INVESTIGATION TO IMPROVE THE PRODUCTIVITY OF MAINTENANCE ACTIVITY OF LOCOSHED

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***ABSTRACT**: Railway is one amongst the world's largest backbones of the transportation network. Railway carries billions passengers' annually working at different atmospheric conditions. The major maintenance of the railway is carried out by loco shed and remaining maintenance activity is handle by electric section. Maintenance management systems are often utilized in organizations, where large-scale preventive maintenance schemes are being founded decrease the probability of failure. However, since preventive maintenance isn't free, a good balance should be made between its costs and benefits. Maintenance activity is carried out at different atmospheric condition work men is facing the environmental effects. More stress is being given to human factors in designing any product. Ergonomics refers to designing for human use [1-3]. Ergonomics tries to attain comfort to the person and achieve the work efficiently. Various disciplines contribute for development and implementation of the knowledge of ergonomics in practice. Members of many professional societies like engineers, psychologists and medical practitioners contribute for development of ergonomics in fact; it's advantageous to be an engineer for successful implementation of ergonomics in manufacturing, design and planning. Considering this fact, this paper is an effort to help the upkeep managers to answer these questions through developing useful mathematical model and performing sensitive analysis of the mathematical model to identify influencing pie term for maintaining good balance between costs and benefit to improve the present method.*

***KEYWORDS**: Sensitivity, Liner piston, Locoshed, Assembly, Maintenance, Mathematical Model)*

1 INTRODUCTION

Present maintenance method is mostly consisted of a planned activity done at frequent time period whose outcome to be costly and time taken process. process require high investment with reduction of overall life of the components [1-3]. Paper supports the maintenance activities based on the study of correlation of the input and output data of the maintenance activities with the help of sensitivity analysis. analysis helpful to the find the priorities to be decided which further help to reduce the maintenance cost and time requirement [4-8]. Maintenance is carried out in four different heads as (1) Main Bogie (2) Power transmission unit (3) gear assembly (4) Engine

The work done in the engine unit is main activity related to power transmission. So the maintenance of engine is crucial activity. Engine crank shaft and piston liner assembly maintenance plays vital role to convert one motion into another. The maintenance of crankshaft and liner piston assembly carried out in heavy schedule (preventive maintenance strategy).

Crankshaft and liner piston assembly operation is the main activity which take 3/4 time for completion and maximum human energy as related to other maintenance activity. In this activity ergonomic principal play an important role as this activity is related to continuous awkward postures and physically effort. Lubricating problem, vibration, temperature rise due to improper maintenance leads to overall efficiency and productivity In addition to this maintenance activity involved assembly and disassembly of the parts involved in the engine. So it consumes more time and more human energy. So, the various variables affecting this phenomenon are finding out by studying the sequence of phenomenon. Data is collected based on sequence of maintenance activity by direct measurement from this data. Input and output variables are decided and model is formed by dimensionless equation using regression analysis. Sensitivity highlights the effectiveness of individual pie terms related to mathematical model which helps to reduce repair time and human energy involved.

2 METHODOLOGY

In order to make the mathematical model of liner piston activity routine schedule, past failure data and their experiences is taken into consideration. Maintenance activity is based on operators, maintenance tools used, specification of liner piston and crankshaft, oil used and other factors such as temperature, humidity, light and noise [9]. So, theory of experimentation as suggested by Hilbert is applied systematically to spot the dependent and independent variables to formulate the mathematical model [10]. Once the correlation is formed the variation of input and output parameters is studied for further modification to improve the productivity.

3 MAN MACHINE SYSTEM

Method such as time study, motion study to enhance the maintenance activities. The approach suggested for formulation of mathematical model to spot the response supported the varied independent variables involved to minimize the time and human energy requirement [11-12]. In our life we come across very many activities. These activities have some environmental system in which these activities take place. The environment or system can be specified in terms of its parameters some of which are always constant in their magnitudes whereas some are variable. The activities are set in action by some parameters which are considered as causes. These causes interact with parameters of the system as a result of this interaction some effects are produced. The above said matter in a diagrammatic form can be presented as shown in Figure 1.

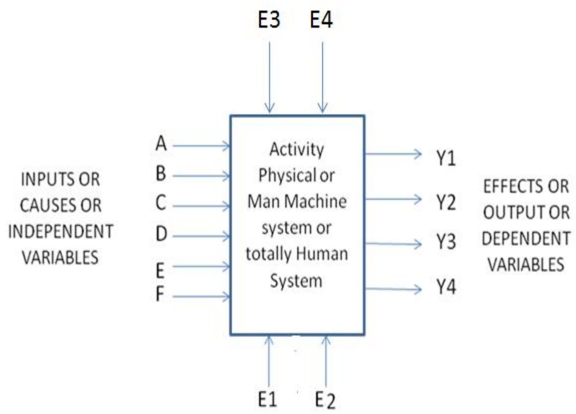

Fig 1 : Block Diagrammatic of an Activity

Figure 1 shows one rectangular block within which is written activity along with its nature i.e activity may be totally physical or it may be a combination of human directed / operated physical activity stated as Man Machine system or it may be an activity mainly dominated by human being stated in the block as "Totally Human System". The functioning of an activity is influenced by two sets of parameters one set is characterizing the features of environment of an activity and other set is planned parameters or causes which influence the functioning of the system.

Accordingly, Figure 1 shows these parameters. The parameters characterizing features of an environment are E1,E2, E3, E4 etc. Some of which are permanently fixed say E1, E2 where as remaining are time variant say E3, E4 on which one has no control. The planned parameters are known as causes shown as A, B, C, D, E etc and effects of an activity are shown as Y1, Y2, Y3, Y4 etc.

If one analyses any activity of society one would be able to identify the causes A to E etc, system parameters E1 to E4 etc and the effects Y1 to Y4 etc . This may be treated as qualitative analysis of the societal activity. This can be demonstrated by one example of everyday life of MAN - MACHINE System of our life.

4 MAINTENANCE ACTIVITY OF LINER PISTON

Various maintenance operations for overhauling of Liner Piston Assembly can be enlisted chronologically as under. (1) Loosening and Taking out nuts (12Nos) coupled to coupler rod and liner piston by 41mm socket tool. (2) Disassembly of 6 liners (3) Lifting of piston and connecting rod assembly (1-6,2-5,3-4) by crane with fitting piston hook keeping connecting shaft in TDC position and lifting Liner by puller and kept on ground by crane. (4) Removing rubber ring of liner by hand. (5) Cleaning of liner connecting rod and piston. (6) Inspection of piston (7) Measuring liner diameter. (8) Checking piston ring gap (1mm-1.5mm) in liner by filler gauge. (9) Fitting of bearing.(10) Fitting of piston pin in lab tested piston to connect Connecting rod by hammer (11) Elongation and Assembly of big end nut bolt with required tightening torque by 41mm socket (12) measuring of diameter /axial clearance of bearing in connecting rod. (13) Applying lube oil and grease on piston-6nos. (14) Setting piston rings -6Nos by bracket compressor. (15) Refitting of overhauled liner-6nos. (16) Refitting of piston and related rod in the engine block.

4.1 Dimensionless pi terms for liner piston

Following variables are identified from the above-mentioned liner piston maintenance activity. The erroneous data be identified and removed from the gathered data. Based on the purified variables as listed below one has to formulate quantitative relationship between the dependent and independent Pi terms of the dimensional equation.

Table 1 List of variables of liner piston

S.N	Description of Variables	Type of variable	Symbol
1	Overhauling time for liner piston	Dependent	To
2	Consumption of Human energy for liner piston	Dependent	H E
3	Productivity of Liner Piston Assembly overhauling	Dependent	Pd
4	Age of worker	Independent	Aw
5	Experience of worker	Independent	Exw
6	Skill of worker	Independent	Skw
7	Enthusiasm of worker	Independent	Ew
8	Habits of worker	Independent	Hw
9	Health of worker	Independent	HlW
10	Anthropometric data of worker	Independent	Ad
11	Temperature of work station	Independent	Tws
12	Humidity of workstation	Independent	Hws
13	Noise of workstation	Independent	Nws
14	Illumination of work station	Independent	IlWs
15	Diameter of liner	Independent	Dsp
16	Length of liner	Independent	Lsp
17	Diameter of piston	Independent	Dsn
18	Length of piston	Independent	Lsn
19	Diameter of piston rings	Independent	Dsb
20	Thickness of piston rings	Independent	Lsb
21	Length of piston stroke	Independent	Dsmab
22	Length of piston pin	Independent	Lsmab
23	Diameter of piston pin	Independent	Dsiab
24	Length of connecting rod	Independent	Lsiab
25	Diameter of big end bearing	Independent	Dsc
26	thickness of big end bearing	Independent	Lsc
27	Diameter of Little end bearing	Independent	Dmj
28	Length of Little end bearing	Independent	Lmj
29	Diameter of big end nut	Independent	Dcpj
30	Length of big end nut	Independent	Lcpj
31	Diameter of big end bolt	Independent	Dbr
32	Length of big end bolt	Independent	Lbr
33	small end bearing axial clearance	Independent	Dsms
34	big end bearing axial clearance	Independent	Lsms
35	Diameter of Bracket compressor to set piston rings	Independent	Dsis
36	Length of Bracket compressor to set piston rings	Independent	Lsis
37	Diameter of Bracket expander to remove piston and liner ring	Independent	Dbrd
38	Length of Bracket expander to remove piston and liner ring	Independent	Lbrd

39	Diameter of socket for big end nut bolt	Independent	Dmjb
40	Length of socket for big end nut bolt	Independent	Tmjb
41	Length of hammer	Independent	Lmjb
42	Diameter of hammer	Independent	Dcpjb
43	Length of Nose plier	Independent	Lf
44	Length of Liner puller	Independent	Lcpjb
45	Thickness Liner puller	Independent	Tcpjb
46	Length of bush puller	Independent	Wf
47	Diameter of bush puller	Independent	Hf
48	Kerosene (solvent) in kg	Independent	Ke
49	Emery belt in kg	Independent	Eb
50	Lube oil	Independent	
51	Height of frame	Independent	Ca
52	Length of frame	Independent	Ax mj
53	Width of frame	Independent	Axcp
54	Saddle bolt elongation	Independent	El sb

Maintenance activity consists of many inputs variables which is further reduces to group pie terms [13-15]. Following is the list of inputs and output Pi term of liner piston activity.

Table 2. Formation of Pie Terms

S.N	Description of Pie terms	Formation of Pie term
1	Worker anthropometric data	D1= [(a*c*e*g)/(b*d*f*h)]
2	Worker data	D 2=[(Ags/Exs),(sks/Ens),(hl s/Hbs)]
3	Crankshaft data	D3=((Dlin/Lc)*(l.li/L.c)*(D.p/L.c)*(L.p/L.c)*D.p/Lc .)*(t.pr/L.c)*(l.pst./L.c)*(D .pp/L.c)*(L.pp/L.c)*(Db.br /L.c)*(t.bg.br/L.c)*(Dlt.brj /L.c)*(t.lt.brj/L.c)*(D.b.nj/ L.c)*(L.b.nt/L.c)* (d.b.bl/L.r)*(l.b.bl/L.c))]
4	Tools used	D4=(Dbr.cm/lbr.cm)(dbr.e x/lbr.ex)(L.st/d.st)(L.hmr/ D.hmr)(l.npl/)
5	Pi term relating specification of solvent ,lube oil and compressed air	D 5=[(ker/l oil),(Ca/Eb)]
6	Pi term relating specification of Axial clearance of crank pin and Saddle bolt elongation	D6= [(Axcp/Elsb),(Axmj/Elsb)]
7	Pi term relating specification of workstation	D7= [(Hfrm/Lfrm),(wfrm/Lfrm)]
8	Pi term related to temperature	D8= temp
9	Pi term related to humidity	D9=humidity %
10	Pi term related of illumination	D10 = [(ilms* Ags/wt)]
11	Pi term related of noise	D11=noise in db
12	Pi term relating to overhauling time (Dependent)	Z1= (field time) 2 x g/ length of saddle)

4.2 Model formulation for time required for maintenance activity

The multiple regression analysis helps to identify the indices of the different pie terms as shown in Eq.(1), $(Z_1)=k_1 * [(D_1)^{a1} * (D_2)^{b1} * (D_3)^{c1} * (D_4)^{d1} * (D_5)^{e1} * (D_6)^{f1} * (D_7)^{g1} * (D_8)^{h1} * (D_9)^{i1} * (D_{10})^{j1} * (D_{11})^{k1}]$

Eq. (1)

The total twelve unknowns is evaluated using the twelve equations formulated based on the regression analysis and arranging in the matrix form.

Model developed for the dependent variable (Z_1) for liner piston as shown in Eq. (2)

$$(Z_1) = 1.0122 *[(\pi_1)^{-0.0973} * (\pi_2)^{-0.1917} * (\pi_3)^{0.1172} * (\pi_4)^{-6.0098} * (\pi_5)^{0.0896} (\pi_6)^{0.378} * (\pi_7)^{0.6869} * (\pi_8)^{-0.5615} * (\pi_9)^{-0.2282} * (\pi_{10})^{0.0887} *(\pi_{11})^{0.0838}]$$

$$(Z_2) = 1.7874 *[(\pi_1)^{0.355}*(\pi_2)^{0.3448}*(\pi_3)^{0.1681}*(\pi_4)^{4.4021}*(\pi_5)^{-.0249}*(\pi_6)^{-0.131}*(\pi_7)^{-3.3313} *((\pi_8)^{-.1018}*(\pi_9)^{-0.147} *(\pi_{10})^{0.0643} *(\pi_{11})^{0.221}]$$

Eq. (2)

The mathematical model for the dependent pie term time requirement for maintenance operation of liner piston activity of the engine is studied with the curve fitting constant and indices of the individual pie terms involved in the model [16-18].

5 SENSITIVITY ANALYSIS

In The change of ±10% is establish in each pie terms separately [19-20]. Thus, the entire limit of the bring in change is 20% is introduced for each pie term at a time to observe the effect of dependent variable time [21]. The change introduced and its effect in the dependent pi terms is evaluated as shown in Table 2. Percentage effect of introduced change for dependent variables is shown in following Table 3.

Table 3. Transform on the output pie term for liner piston

Pi terms/response variable	Z1	Z2
p1 (D1)	-1.95%	7.11%
p2 (D2)	-3.85%	6.91%
p3 (D3)	2.35%	3.37%
p4 (D4)	-131.97%	89.24%
p5 (D5)	1.80%	-0.50%
p6 (D6)	-7.60%	-2.63%
p7 (D7)	13.75%	69.25%
p8 (D8)	-11.31%	-2.04%
p9 (D9)	-4.58%	-2.97%
p10 (D10)	1.78%	-1.29%
p11 (D11)	1.68%	4.45%

Outcome of establish change on the dependent π term- Time requirement of liner piston maintenance activity is shown in the Fig. 2.

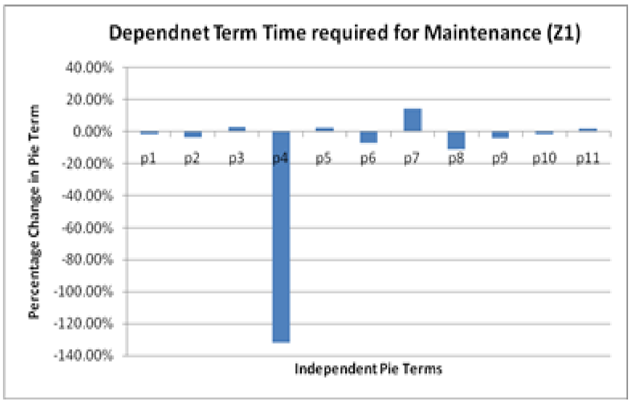

Fig 2 : Effect of change in pie term on maintenance time

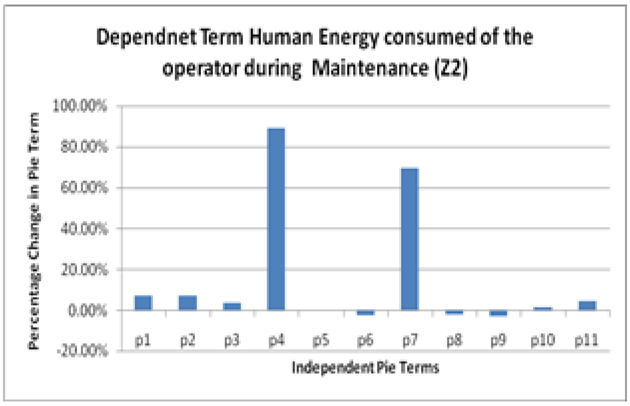

Fig 3 : Effect of change in pie term on maintenance human energy

6 RESULT AND DISCUSSION

Any When a change of 20 % is introduced in the value of independent π term π1 related to anthropometric data of worker, corresponding change of 1.95 % is observed in the value of dependent variable Z1 i.e. Maintenance time. The change brought in the value of Z1, because of the change in the value of the other independent π term π2 related to data of worker is - 3.85%. Similarly, the change of about +2.35%, -131.97%, +1.8%, -7.6% , 13.75%, -11.31%, -4.58%, 1.78% and 1.68% takes place in the value of Z1, because of the change in the values of π3 specification of crankshaft, π4 specification of tools, π5 solvent, oil, π6 crank pin, π7 specification of workstation, π8 temperature ,π9 humidity, π10 illumination and π11 noise respectively.

It can be seen that the maximum alteration takes place in Z1, because of the π term π7 related to specification of workstation, whereas the least change takes place due to π11. Thus, π7 is most sensitive πterm and π11 term related to specification of noise is the least sensitive π term. The sequence of the various π terms in the descending order of sensitivity is π3, π5, π10, π1, π2, π9, π6, π8 and π4.

When a total 20% i.e. ±10% limit of the change is introduced in first dependent pi term (p1) i.e. anthropometric data then 7.11%change occurs in the value of Z2 i.e. human energy consumed for liner piston maintenance activity. Again 6.91% brought in the value of dependent pi terms (Z2) i.e. human energy due to change introduced in the value of second next pi term (p2) i.e. workers data

Similarly, the change of about 3.37 %, 89.24% ,-0.5%,-2.63 % 69.25%, -2.04%,-2.97%,-1.29% and 4.45% takes place due to change in the pi term values of p3,p4,p5,p6,p7,p8,p9,p19 and p11 respectively

Optimum values of independent pi terms for minimize time for liner piston activity are found to be z1=1471.74 and corresponding to this values independent pi terms.p1, p2, p3, p4 p5, p6, p7, p8, p9, p10 and p11 are obtained as 0.5311, 1.629, 2.238 x 10^{10}, 0.4599, 38.90, 0.1173, 0.2138, 0.26, 23.98, 87096 and 69.18

Optimum values of independent pi terms for minimize human energy for liner piston activity are found to be z2 =2388.016 and corresponding to this values independent pi terms.p1, p2, p3, p4 p5, p6, p7, p8, p9, p10 and p11 are obtained as 0.5311, 1.629, 2.238x10^{10}, 0.4599, 38.90, 0.1173 ,0.2138, 0.26, 23.98, 87096 and 69.18.

Table 4. Sensitivity Analysis for Time of Liner Piston maintenance activity (Z_1)

		p_1 (π_1)	p_2 (π_2)	p_3 (π_3)	p_4 (π_4)	p_5 (π_5)	p_6 (π_6)	p_7 (π_7)	p_8 (π_8)	p_9 (π_9)	p_{10} (π_{10})	p_{11} (π_{11})	Computed Z_1	% Change
1	MEAN	1.09	2.83	2290000000	0.46	76.22	0.14	0.214	0.332	50.66	251024	79.08	5069.086	
	10 % ABOVE	1.20	2.83	2290000000	0.46	76.22	0.14	0.214	0.332	50.66	251024	79.08	5022.294	
	10 % BELOW	0.98	2.83	2290000000	0.46	76.22	0.14	0.214	0.332	50.66	251024	79.08	5121.319	
				2290000000									% Change	-1.95%
2	MEAN	1.09	2.83	2290000000	0.46	76.22	0.14	0.214	0.332	50.66	251024	79.08	5069.086	
	10 % ABOVE	1.09	3.12	2290000000	0.46	76.22	0.14	0.214	0.332	50.66	251024	79.08	4977.31	
	10 % BELOW	1.09	2.55	2290000000	0.46	76.22	0.14	0.214	0.332	50.66	251024	79.08	5172.51	
													% Change	-3.85%
3	MEAN	1.09	2.83	2290000000	0.46	76.22	0.14	0.214	0.332	50.66	251024	79.08	5069.086	
	10 % ABOVE	1.09	2.83	2519000000	0.46	76.22	0.14	0.214	0.332	50.66	251024	79.08	5126.027	
	10 % BELOW	1.09	2.83	2061000000	0.46	76.22	0.14	0.214	0.332	50.66	251024	79.08	5006.876	
				2290000000									% Change	2.35%
4	MEAN	1.09	2.83	2290000000	0.46	76.22	0.14	0.214	0.332	50.66	251024	79.08	5069.086	
	10 % ABOVE	1.09	2.83	2290000000	0.51	76.22	0.14	0.214	0.332	50.66	251024	79.08	2858.695	
	10 % BELOW	1.09	2.83	2290000000	0.41	76.22	0.14	0.214	0.332	50.66	251024	79.08	9548.233	

				22900 00000									% Change	- 131.97 %
5	MEAN	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.332	50.66	2510 24	79.08	5069.086	
	10 % ABOVE	1.09	2.83	22900 00000	0.46	83.84	0.14	0.214	0.332	50.66	2510 24	79.08	5112.56	
	10 % BELOW	1.09	2.83	22900 00000	0.46	68.60	0.14	0.214	0.332	50.66	2510 24	79.08	5021.457	
													% Change	1.80%
6	MEAN	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.332	50.66	2510 24	79.08	5069.086	
	10 % ABOVE	1.09	2.83	22900 00000	0.46	76.22	0.15	0.214	0.332	50.66 7	2510 24	79.08	4889.711	
	10 % BELOW	1.09	2.83	22900 00000	0.46	76.22	0.13	0.214	0.332	50.66	2510 24	79.08	5275.043	
				22900 00000									% Change	-7.60%
7	MEAN	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.332	50.66	2510 24	79.08	5069.086	
	10 % ABOVE	1.09	2.83	22900 00000	0.46	76.22	0.14	0.235	0.332	50.66	2510 24	79.08	5412.056	
	10 % BELOW	1.09	2.83	22900 00000	0.46	76.22	0.14	0.192	0.332	50.66	2510 24	79.08	4715.186	
													% Change	13.75%
8	MEAN	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.332	50.66	2510 24	79.08	5069.086	
	10 % ABOVE	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.365	50.66	2510 24	79.08	4804.937	
	10 % BELOW	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.299	50.66	2510 24	79.08	5378.021	
													% Change	- 11.31%
9	MEAN	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.332	50.66	2510 24	79.08	5069.086	
	10 % ABOVE	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.332	55.73	2510 24	79.08	4960.025	
	10 % BELOW	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.332	45.60	2510 24	79.08	5192.44	
													% Change	-4.58%
1 0	MEAN	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.332	50.66	2510 24	79.08	5069.086	
	10 % ABOVE	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.332	50.66	2761 27	79.08	5112.122	

	10 % BELOW	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.332	50.66	2259 22	79.08	5021.934	
													% Change	1.78%
1 1	MEAN	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.332	50.66	2510 24	79.08	5069.086	
	10 % ABOVE	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.332	50.66 7	2510 24	86.99	5109.735	
	10 % BELOW	1.09	2.83	22900 00000	0.46	76.22	0.14	0.214	0.332	50.66 7	2510 24	71.17	5024.527	
													% Change	1.68%

7 CONCLUSION

The performance of the equations is established by sensitivity analysis. This behavior is truly justified and optimum value for output parameters and set of input parameters are also found to minimize the repair time and human energy consumed.

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