM method uses predictive maintenance, preventive maintenance, real time monitoring(RTM), and proactive maintenance techniques in a co-ordinate way to increase the chance. That a machine or part will work in the required way up to its design life cycle with a minimum maintenance cost[5,6]

2. Reliability-Cantered Maintenance Methodology

Reliability cantered maintenance RCM is nothing but a mix of different maintenance practice such as time or interval based, condition based, reactivate and proactive only difference in the strategy is that , rather than being applied independently , they are integrated to take benefits of their strength to increase efficiency, equipment reliability and life cycle cost.

Many innovative approaches to maintenance like, total productive maintenance(TPM), preventive maintenance, reliability centered maintenance has aim to ensure enhancing of effectiveness of machine to ultimately improve the productivity and cut down time[7].

2.1. component of reliability cantered maintenance

Various components of RCM is shown in fig. RCM methodology consist of preventive maintenance, condition based maintenance, productive maintenance and reactive maintenance and its example which shown in **fig.1** [9].

This methodology can be applied in seven steps

- Step1: system selection and data collection.
- Step2: system boundary definition.
- Step3: system description and functional block.
- Step4: failure mode effect analysis.
- Step5 : logic tree diagram.
- Step6: Criticality analysis.
- Step7: task selection.

Fig.3 steps for applying methodology in compressed air system

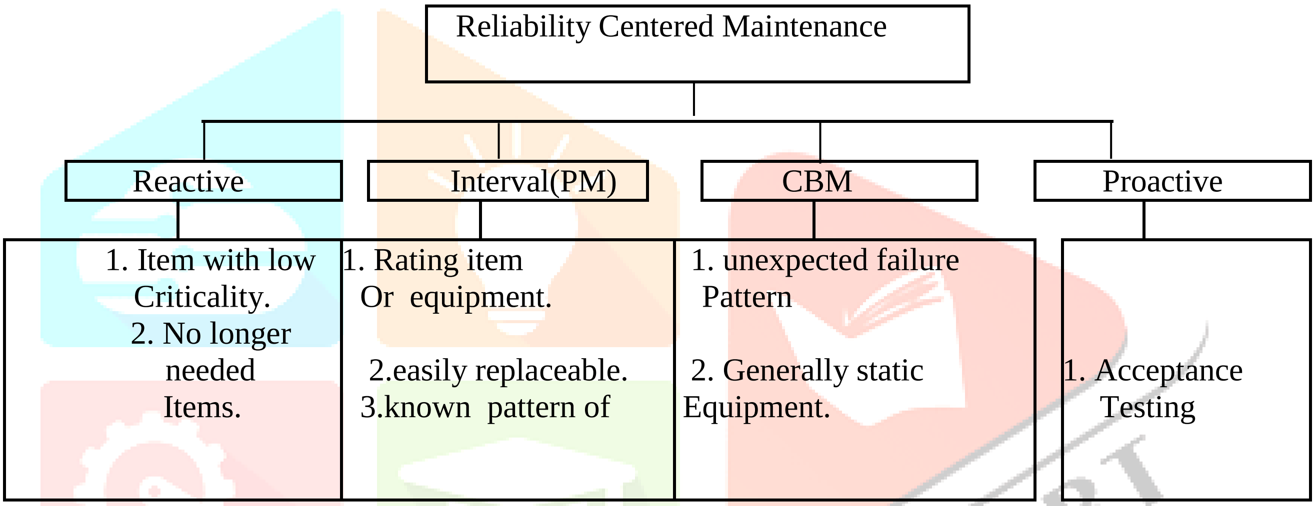

Figure 1. Components of RCM program.

3. Case Study

3.1 Selection Of Criticality Equipment For Analysis

Here we selected compressed air system as a critical system which is used in almost all industrial applications. This system provide compressed air for various industrial application like air hammers drill wrenches etc.

3.2 System boundary overview

Standard ISO 14224[8] recommends a taxonomy and how to proceed to define boundaries. Boundary description is imperative for collecting, merging and analysing RM data from different industry, plants or sources.**fig.4** and **fig.5** shows boundary diagram for motor and air compressor respectively

3.3 system description

Air compressor unit is a important part in thermal power plant and industrial like auto part manufacturing etc. Air compressor is a device that convert power using electric motor, diesel engine into potential energy stored in pressurised air. Compressor unit consist of various component like motor, drain valve and exhaust valve etc. component of typical compressor unit shown in **fig.2** electric motor provide power to the compressor head, in turn compressor head compresses quantity of air into storage tank. There are two basic type compressor used

1) Positive displacement

It has two type reciprocating and rotary.

2) dynamic

While dynamic has also two types one is centrifugal and another is axial.

Various component in compressor unit perform various function. Proper working of these component ensures the safe operation of compressor.

While studding the failure pattern of component its far determine that a number of them are often fail to work earlier than predicted. Moreover, disaster of such component reason the shutdown of compressor unit and subsequently affects the running of overall plant.

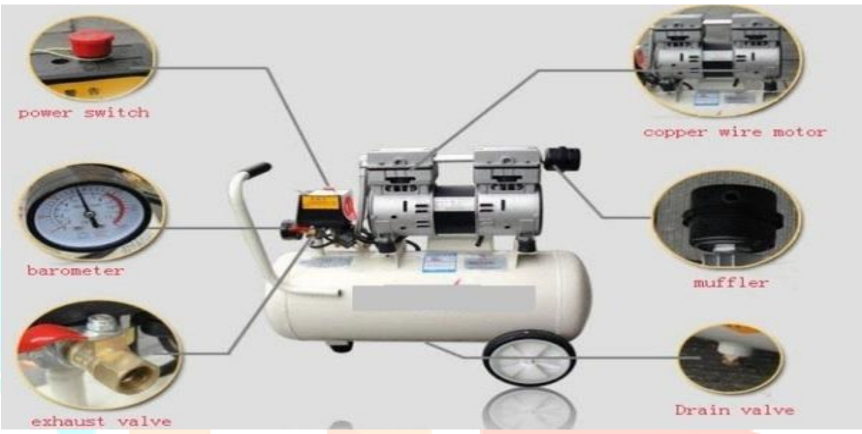

Fig.2 Typical compressor air unit

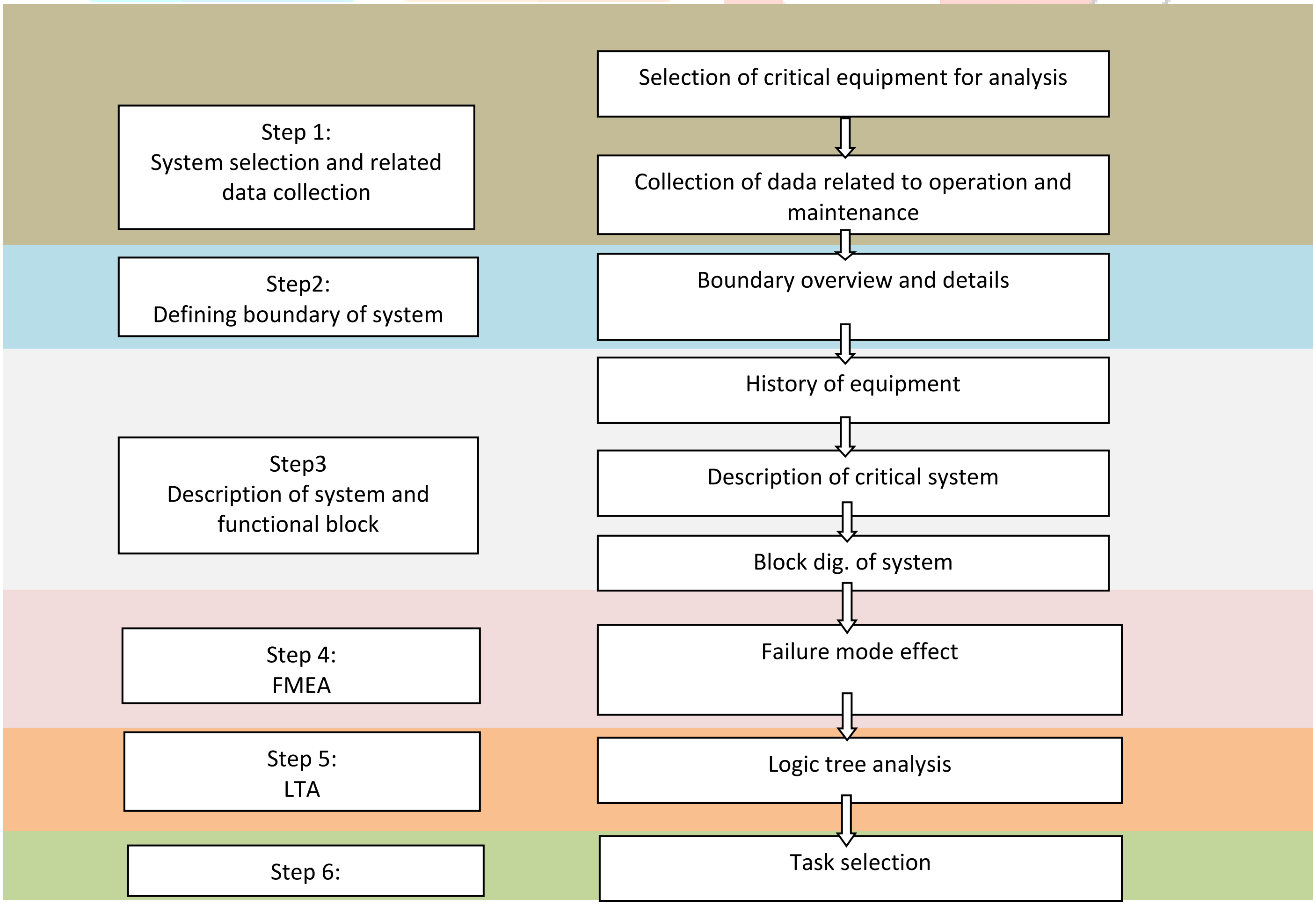

fig.3 steps of applying RCM

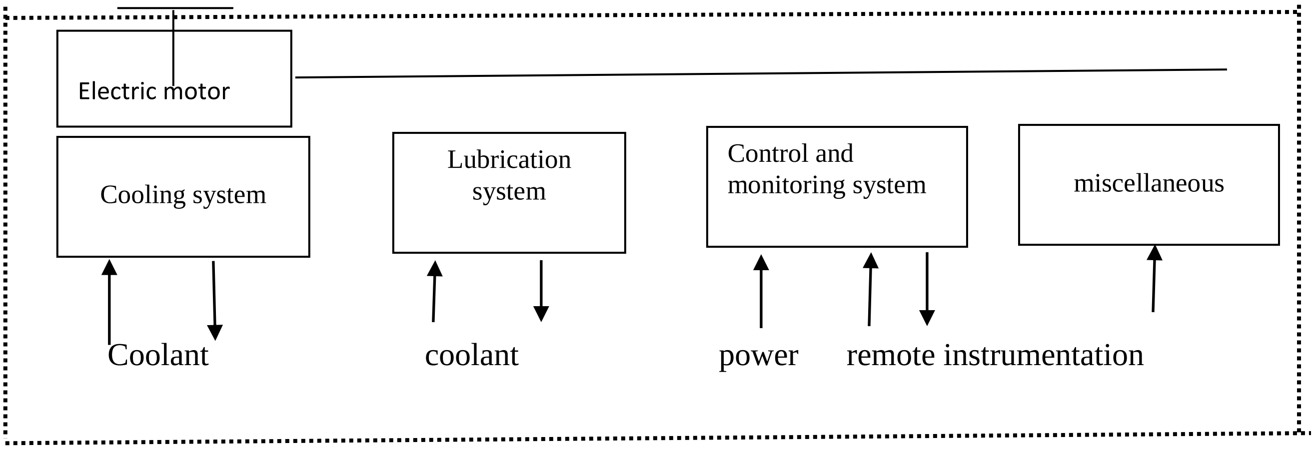

Fig.4 Boundary Diagram of Motor

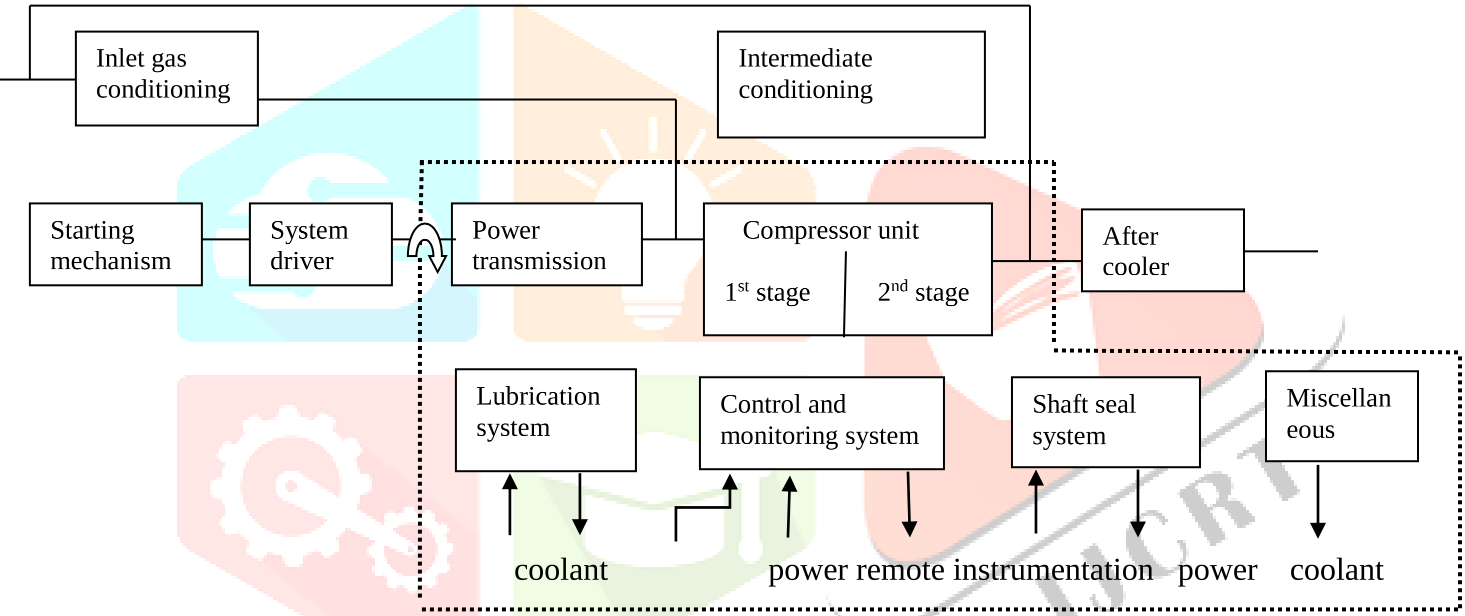

Fig.5 boundary diagram for air compressor

3.4 Functional block diagram

The functional block diagram for compressed air system shown in **fig.6**. this figure shows the input output resources of compress air system.

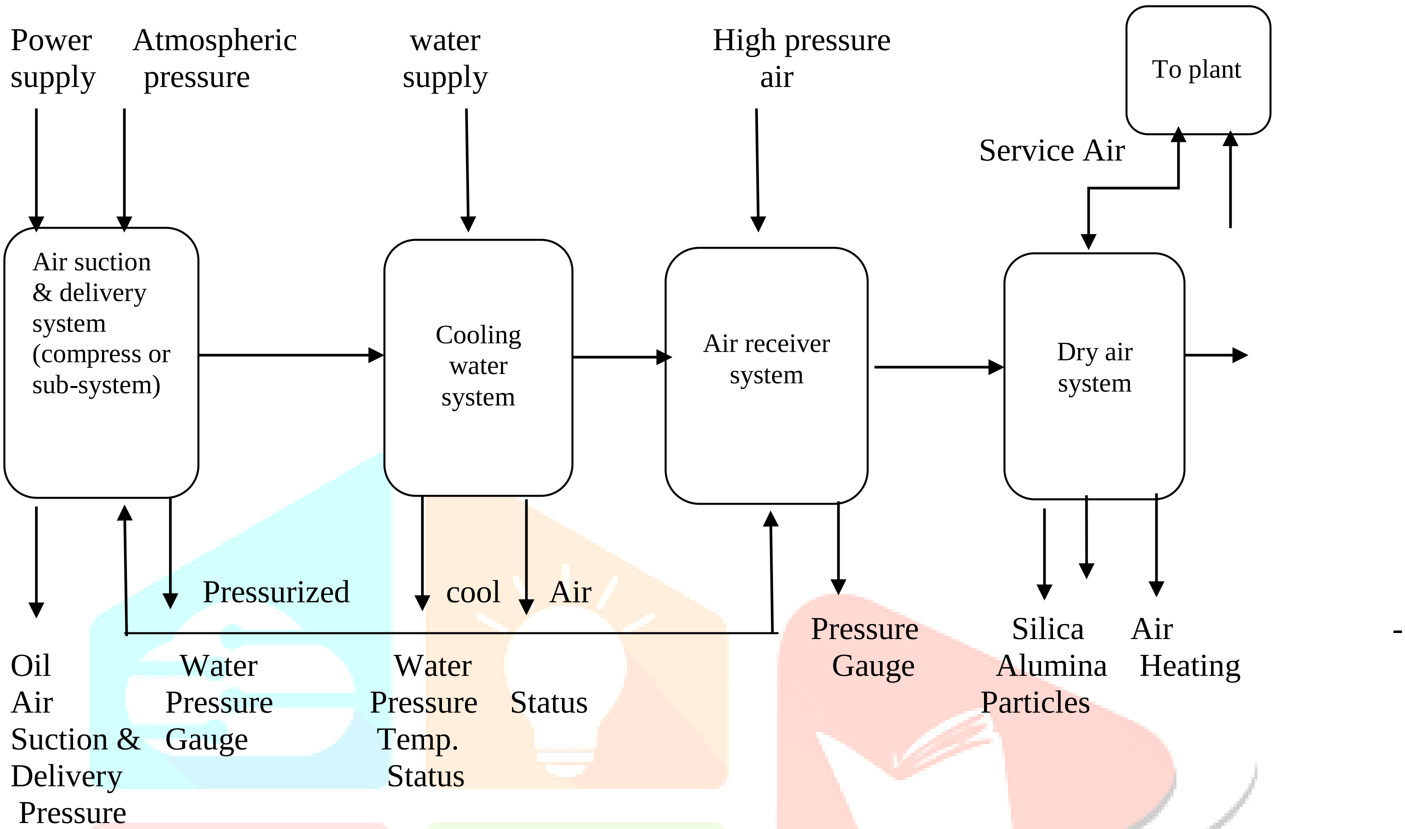

Fig.6 Functional block diagram of compressor

4. FMEA Analysis

4.1 Failure mode effect analysis of compressor

Failure mode and impact analysis is a tool that examines capacity product or process failure, also evaluates risk priorities, allow decide remedial action to keep away from diagnosed issues, The spreadsheet format permits smooth evaluation of the analysis .FMEA figuring out and the advent of purposeful failure [10]

Table 1 shows the failure mode effect analysis for critical equipment in compressed air system.

Table 1. FMEA of compressor

Compressor equipment	Failure mode	Effect	Task Performed Description
1) Delivery valve & Air suction	Components of valve	Moderate cost Very high failure rate	1) check fracture component 2)check chock up of valve component 3) Replace lapping if necessary 4) Periodic cleaning of air suction valve
2) Piston ring rod assembly	Failure in piston ring	Moderate cost of replacement High failure rate	1) Inspect for suction pressure weather it is high or low 2) check piston ring
	Failure in guide ring	Moderate in cost High failure rate	1) check suction pressure high or low 2) check piston ring

	Other piston assembly part	Low failure rate High cost	1) keep one H.P / L.P piston assembly with guide ring 2) check guide ring every 6 month
3) Unloader assembly	' O' ring for unloader	Low cost Low failure rate	1) replace when Necessary
4) Main bearing	Bearing seized	High cost Low failure rate	Check during over hand
5) Lubrication system	Oil level trapping Oil level gasket 'O' ring for oil filter	Low cost Low failure	Check for oil level &replace parts
6) Belt	Belt	High cost Moderate failure	1) Tightening of belt 2) Keep match sets of belt
7) NRV (Non Return Valve)	NRV seat NRV plate NRV spring NRV holder	Low cost Low failure	1) Replace 2) Failure pack
8) Packing	Oil seal Spice packing	Moderate cost Moderate failure rate	1) Check with 3 month
	Thrust washer 'O' ring sealing ring	Low cost Low failure	1) Replace failure part
9) Suction failure	All suction failure	Moderate cost Moderate failure	1) Cleaning of suction failure 2) Replaceable
10) Cooling system	'O' Ring for I/C 'o' Ring for A/C water leakage gasket	Moderate cost Moderate failure	1) Acid cleaning 2) Use clean water for cooling 3) Use of strainer for filtration

4.1.2 FMEA For compressor motor

Table.2 FMEA of Compressor

Motor component	Failure mode	Effect	Cause	Recommendation
Bearing Rotating shaft	High vibration Bearing failed	Overload and overheat High repairing cost due to possible shaft damage	Incorrect type of lubrication Aging Lack of maintenance	1) Monitor bearing health condition with vibration and thermograph 2) Use standard procedure for bearing mounting and lubrication
Shaft	Misalignment	Equipment shut down to avoid bearing damaged expensive repair	Physical damage Improper manufacture Corrosion	1) Take the care while alignment of motor shaft with load 2)Check alignment if any vibration is affected
Stator part	Stator defect	Motor inefficiency and high cost	Eccentricity Short lamination	1) Monitor motor stator condition with proper method

		to repair	Loose connection	
Rotor part	Rotor defect	Bearing damage motor Motor rebuild high cost	Eccentric rotor Broken rotor part	Monitor rotor condition with proper method
Winding	Winding failure and shortage	Motor failure	Overheat Moisture Insulation breakdown High vibration	Monitor machine vibration on regular basic

5. Logic tree Analysis

Fig.7 shows the logic tree analysis of reliability centered maintenance strategy applied to compressed air system. In logic tree failure modes which have passed the earlier screening will again be checked against the logic tree to allot the resources.

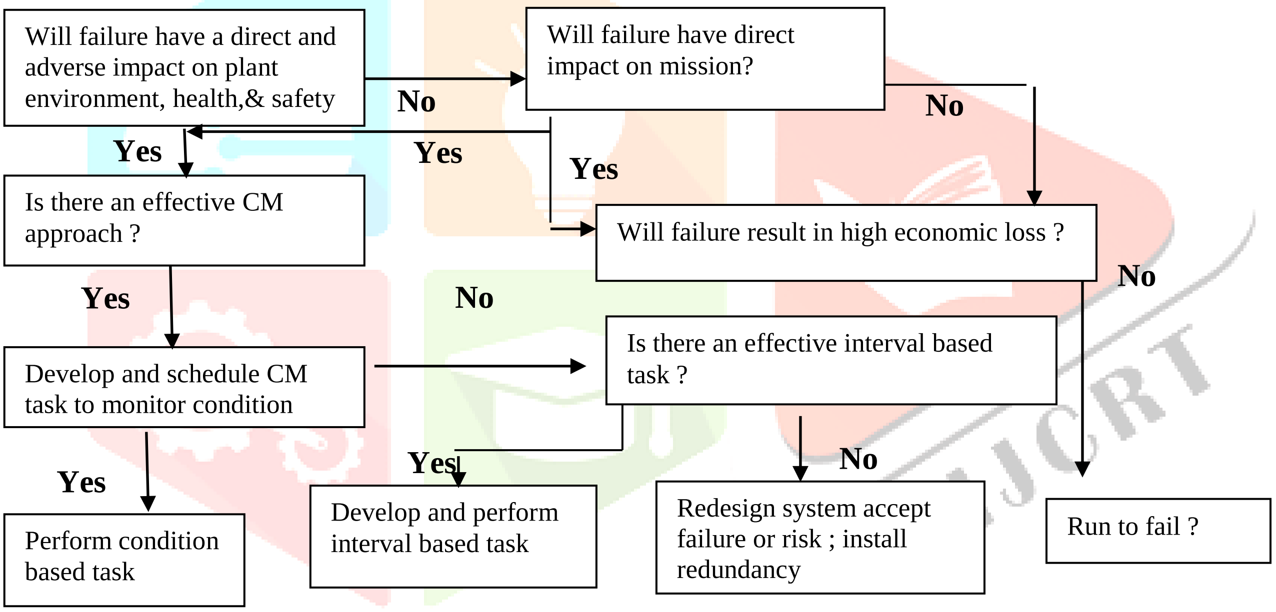

Fig.7 Logic Tree Analysis

6. Criticality Analysis Of System Components

Criticality evaluation is a method used to evaluate how equipment failure effect organization overall performance as a way to systematically rank plant assets for the motive of work prioritization. In standard, FMEA and criticality analysis require the identification of data given in table 3. The criticality classed primarily based on impact of fault and on the time, from occurrence till the effect takes place at the installation. From **table 3** we can write

$CE = (35*P + 30*S + 20*A + 15* C) / 4$

Where**,**

CE = Criticality of equipment

P = Impact on production

S = Is the safety factor

A = Availability of standby equipment

C = Capital cost

Fig.8 Shows the algorithm for criticality analysis. This figure suggest the calculation step of equipment criticality. criticality value and index find out by taking safety related effects weight of 30%, production related 35%, and cost & availability for standby related 15% & 20% respectively. **table.4** shows the criticality index and according to this failure classified in group A, B, C & D **table 5** and **6** shows criticality analysis for compressor and motor.

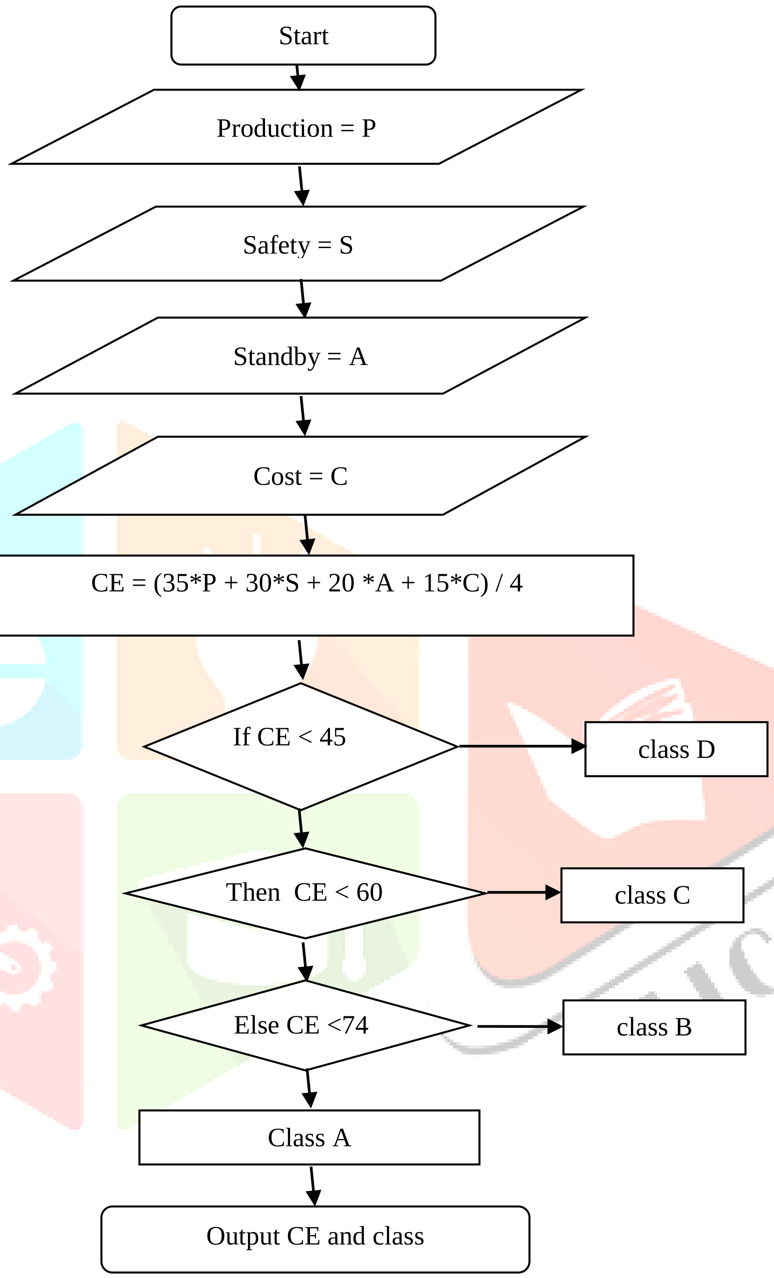

Fig.8 Algorithm for criticality analysis

Table.3 Criticality analysis

Criteria		Weight	Importance levels
Impact on production	P	35%	3 = Very important 2 = Important 1 = Normal
Impact on safety	S	30%	3 = Very important 2 = Important 1 = Normal
Availability of standby	A	20%	3 = Without standby 2 = With standby and medium availability

			1 = With standby and high availability
Equipment value	C	15%	3 = High value 2 = Normal 1 = Low value

Table 4. Criticality Index Group

Group	Criticality index
A	3 - 2.5
B	2.5 – 2
C	2 – 1.5
D	1.5 - 1

Table 5. Criticality Analysis For Compressor

Failure Mode	Failure Cause	Criticality Analysis				Criticality Index	Group
		Production	Safety	Standby	Cost		
Failure delivery valve	1. Fracture of components	2	2	2	1	1.85	**D**
	2. Failure of air suction filter	3	2	3	2	2.5	**B**
	3.Lapping failure	3	2	1	1	2	**C**
	4.Dirty air suction filter	3	3	3	3	3	**A**
Failure in piston ring-rod assembly	1. Due to high suction pressure	1	2	1	3	1.6	**D**
	2.Guide ring	2	1	2	3	1.85	**C**
Main bearing	Misalignment and improper lubrication	3	2	3	3	2.87	**A**
Belt assembly	Improper selection and tightening	3	2	3	2	2.55	**B**

Table 6. Criticality Analysis For Motor

Failure Mode	Failure Cause	Criticality Analysis				Criticality Index	Group
		Production	Safety	Standby	Cost		
High vibration bearing failure	Overload and overheat	2	2	1	3	1.8	**C**
Shaft failure	Misalignment	3	3	1	3	2.6	**A**
Stator failure	Stator defect	3	3	1	3	2.7	**A**
Rotor failure	Rotor defect	3	3	2	3	2.8	**A**

7. Task Selection

A notable power of RCM is the way it gives simple, specific and without difficulty understood Criteria. For finding out which of the proactive duties is technically viable in any context. Technical feasibility of proactive task depends on technical characteristics of task. It worth doing is also governed by how well it react or deals with the consequences of failure.

If preventive or proactive task cannot be found technically possible and well worth doing, then suitable default movement should be taken. Preservation duties such as Run-to Failure (RTF), Time Directed (TD) maintenance, condition directed maintenance (CD) and failure finding (FF). **Table.7** shows the maintenance task for compressor according to RCM

Table.7 Maintenance tasks

Components / failure mode	Previous preventive maintenance	Previous PM frequency	RCM maintenance	Frequency
1.valve components	Cleaning of air suction filter and valve	3 Months	FF	Monthly
2. Piston ring rod assembly	Piston ring, guide ring assembly	6 months	CD	6 Months
	Other piston assembly	6 months	TD	12 months
3. unloader	Check unloader part	12 months	RTF	----
4. main bearing	Bearing check	12 months	TD	12 months
5. NRV	Replace fractured part	12 months	CD	3 months
6. lubrication	Oil filter cleaning	3 months	RTF	----
7. belt	Belt tightening	3 months	CD or RTF	----

Table.8 Labour saving cost

Item	Labour type	Number of labour per day (current maintenance)	Number of labour per day(RCM proposed)
Engineer (1000$/month)	Mechanical	6	5
	Electrical	5	4
	Control	4	3
	Mechanical	7	5
	Electrical	7	5
Total cost ($/year)		314400	240000
Cost saving(%) = 23.67			

From table saving in cost

Current maintenance labour cost (Engineer + technicians)

1) **Engineers** (Mechanical + Electrical + control)= 15nos. With 1000$/ months
   15*12months*1000 = 180000$/months

2) **Technicians** (Mechanical + Electrical) = 14nos.with 800$/months
   14*12months*800 = 134400$/months

Total Current maintenance labour cost (Engineer + technicians) =180000 + 134400= **314400$/year**

RCM proposed labour cost(Engineer + technicians)

1) **Engineers**(Mechanical + Electrical + Control) =12nos.with 1000$/months
   12*12months*1000 = 144000$/months

2) **Technicians** (Mechanical + Electrical)
= 10nos.with 800$/months
10*12months*800 = 96000$/months

RCM proposed total maintenance labour cost(Engineers + Technicians)
= 144000 + 96000 = **240000$/year**

% saving in cost =
(100 – ((RCM proposed maintenance cost / current maintenance labour cost)*100))
% saving in cost = (100-((240000 / 314400)*100)) = **23.67%**

Result
Papers shows that if RCM proposed maintenance is carried out results cost of labour for maintenance is decreased from 314000$/a$/year to 2400000$/year (about 23.67%) cost saving.

Conclusion-

After performing RCM on compressed air system following points are observed

- Air suction filter should be cleaned monthly. It will prevent the dust dirt chock up the valve parts so that failure rate will minimize**.**
- Lubrication of oil sample should be tested periodically in laboratory so that the strategy for oil replacement can be made.
- Water strainer should be provided for filtering the raw water. It will prevent the failures in the cooling system.

RCM prepared maintenance scheduled leads to saving in upkeep price in each class. Its far concluded that reliability cantered maintenance is pattern and effective preservation making sure in the course of that maintenance caused disasters are either removed or minimize. It does no longer required e numerical calculation. It re-examine the validity of preceding preventive preservation agenda and develop cost powerful preventive protection agenda. It predicts spare elements inventories and risk maintenance decision for the machine or plant.

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