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Integration of Process Costing into Inspection Process Determination

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ABSTRACT

This paper utilizes the concept of process costing methodology to determine an appropriate inspection point of a continuous process. Three types of inspection processes are considered. They are before, during, and after production inspection processes. The objective of this paper is to determine an appropriate setting of a during production inspection process where the unit cost is minimized. Two situations are considered in the during production inspection process, scrapped and reworked situations. Optimization models of finding an appropriate inspection point are proposed and numerical examples are given to illustrate the uses of the models.

Nomenclature

The following nomenclatures are used in this research.

Variable	Descriptions
UC	Unit cost
C_M	Original material cost per unit
AC_M	Actual material cost per unit

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P_C	Process percentage from beginning to the during production inspection process
C_C	Original conversion costs per unit
AC_C	Actual conversion costs per unit
C_{I1}	The during production inspection cost
$\Pr_1$	Probability of passing the during production inspection process
C_{I2}	The after production inspection cost
$\Pr_2$	Probability of passing the after production inspection process
UC_I	Unit inspection costs
D	Defective rate in the case of no during production inspection process

1. Introduction

Costing is an important process that many companies engage in to keep track of where their money is being spent in the production and distribution processes (Hammer, et al., 1993; Shim and Siegel, 2009). Costing system is an accounting system established to monitor a company's costs, providing management with information on operations and performance. The primary objective of any costing system is to determine the cost of the products manufactured or the services provided by the company.

Job order costing and process costing are the two most widely used cost accumulation methods, and they have several aspects in common. Although the ultimate objective of both methods is the unit product cost, the two methods differ fundamentally in their approaches. In job order costing, cost is traced to an individual batch, lot, or contract. Job order costing is applicable to made-to-order works in factories, workshops, and repair shops; to work by builders and construction engineers; and to service businesses such as medical, legal, architectural, accounting, and consulting firms.

In process costing, cost is traced to a department, operation, or some other subdivision within the factory. Process costing accumulates all the costs of operating a process for a period of time and then divides the costs by the number of units of product that passed through that process during the period; the result is a unit cost.

Manufacturing cost – also called production cost or factory cost—is usually defined as the sum of three cost elements: direct material cost, direct labor cost, and factory overhead cost. Direct material cost and direct labor cost together are called prime cost. Direct labor cost and factory overhead cost together are called conversion cost. Material cost, in this case, means direct material, which can be easily identified with the unit of production. For example, cost of glass is a direct material cost in light bulb manufacturing (Lanen *et al*., 2008). Conversion cost is a cost of converting raw materials into products and it is the combination of direct labor and factory overhead costs. In a process, direct material cost may be added in a lump sum at a point in the production process. This research assumes that direct material cost is added at the beginning of the production process. Conversion cost (direct labor cost plus factory overhead cost) is normally assumed that the costs considered to be added uniformly in proportion to how complete the unit is. This research is also used the assumption.

During production, there may be defective. Inspection processes can aid in classifying products into good and defective items. Inspection is an appraisal activity that compares goods or services to a standard. Inspection can occur at three points: before production, during production, and after production. The logic of checking conformance before production is to make sure that inputs are acceptable. The logic of checking performance during production is to make sure that the conversion of materials into goods is proceeding in an acceptable manner. The logic of checking conformance of output is to make a final verification of conformance before passing goods on the customers (Stevenson, 2007). This research assumes that the incoming materials are acceptable and considers only during production and after production inspections.

This research combines the concept of process costing methodology to determine an appropriate inspection point (during production inspection point). Since the process costing methodology is used to calculate the unit cost, this objective of this paper is to determine an appropriate inspection point that minimizes the unit cost. Two situations are considered in the during production inspection process. They are scrapped and reworked situations. Optimization models of finding an appropriate inspection point are proposed and numerical examples are given to illustrate the uses of the models.

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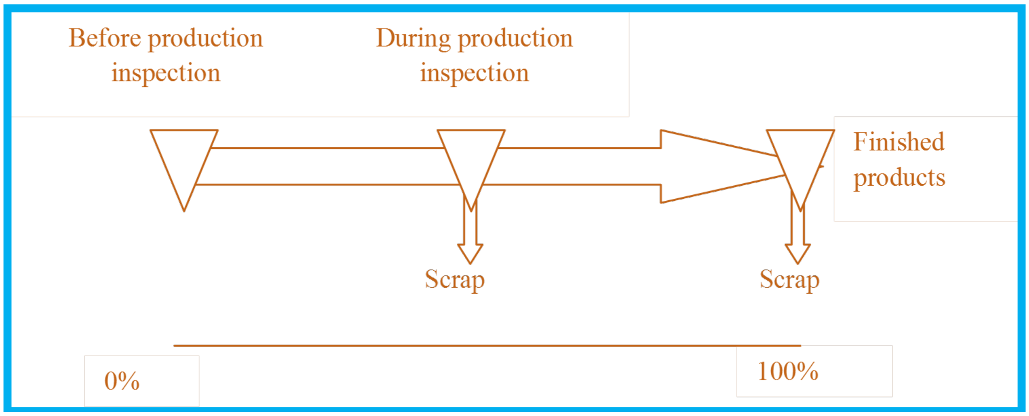

Figure 1: Scrapped situation

2. The Situations

In a continuous process, all materials are inspected to ensure that they are in the acceptable ranges of conformance. Then the materials are added in to the process. This paper assumes that the materials are added in a lump sum at the beginning of the process. To transform the materials to finished products, labor and overhead costs are required. The summation of labor and overhead costs is called conversion cost. Conversion cost is normally assumed that the costs considered to be added uniformly in proportion to how complete the unit is. A during production inspection process is exist. This paper tries to determine an appropriate inspection point of a during production inspection process. Two situations are considered: scrap and rework.

The first situation is called scrap. In this situation, when the on-going product enters the inspection process. The on-going product is classified into two types. If the on-going unit is in an acceptable manner, the unit is continuous produced otherwise it is scraped. After finishing production, an after production inspection exists. If the unit conformance is in an acceptable manner, the unit is sent to an inventory. If not, the unit is scrapped. Assume that the probability of occurring defective items is increased uniformly in proportion to how complete the unit is. Figure 1 explains this situation called scrapped situation. The numbers of percentage on the line in Figure 1 show how much units have been processed. 0% means the units haven't started processing and 100% means the units turn to be finished products.

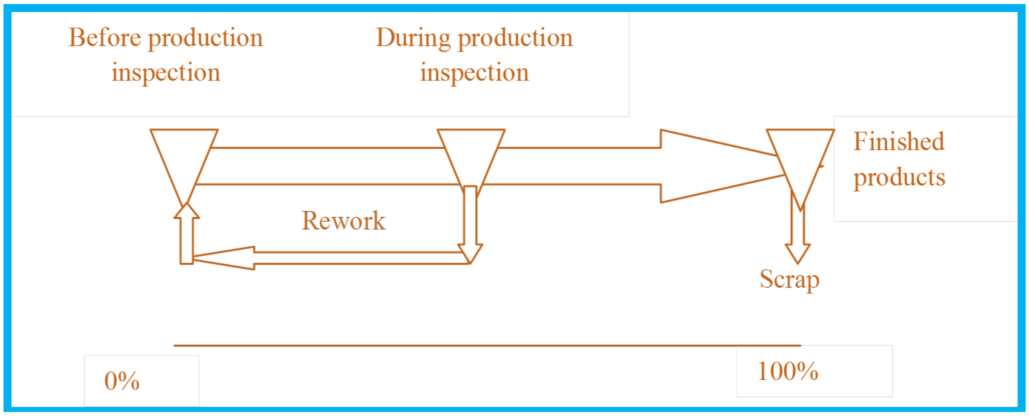

Figure 2: Reworked situation

The second situation is called rework. In this situation, at the during production inspection point, the on-going unit would be continuously produced if the conformance is in an acceptable manner. On the contrary, if the conformance is out of an acceptable manner, the on-going unit is reworked. The reworked process starts at the beginning of the process without adding any more material. After finishing production, an after production inspection exists. If the unit conformance is in an acceptable manner, the unit is sent to an inventory. If not, the unit is scrapped. Assume that the probability of occurring defective items is increased uniformly in proportion to how complete the unit is. Figure 2 shows the situation in summary.

3. The Models

This paper applies the concept of process costing methodology and the primary objective of any costing system is to determine the cost of the products manufactured or the services provided by the company. Therefore, the minimization of unit cost is employed. The unit cost can be calculated by the summation of actual material cost per unit, actual conversion costs per unit, and unit inspection costs (Equation (1)).

$$UC = AC_M + AC_C + UC_I \tag{1}$$

To calculate AC_M, AC_C, and UC_I, the probabilities of passing the during production inspection process and passing the after production inspection process are required. Since the

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probability of occurring defective items is increased uniformly in proportion to how complete the unit is, the probability of occurring defective items at the during inspection point is $D \cdot P_c$. 100% inspection is utilized at the during process inspection point. Therefore, the probability of passing the during production inspection process is:

$$\Pr_1 = 1 - \left(D \cdot P_C\right). \tag{2}$$

After passing the during process inspection point, 100% on going units are conformance units. Defects may incur only by producing after the inspection point. Therefore, the probability of passing the after production inspection process is

$$\Pr_2 = 1 - \left(D \cdot \left(1 - P_C\right)\right). \tag{3}$$

Two situations are considered in this paper: scrapped and reworked situations. The first situation is scrapped situation. If units are scrapped, materials spent to the units are lost. Actual material cost is calculated by subsidizing those scrapped items. Therefore, with the probabilities of passing the first and second inspection processes ($\Pr_1, \Pr_2$), actual material cost per unit (AC_M) can be calculated as

$$AC_M = C_M / (\Pr_1 \cdot \Pr_2). \tag{4}$$

Similarly, scrapped items during both inspection processes already pay some conversion cost. Conversion cost is assumed to be added uniformly in proportion to how complete the unit is. Hence, conversion cost incurred from the beginning of the process to the during production inspection is $\left(C_C \cdot P_c\right)$. With $\Pr_1$, the average conversion cost incurred from the beginning of the process to the during production inspection is $\left(\left(C_C \cdot P_c\right) / \Pr_1\right)$. The conversion cost incurred from the during production inspection is $C_C \cdot \left(1 - P_c\right)$. The conversion cost incurred before passing the after production inspection is $\left(\left(C_C \cdot P_c\right) / \Pr_1 + C_C \cdot \left(1 - P_c\right)\right)$. With the probability of passing the after production inspection ($\Pr_2$), actual conversion cost per unit is

$$AC_C = \left(\left(C_C \cdot P_c\right)/\Pr_1 + C_C \cdot \left(1 - P_c\right)\right)/\Pr_2 . \tag{5}$$

Total inspection costs are the combination of the during and after production inspection costs. To subsidize the inspection costs incurred to scrapped items, the equation of unit inspection costs can be shown as

$$UC_I = \left(C_{I1}/\Pr_1 + C_{I2}\right)/\Pr_2 \tag{6}$$

The unit cost is then the summation of actual material cost, actual conversion cost, and total inspection costs (Equation (7)).

$$UC = C_M/(\Pr_1 \cdot \Pr_2) + \left(\left(C_C \cdot P_c\right)/\Pr_1 + C_C \cdot \left(1 - P_c\right)\right)/\Pr_2 + \left(C_{I1}/\Pr_1 + C_{I2}\right)/\Pr_2 . \tag{7}$$

The second situation, reworked situation, with the probability $\left(1 - \Pr_2\right)$, the items are scrapped and material of those scrapped items are lost. Actual material cost is calculated by subsidizing those scrapped items. Hence, the actual material cost per unit is:

$$AC_M = C_M/\Pr_2 . \tag{8}$$

Before entering the after production inspection process, conversion costs incur as $C_C + \left(1 - \Pr_1\right) P_c \cdot C_C$, where C_C is an original conversion costs per unit and $P_c * C_C$ is the conversion costs of reworked process. The actual conversion costs then can be calculated as:

$$AC_C = \left(C_C + \left(1 - \Pr_1\right) P_c \cdot C_C\right)/\Pr_2 \tag{9}$$

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Total inspection costs are the combination of the during and after production inspection costs. The during production inspection cost may not incur once per item. There is a probability $(1-\Pr_1)$ that the items are reworked. Therefore, the inspection cost of during production inspection process is $C_{I1}/\Pr_1$ and the unit inspection cost can be shown as:

$$UC_I = \left(C_{I1}/\Pr_1 + C_{I2}\right)/\Pr_2 \tag{10}$$

Based on above, the unit cost turns to be:

$$UC = C_M/\Pr_2 + \left(C_C + \left(1-\Pr_1\right)P_c \cdot C_C\right)/\Pr_2 + \left(C_{I1}/\Pr_1 + C_{I2}\right)/\Pr_2 . \tag{11}$$

4. Numerical Example

In an electronic manufacturing process, direct materials are normally used in the beginning of the process. The cost of direct materials is then applied in the beginning of the process. Assuming that direct labor and others are added uniformly in proportion to how complete the unit is. The cost of direct labor and others or conversion cost is then applied uniformly in proportion to how complete the unit is. Assume that the probability of occurring defective items is increased uniformly in proportion to how complete the unit is. There are three inspection processes: before production, during production, and after production. Direct materials have 100% inspection before entering the process. The unit costs of material and conversion are 100 and 1,000 respectively. The during and after production inspection costs are 20 and 50. Lastly, defective rate in the case of no during production inspection process is 20% or 0.2.

Applying the model and minimizing the UC by using solver, it is shown that the optimum during production inspections in the cases of scrapped and reworked are at 51.96 and 66.27 percentage from beginning process respectively. The associated unit costs are 1,376.42 and 1,352.10. Figure 3 shows the relations between P_C and UC in both situations. It can be seen that the relation patterns of both situations seem to be the same. By increasing P_C, UC is decreased until a turning point. Then keep increasing P_C would bring UC up. By comparing

AC_M and AC_C, AC_M seems to be less sensitive than AC_C (Figures 4-5). Further analyses are giving in the changes of material and conversion costs. Figures 6-7 show the results. It can be seen that in the scrapped situation, changing C_M would not affect P_C but in the reworked situation, changing C_M is highly influence to P_C. Considering C_C, P_C of the reworked situation is highly sensitive than that of the scrapped situation. P_C of the reworked situation is always higher than that of the scrapped situation.

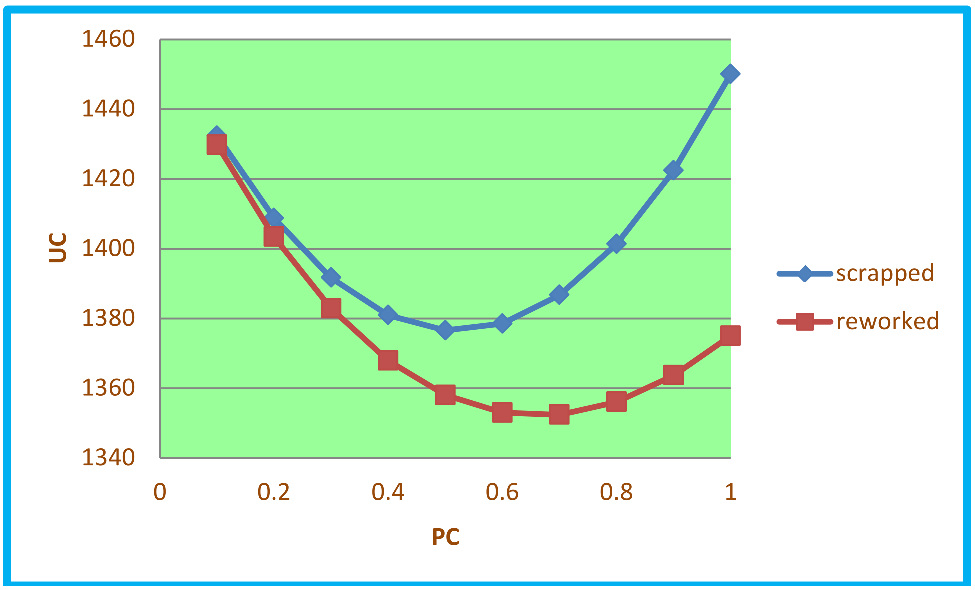

Figure 3: Relations between P_C and UC

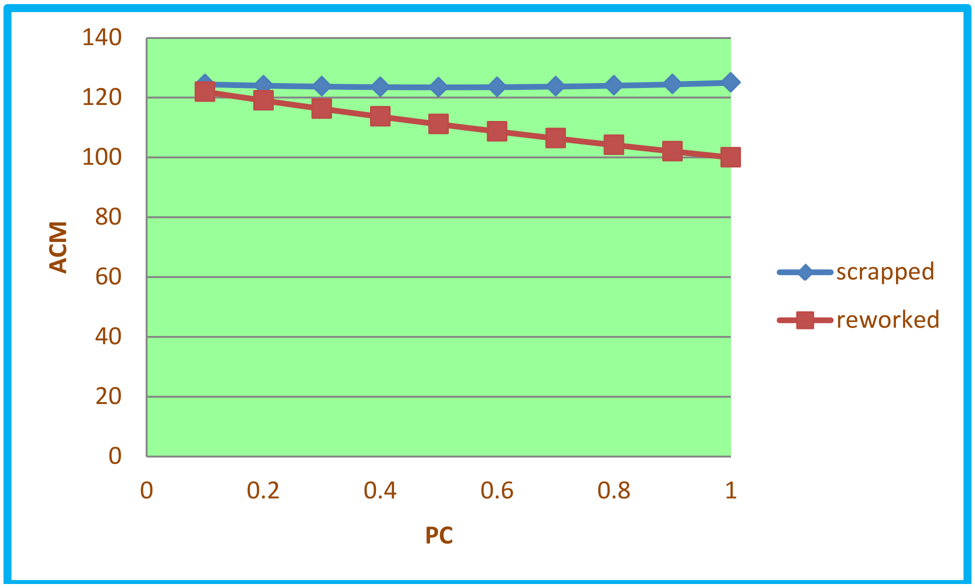

Figure 4: Relations between P_C and AC_M

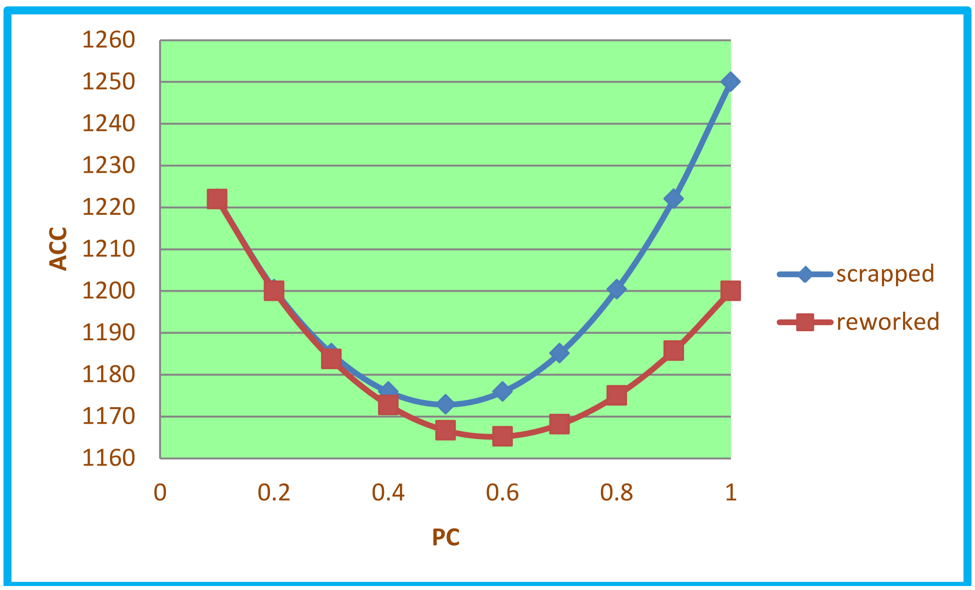

Figure 5: Relations between P_C and AC_C.

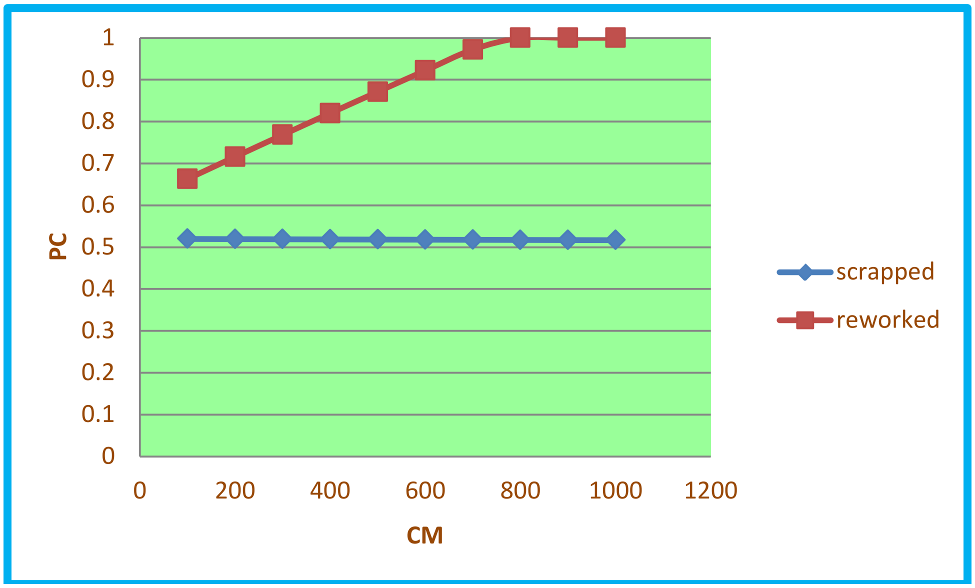

Figure 6: Relations between C_M and P_C.

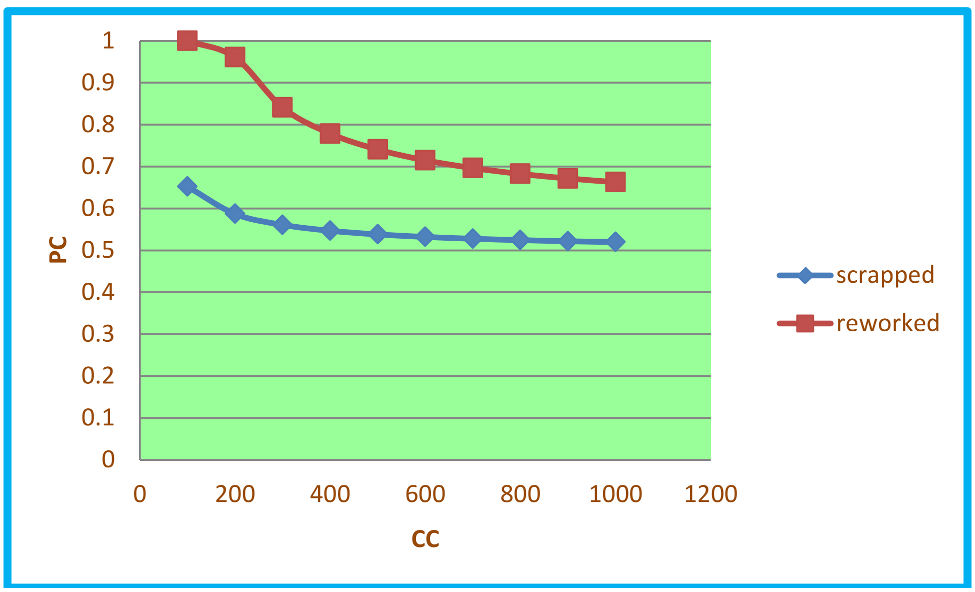

Figure 7: Relations between C_C and P_C.

5. Discussions

This paper uses the concept of process costing methodology to determine an appropriate setting of during production inspection point whereas assuming that the before and after production inspections are utilized. The numerical example given above shows the means to find the

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appropriate setting. Based on the example, it can be seen that by increasing P_C, UC is decreased until a turning point. Keep increasing P_C would bring UC up. Moreover, comparing between the two situations, P_C of reworked situation would be greater than that of scrapped situation and unit cost of scrapped situation would be greater than that of reworked situation. Finally, it can be concluded that selecting an inappropriate P_C would increase unnecessary costs.

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