Maintenance Management Plan of Heavy Machinery

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Abstract - Heavy machinery is a major resource for a highway department. The goal of this study is to develop a three-wheel roller and truck maintenance plan for reducing the maintenance cost. This plan is designed to add values to maintenance procedures and reduce the risks and exposures to loss the department is currently experiencing. Therefore, not only is the need improved maintenance performance addressed, but also worker and property exposures are controlled as well. Breakdown and preventive maintenance plans were used for highway department. Moreover, compute for standby machine when an online machine fails is another way to maintain service.

Indexed Terms - Heavy machinery, maintenance cost, risks and exposures, Breakdown and preventive maintenance plans, maintain service.

I. INTRODUCTION

Maintenance is a huge profit center when it is done correctly. It can make as much money for an industrial company as the operations group tasked to make the company’s products. But you have to do maintenance in a certain way. There is a best practice way to do maintenance planning and scheduling that guides companies and their maintenance crews to world class performance. Maintenance Planning and Scheduling is a key component in delivering maintenance services effectively and efficiently.

After leaving the maintenance manager roll in an industrial process chemical manufacturer in 2005 I started presenting maintenance planning and scheduling training courses around Australia and Asia. The course I present is designed and built from a business owner’s point of view. Unlike other maintenance planning and scheduling trainers who teach you the mechanics of maintenance planning and scheduling, I also teach you how to make vast sums money from maintenance through its proper preparation, organization and delivery.

Maintenance done as explained in this book is not a cost. Great maintenance is a rainmaker of moneys now lost to waste, catastrophe and misunderstanding. Maintenance planning and scheduling for reliability helps to double operating profit in the average industrial company.

Doing maintenance planning and scheduling is important. But the incredible difference to a company comes from what is done when you do the planning. The secret knows how to plan and prepare maintenance work so that it creates world class reliability. With world class reliability comes magnificent operational performance, and more operating profits than you can imagine. World class maintenance practices can double your margin and sustain it thereafter.

II. MAINTENANCE

A. Maintenance Management and Control

The management and control of maintenance activities are equally important to performing maintenance. Maintenance management may be described as the function of providing policy guidance for maintenance activities, in addition to exercising technical and management control of maintenance programs. Generally, as the size of the maintenance activity and group increases, the need for better management and control become essential.

(i) Maintenance Department Functions and Organization

A maintenance department is expected to perform a wide range of functions including:

- Planning and repairing equipment/facilities to acceptable standards.
- Performing preventive maintenance; more specifically, developing and implementing a regularly scheduled work program for the purpose of maintaining satisfactory
equipment/facility operation as well as preventing major problems.

- Preparing realistic budgets that detail maintenance personnel and material need.
- Managing inventory to ensure that parts/materials necessary to conduct maintenance tasks are readily available.
- Keeping records on equipment, services, etc.
- Developing effective approaches to monitor the activities of maintenance staff.
- Developing effective techniques for keeping operations personnel, upper-level management, and other concerned groups aware of maintenance activities.
- Training maintenance staff and other concerned individuals to improve their skills and perform effectively.
- Reviewing plans for new facilities, installation of new equipment, etc.
- Implementing methods to improve workplace safety and developing safety education-related programs for maintenance staff.
- Developing contract specifications and inspecting work performed by contractors to ensure compliance with contractual requirements.

Generally, centralized maintenance serves well in small- and medium-sized enterprises housed in one structure, or service buildings located in an immediate geographic area. Some of the benefits and drawbacks of centralized maintenance are as follows:

(ii) Benefits

- More efficient compared to decentralized maintenance.
- Fewer maintenance personnel required.
- More effective line supervision.
- Greater use of special equipment and specialized maintenance persons.
- Permits procurement of more modern facilities.
- Generally, allows more effective on-the-job training.

(iii) Drawbacks

- No one individual becomes totally familiar with complex hardware or equipment.
- More difficult supervision because of remoteness of maintenance site from the centralized headquarters.
- Higher transportation cost due to remote maintenance work.

B. Preventive Maintenance

Preventive maintenance (PM) is an important component of a maintenance activity. Within a maintenance organization it usually accounts for a major proportion of the total maintenance effort. PM may be described as the care and servicing by individuals involved with maintenance to keep equipment/facilities in satisfactory operational state by providing for systematic inspection, detection, and correction of incipient failures either prior to their occurrence or prior to their development into major failure.1 Some of the main objectives of PM are to:

1. Enhance capital equipment productive life,
2. Reduce critical equipment breakdowns,
3. Allow better planning and scheduling of needed maintenance work,
4. Minimize production losses due to equipment failures,
5. Promote health and safety of maintenance personnel.

(i) Preventive Maintenance Elements, Plant Characteristics in Need of a PM

There are seven elements of PM as shown in Figure 1.

Figure 1. Elements of preventive maintenance.

Each element is discussed below:

1. Alignment
2. Servicing
3. Testing
4. Inspection
5. Installation
6. Calibration
7. Adjusting

(ii) Important Steps for Establishing a PM Program

To develop an effective PM program, the availability of a number of items is necessary. Some of those items include accurate historical records of equipment, manufacturer’s recommendations, skilled personnel, past data from similar equipment, service manuals, unique identification of all equipment, appropriate test instruments and tools, management support and user cooperation, failure information by problem/cause/action, consumables and replaceable components/parts, and clearly written instructions with a checklist to be signed off.

There are a number of steps involved in developing a PM program. Figure 2 presents six steps for establishing a highly effective PM program in a short period. Each step is discussed below.

![Figure 2. Six steps for developing a PM program](image)

C. Corrective Maintenance

Although every effort is made to make engineering systems as reliable as possible through design, preventive maintenance, and so on, from time to time they do fail. Consequently, they are repaired to their operational state. Thus, repair or corrective maintenance is an important component of maintenance activity. Corrective maintenance may be defined as the remedial action carried out due to failure or deficiencies discovered during preventive maintenance, to repair an equipment/item to its operational state.

Usually, corrective maintenance is an unscheduled maintenance action, basically composed of unpredictable maintenance needs that cannot be preplanned or programmed on the basis of occurrence at a particular time. The action requires urgent attention that must be added, integrated with, or substituted for previously scheduled work items. This incorporates compliance with “prompt action” field changes, rectification of deficiencies found during equipment/item operation, and performance of repair actions due to incidents or accidents. A substantial part of overall maintenance effort is devoted to corrective maintenance, and over the years many individuals have contributed to the area of corrective maintenance. This chapter presents some important aspects of corrective maintenance.

(i) Corrective Maintenance Types

Corrective maintenance may be classified into five major categories as shown in Figure 3. These are: fail-repair, salvage, rebuild, overhaul, and servicing. These categories are described below.

![Figure 3. Types of corrective maintenance](image)

(ii) Corrective Maintenance Steps

Different authors have laid down different sequential steps for performing corrective maintenance. For example, Reference 2 presents nine steps (as applicable): localize, isolate, adjust, disassemble,
repair, interchange, reassemble, align, and checkout. Reference 3 presents seven steps (as applicable): localization, isolation, disassembly, interchange, reassemble, alignment, and checkout.

For our purpose, it is assumed that corrective maintenance is composed of five major sequential steps, as shown in Figure 4.

- Using group rather than individual replacement for low valued items.

These alternatives can be used in different combinations to formulate satisfactory short-term maintenance policies.

(i) Preventive Versus Breakdown

Management may choose to allow a machine to operate until it breaks down after a run time \( T \), the maintenance crew then proceeds to fix the machines, taking an average repair time equal to \( T_r \), the mean value of a repair-time distribution \( f(T) \). After repair the machine runs until the next breakdown, and so on. This policy is known as the breakdown maintenance shown in Figure 3.1 (a).

As alternative approach is to operate the machine for a certain period \( T_p \) and then inspect it to assess its operating status and replace of necessary any critical components for which a breakdown in imminent. The average time for performing the preventive maintenance is \( T_m \), a mean value of a preventive maintenance time distribution \( g(T) \). The fixed time \( T_p \) between successive inspections is called the preventive maintenance period.

The sum of \( T_m \) and \( T_p \) is the complete preventive maintenance cycle. Occasionally, the machine may breakdown between the regular inspectors, in which case the maintenance crew will repair it with the same average repair time \( T_r \), this maintenance policy is known as preventive maintenance and shown in Figure 3.1 (b).

- Training machined operations.
- Training maintenance-crew workers.
- Making use of decoupling i.e., work in process and finished goods inventories, to allow limited operation during the maintenance.
- Providing adequate inventory of space parts to reduces repair time.
- Using preventive maintenance to reduce the frequency of breakdowns.
- Using overtime to make up for lost production due to repairs.

III. MAINTENCE AND REPLACEMENT

A. Short-Term Maintenance Policies

For an existing system with those factors that determine the inherent reliability of the operation system have been decided in the design phase. It is still possible, however to take a number of steps in the short run that can keep the process in good working conditions. They may include the following.

- Training machined operations.
- Training maintenance-crew workers.
- Making use of decoupling i.e., work in process and finished goods inventories, to allow limited operation during the maintenance.
- Providing adequate inventory of space parts to reduces repair time.
- Using preventive maintenance to reduce the frequency of breakdowns.
- Using overtime to make up for lost production due to repairs.

Figure 4. Corrective Maintenance Sequential Steps

Figure 5. Alternative Short-Term Maintenance Policies

If the expected cost of breakdown per period without preventive maintenance is greater than the expected...
cost of breakdown with preventive maintenances, prevent is the best policy.

![Figure 6. Balance of Cost Defining an Optimal Preventive Maintenance](image)

**B. Maintenance and Maintenance Engineering Objectives**

Even though maintenance engineering and maintenance have the same end objective or goal, the environments under which they operate differ significantly. More specifically, maintenance engineering is an analytical function as well as deliberate and methodical. In contrast, maintenance is a function that must be performed under normally adverse circumstances and stress, and its main objective is to rapidly restore the equipment to its operational readiness state using available resources.

**IV. MAINTENANCE CALCULATION**

**A. General Information**

Plan of break-down maintenance for three-wheel roller

For breakdown maintenance

The cost of the overhaul and repair = 1,400,000 kyats

For preventive maintenance

The cost of the overhaul = 300,000 kyats

Individual repairs cost = 150,000 kyats

Information inputs may pertain to the history of Three-wheel Rollers in terms of number of machines and number of hours between major breakdowns is shown in Table I.

**Table I. Breakdown Data of Three-Wheels Roller**

<table>
<thead>
<tr>
<th>Number of Three-wheels Roller</th>
<th>Number of Hours Between Major Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1000-2000</td>
</tr>
<tr>
<td>40</td>
<td>2000-3000</td>
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<tr>
<td>180</td>
<td>3000-4000</td>
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<tr>
<td>240</td>
<td>4000-5000</td>
</tr>
<tr>
<td>270</td>
<td>5000-6000</td>
</tr>
<tr>
<td>140</td>
<td>6000-7000</td>
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<tr>
<td>100</td>
<td>7000-8000</td>
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<tr>
<td>10</td>
<td>8000-9000</td>
</tr>
<tr>
<td>10</td>
<td>9000-10000</td>
</tr>
</tbody>
</table>

**B. Calculation of Breakdown Maintenance Policy**

All breakdowns occur at the end of each interval.

Average number of hours between breakdowns

\[ L_{avg} = [(2 \times 0.01) + (3 \times 0.04) + (4 \times 0.18) + (5 \times 0.24) + (6 \times 0.27) + (7 \times 0.14) + (8 \times 0.1)] \times 10^3 \approx 5,650 \text{ hrs} \]

Number of breakdowns for each 1000 hours

10000/5650 \times 1000 = 1,769.9115 machines

**Table II. Calculated Results for Probability of Failure**

<table>
<thead>
<tr>
<th>Number of Three-Wheel Roller</th>
<th>Probability of Failure P(I)</th>
<th>Number of Hours Between Major Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.01</td>
<td>1000-2000</td>
</tr>
<tr>
<td>40</td>
<td>0.04</td>
<td>2000-3000</td>
</tr>
<tr>
<td>180</td>
<td>0.18</td>
<td>3000-4000</td>
</tr>
<tr>
<td>240</td>
<td>0.24</td>
<td>4000-5000</td>
</tr>
<tr>
<td>270</td>
<td>0.27</td>
<td>5000-6000</td>
</tr>
<tr>
<td>140</td>
<td>0.14</td>
<td>6000-7000</td>
</tr>
<tr>
<td>100</td>
<td>0.1</td>
<td>7000-8000</td>
</tr>
<tr>
<td>10</td>
<td>0.01</td>
<td>8000-9000</td>
</tr>
<tr>
<td>10</td>
<td>0.01</td>
<td>9000-10000</td>
</tr>
</tbody>
</table>
Total breakdown maintenance cost per 1000 hours
\[ = 1,769.9115 \times 1,400,000 \]
\[ = 2,477,876,100 \text{ kyats} \]

C. Calculation of Preventive Maintenance Policy

Preventive maintenance policy on scheduled basis.

Total preventive Maintenance cost (TPM) = total preventive cost (TBC) + total breakdown cost (TPC)

D. Calculation of Standby Machine for Three-Wheels Roller

Plan of stand by machine for three-wheels Rollers calculation for probability of failures.

Poisson Distribution
\[ P_n = e^{-\lambda} \frac{\lambda^n}{n!} \]

\( \lambda \) = average of machines undergo repairs = 3 machines
\( e = 2.7183 \)

Stand by cost = 20,000 kyats/day

Loss in work and service = 100,000 kyats/machine/day

Conditions get serious when six or more machines are out of operation at once.

So, addition loss = 200,000 kyats

Minimum total cost = 112,960 kyats

Five standby machines should be used the plant have minimum total costs.

E. Calculation of Breakdown Maintenance for Truck

Number of truck = 1,200

Breakdown cost/truck = \( C_b = 1,000,000 \text{ kyats} \)

Preventive maintenance cost/truck = \( C_p = 200,000 \text{ kyats} \)

Individual breakdown maintenance cost/truck = \( C_{bi} = 450,000 \text{ kyats} \)

Table III. Breakdown Data for Truck

<table>
<thead>
<tr>
<th>Truck use (miles)</th>
<th>Probability of Breakdown (p_i)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1500</td>
<td>0.2</td>
</tr>
<tr>
<td>3000</td>
<td>0.1</td>
</tr>
<tr>
<td>4500</td>
<td>0.1</td>
</tr>
<tr>
<td>6000</td>
<td>0.15</td>
</tr>
<tr>
<td>7500</td>
<td>0.2</td>
</tr>
<tr>
<td>9000</td>
<td>0.25</td>
</tr>
</tbody>
</table>

F. Calculate the average life between two consecutive breakdown of truck.

\[ L_{avg} = \sum_{i=1}^{n} p(i) \]

Calculate the average numbers of breakdown per miles

\[ B_{avg} = \frac{\text{total number of truck}}{L_{avg}} \]

Calculate the expected total cost

\[ TC_b = C_b \times B_{avg} \]

G. Calculate the Expected Total Costs of Preventive Maintenance Policy

The expected no of breakdown of preventive maintenance

(1) every 1500 miles
\[ B_1 = N \times P_1 \]

(2) every 3000 miles
\[ B_2 = N (P_1 + P_2) + B_1P_1 \]

(3) every 4500 miles
\[ B_3 = N (P_1 + P_2 + P_3) + B_2P_1 + B_1P_2 \]

(4) every 6000 miles
\[ B_4 = N (P_1 + P_2 + P_3 + P_4) + B_3P_1 + B_2P_2 + B_1P_3 \]

(5) every 7500 miles
\[ B_5 = N (P_1 + P_2 + P_3 + P_4 + P_5) + B_4P_1 + B_3P_2 + B_2P_3 + B_1P_4 \]
(6) every 9000 miles

\[ B_{6} = N (P_{1} + P_{2} + P_{3} + P_{4} + P_{5}) + B_{3}P_{1} + B_{4}P_{2} + B_{5}P_{3} + B_{2}P_{4} + B_{1}P_{5} \]

**H. Calculation of Standby Machine for Truck**

Plan of stand by machine for truck calculation for probability of failures

Poisson Distribution

\[ P_{n} = \frac{e^{-\lambda} \lambda^{n}}{n!} \]

\( \lambda \) = average of machines undergo repairs = 4 machines

\( e \) = 2.7183

Stand by cost = 50,000 kyats/day

Loss in work and service = 120,000 kyats/machine/day

Conditions get serious when five or more machines are out of operation at once.

So, addition loss = 450,000 kyats

Minimum total cost = 292,970 kyats

Four standby machines should be used the plant have minimum total costs.

**III. RESULTS AND DISCUSSION**

The purpose of this thesis was to develop a maintenance plan for three-wheels roller and truck owned by highway department. They are having breakdowns and problems with their heavy machinery that is exposing their workers to risks and costing the department money. These troubles are believed to be related to inadequate field maintenance of their three-wheels roller and truck. The goal of this thesis was to provide a plan to help improve thesis conditions.

Basic risk management principles were also reviewed because the department considered it imperative to integrate them when controlling these losses. From the results, the highway department could benefit from a preventive maintenance plan. Such a plan could help protect workers and company assets.

Management needs to provide an expectation of minimum care standards to be used in the maintenance and repair of highway department’s three-wheels roller and truck heavy machinery.

**Table IV. Results Data of Total Preventive Maintenance Cost for Three-Wheels Roller**

<table>
<thead>
<tr>
<th>Hours Plan</th>
<th>Total Preventive Maintenance Cost (TPM) (kyats)</th>
<th>TPM/1000hrs (kyats)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 hours plan</td>
<td>301,500,000</td>
<td>301,500,000</td>
</tr>
<tr>
<td>3000 hours plan</td>
<td>307,500,000</td>
<td>153,750,000</td>
</tr>
<tr>
<td>4000 hours plan</td>
<td>334,515,000</td>
<td>111,605,000</td>
</tr>
<tr>
<td>5000 hours plan</td>
<td>370,560,000</td>
<td>92,640,000</td>
</tr>
<tr>
<td>6000 hours plan</td>
<td>411,540,000</td>
<td>8,230,800</td>
</tr>
<tr>
<td>7000 hours plan</td>
<td>433,440,000</td>
<td>72,240,000</td>
</tr>
<tr>
<td>8000 hours plan</td>
<td>452,670,000</td>
<td>64,667,142.8</td>
</tr>
<tr>
<td>9000 hours plan</td>
<td>456,810,000</td>
<td>57,101,250</td>
</tr>
<tr>
<td>10000 hours plan</td>
<td>464,880,000</td>
<td>51,653,333.33</td>
</tr>
</tbody>
</table>

Minimum preventive maintenance cost/1000 hrs = 51,653,333.33 kyats

Choose 10000 hours plan for maintenance policy

Total breakdown maintenance cost /1000hrs = 2477876100 kyats

The best policy therefore is to have preventive maintenance for Three-Wheels roller.

**Table V. Results Data of Preventive Maintenance Policies for Truck**

<table>
<thead>
<tr>
<th>Preventive maintenance every miles</th>
<th>Total expected Breakdowns in Every miles</th>
<th>Mean no. of Breakdowns per 1500 miles (kyats)</th>
<th>Expected breakdown cost per 1500 miles (kyats)</th>
<th>Expected preventive maintenance cost per 1500 miles (kyats)</th>
<th>Expected cost total 1500 miles maintenance Policy (kyats)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3500</td>
<td>240</td>
<td>108,000,000</td>
<td>9,800,000</td>
<td>108,000,000</td>
<td>9,800,000</td>
</tr>
<tr>
<td>3000</td>
<td>204</td>
<td>87,800,000</td>
<td>6,666,667</td>
<td>87,866,666,67</td>
<td>6,666,667</td>
</tr>
<tr>
<td>4500</td>
<td>195,2</td>
<td>87,800,000</td>
<td>6,666,667</td>
<td>87,866,666,67</td>
<td>6,666,667</td>
</tr>
<tr>
<td>6000</td>
<td>210,48</td>
<td>94,718,000</td>
<td>5,000</td>
<td>94,718,000</td>
<td>5,000</td>
</tr>
<tr>
<td>7500</td>
<td>240,748</td>
<td>108,336,000</td>
<td>4,000</td>
<td>108,376,000</td>
<td>4,000</td>
</tr>
<tr>
<td>9000</td>
<td>282,1168</td>
<td>126,952,560</td>
<td>3,333,333</td>
<td>126,952,560</td>
<td>3,333,333</td>
</tr>
</tbody>
</table>
The best preventive maintenance policy in every 4500 miles

$$TC_p = 87,906,666.67 \text{ kyats}$$

Since total cost for breakdown maintenance

$$TC_b = 1,894,737,000 \text{ kyats}$$

$$TC_p < TC_b$$

The best policy therefore is to have preventive maintenance for truck.

Table VI. Results Data of Poisson Distribution for Three-Wheels Rollers and Truck

<table>
<thead>
<tr>
<th>Poisson Distribution (P_n)</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Three-wheels Rollers</td>
</tr>
<tr>
<td>P_0</td>
<td>0.0498</td>
</tr>
<tr>
<td>P_1</td>
<td>0.149</td>
</tr>
<tr>
<td>P_2</td>
<td>0.224</td>
</tr>
<tr>
<td>P_3</td>
<td>0.224</td>
</tr>
<tr>
<td>P_4</td>
<td>0.168</td>
</tr>
<tr>
<td>P_5</td>
<td>0.101</td>
</tr>
<tr>
<td>P_6</td>
<td>0.0504</td>
</tr>
<tr>
<td>P_7</td>
<td>0.0216</td>
</tr>
<tr>
<td>P_8</td>
<td>0.008</td>
</tr>
<tr>
<td>P_9</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Table VII. Results Data of the Optimum Number of Standby Machines for Three-wheels Rollers

<table>
<thead>
<tr>
<th>No of Standby (n)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Lost cost (0)</th>
<th>standby cost (0)</th>
<th>total cost (0)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0480</td>
<td>0.014</td>
<td>0.0225</td>
<td>0.0118</td>
<td>0.0101</td>
<td>0.0226</td>
<td>0.0106</td>
<td>0.0063</td>
<td>0.0040</td>
<td>0.003</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Table VIII. Results Data of the Optimum Number of Standby Machines for Truck

<table>
<thead>
<tr>
<th>No of Standby (n)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Lost cost (0)</th>
<th>standby cost (0)</th>
<th>total cost (0)</th>
</tr>
</thead>
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<td></td>
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Figure 7. Three-Wheels Roller (Sakai R2H-2K 3)

Figure 8. Truck
IV. CONCLUSIONS

In this study, breakdown maintenance cost for three-wheels roller was 2,477,876,100 kyats and preventive maintenance cost was 51,653,333.33 kyats. The best policy therefore is to have preventive maintenance for three-wheels roller. Moreover, five standby machines should be used the plant have minimum total cost, about 112,960 kyats.

The result of breakdown maintenance cost for truck was 1,894,737,000 kyats. The best preventive maintenance policy in every 4500 miles for truck was 87,906,666.67 kyats. The best policy therefore is to have preventive maintenance for truck. Finally, four standby trucks should be used the plan have minimum total cost about 292,970 kyats.

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REFERENCES