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INCREASING LINE EFFICIENCY BY USING TIMESTUDY AND LINE BALANCING IN A FOOD MANUFACTURING COMPANY

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ABSTRACT

This paper presents a study that aims to increase the productivity and efficiency of a food processing line in a company. The selected line is the bun production line because the line contributes the highest demand. The method selected to improve this line is a combination of line balancing and work study methods. Line balancing was used to measure the inefficiency of the line and later was used to measure the effectiveness of the proposed solution. Line balance loss analysis and work study methods specifically method and time study are used to identify opportunity for improvement as well as to evaluate the effectiveness of the proposed improvements. Improved methods were proposed and time study conducted. Evaluation on the effect of the proposed improvements shows that the line balance loss is reduced from 69% to 23% and efficiency of the line is increased from 30% to 76%.

Keywords : *line balancing, work improvement, work design, economic analysis*

1.0 INTRODUCTION

Productivity in manufacturing industry plays an important role in keeping the company competitive for the market as well as for its survival. Many leading companies are implementing changes and new work methods in order to survive in an environment where only the leanest, and most responsive will survive [1]. It is importance for a company to earn profit and this may be increased through improvement on productivity [2].

Productivity improvement means producing more output with the same amount of resource used. It is defined as the ratio between output and input [3, 4]. Removing non-value-added input and optimizing production cycle time will improve the performance of manufacturing process, thus making manufacturing companies sustainable and competitive [5].

This study aims to improve the productivity and efficiency of the production line in a small and medium size food industry. Based on data collected through observations, interviews and study of production documents and reports, line balancing has been identified as a problem that is affecting the efficiency of the production line.

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This study proposes and evaluates the effectiveness of the proposed solutions. The case study company has been in operation since thirty years ago making and selling its own branded bakery products. The company is now producing about 60 types of bakery products. However, this study covers only the production line for the product with the highest demand which is the Bun. Data collected through observations, interviews and documentation study and identified the main problem related to productivity is that the production line is unbalanced. The cause of the problems are related to man, machinery, material and method and is presented in the form of cause and effect diagram, also known as Ishikawa diagram as shown in Figure 1. This situation causes the inefficient utilization of operators and machines in the production line. This problem affects the company's production capacity to achieve daily demand.

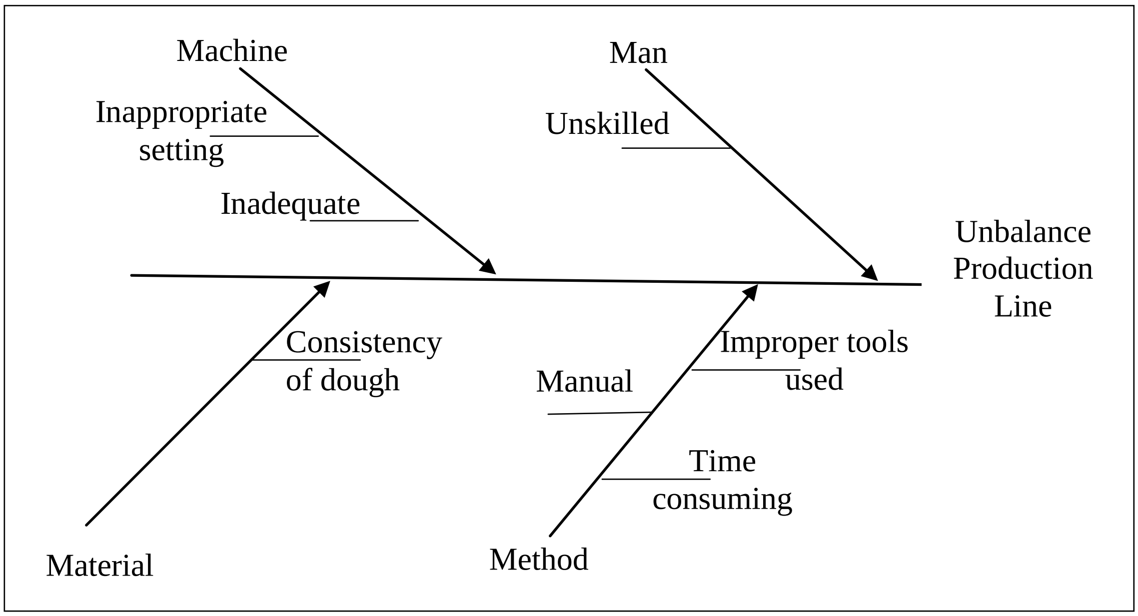

Figure 1: Cause and effect diagram

Although there are many causes to the problem of unbalanced production line that have been identified, this study only focuses on solutions related to method of work and line balancing.

2.0 PROBLEM IDENTIFICATION

Data collection is an important stage in identifying the problems in the current production line. During the observation of each process in different stations, direct time study was carried out. Time study is used to establish the standard time for each work station. The result of the time study is shown in Table 1. The resulted standard time will be used as the cycle time.

Data in Table 1 is represented in Figure 2 as histogram to illustrate the distribution of workload between the workstations. It shows that the workload between the stations are not balance and some will be idle for a long time while others will experience bottleneck especially in the packaging process.

The fermentation and cooling workstations are not considered in Figure 2 because they are natural processes that cannot be shortened or improved through work study without affecting product quality. The histogram in Figure 2 shows that bottleneck in the production line occurs at the weighing and dough formation/divider and the packaging workstation. The weighing and dough divider process is mostly machine operation but packaging process is done manually. This project will focus on improving the packaging process as it has the highest cycle time and is a manual process, thus, suitable for improving using workstudy method.

Table 1: Standard Time for product Bun

Workstation / Operation	Mean Cycle Time per unit (sec)	Rating (%)	Allowance (%)	Normal Time per unit (sec)	Standard Time per unit (sec)
Mixing	0.54	100	0	0.54	0.54
Refinery	0.08	100	0	0.08	0.08
Weighing and dough formation/divider	2.2	100	0	2.2	2.2
Fermentation	7.01	100	0	7.01	7.01
Baking	0.63	100	0	0.63	0.63
Cooling	2.5	100	0	2.5	2.5
Packaging	3.04	120	0.11	3.9	4.329
Storage	0.21	90	0.11	0.19	0.21
Total					17.499

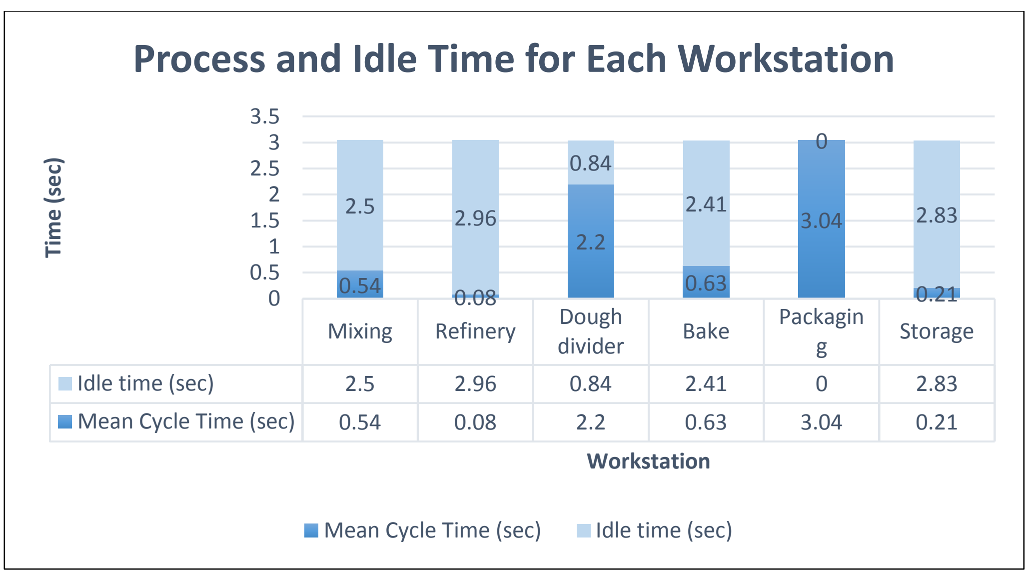

Figure 2: Process and Idle Time for Each Workstation

In analyzing the line balance loss, the takt time should be considered so that work for each workstation can be distributed the work equally, minimizing idle worker for each workstation. Formula (1) is the computation for takt time [6]:

Takt Time = Working time / demand (1)

Total working time= 7.5 hours/day × 6 days /week × 4 weeks/month

=180 hours/month

=648 000 sec/month

However, product Bun shares the production line with other products. Based on activity sampling 69.74% (451,915 sec/month) of the production or work time is used to produce Bun. The demand per month for Bun is about 380,000 units. Therefore using equation (1);

Takt Time = Working time / demand
= 451 915 / 380,000
= 1.19 sec/unit

Based on this result, each workstation should not exceed 1.19 sec/unit to improve the production line and maintain the production at equal rates. Generally, total workstation after the improvement should not be lower than a theoretical minimum workstation. If not, the time to complete each task is not enough. Theoretical minimum workstation is calculated as follows;

Total Work Element, (standard time minus the fermentation and cooling time) Te = 7.989 s

Equation (2) shows the formula for calculating theoretical minimum work station [6].

$$\text{Theoretical minimum work station} = \frac{\sum t}{Takt\ time} \quad (2)$$

Using equation (2), for this case study;

$$\text{Theoretical minimum work station} = \frac{7.989\ s}{1.19\ s}$$

$$= 6.7 \approx 7 \text{ workstation}$$

The efficiency and line balancing loss is calculated using equation (3) as shown below [6].

$$\text{Efficiency} = \frac{\sum t}{nc} \times 100 \quad (3)$$

For this case study, using equation (3);

Efficiency = [7.989 / (6 × 4.329)] × 100
= 30.76 %

The percentage of Line Balance Loss is calculated using equation (4) as follows [6].

$$\text{Percentage of Line Balance Loss (\%LBL)} = \frac{nT_{max} - \sum t_i}{nT_{max}} \times 100 \qquad (4)$$

Using equation (4), for this case study;

$$\text{Percentage of Line Balance Loss (\%LBL)} = \frac{(6)(4.329) - (7.989)}{(6)(4.329)} \times 100$$
$$= 69.24\ \%$$

The percentage of line balancing loss is quite high, which is 69.24 %. This indicates that the current assembly line is not so efficient due to inappropriate work allocation and imbalance processing time for the workstations.

3.0 PROPOSED SOLUTION

The proposed solution consists of two parts. One will use line balancing method specifically largest candidate rule and the other will use work design method that is method study and time measurement.

3.1 Balancing Model : Largest Candidate Rule

Each workstation is divided into smaller work elements. The identified working elements and the time are shown in Table 3.

Station	No	Working elements	T_e	Cycle time (sec)	Precedence
Mixing	1	Pour ingredients into mixer	0.03	0.54	None
Refinery	2	Mix the ingredients	0.51		1
Weighing and dough formation/divider	3	Refine the big dough	0.08	0.08	2
Fermentation	4	Divide dough	2.18	2.2	3
Baking	5	Arrange dough on tray	0.02		4
Cooling	6	Fermentation room	7.01	7.01	5
	7	Put inside oven	0.03	0.63	6
Packaging	8	Bake	0.58		7
Mixing	9	Arrange on trolley rack	0.02		8
Refinery	10	Cooling process	2.5	2.5	9
Weighing and dough	11	Take out burger bun from mould	1.13	3.25	10
formation/divider	12	Inspection	0.01		11
Fermentation	13	Arrange in packaging bag	1.82		12
Baking Cooling	14	Sealing	0.3		13
	15	Arrange on trolley rack	0.04	0.05	14
Packaging	16	Send to storage	0.02		15

Table 3: Work Elements of Largest Candidate Rule

For Largest Candidate Rules, the process time of work element is arranged in descending order, as shown in Table 4. After that, the work elements are assigned into station starting from the top of the list, with the rules that the precedence order is not violated and the station time assigned is not exceeding the ideal task time of 1.19 sec/unit. The precedence diagram is shown in Figure 3. This is repeated for other stations until all elements have been assigned.

Table 4 : Work elements in descending order of cycle time

No	Working elements	T_e	Precedence
6	Fermentation room	7.01	5
10	Cooling process	2.5	9
4	Weighing and make dough	2.18	3
13	Arrange in packaging bag	1.82	12
11	Take out burger bun from mould	1.13	10
8	Bake	0.58	7
2	Mix the ingredients	0.51	1
14	Sealing	0.3	13
3	Refine the big dough	0.08	2
15	Arrange on trolley rack	0.04	14
1	Pour ingredients into mixer	0.03	None
7	Put inside oven	0.03	6
5	Arrange dough on tray	0.02	4
9	Arrange on trolley rack	0.02	8
16	Send to storage	0.02	15
12	Inspection	0.01	11

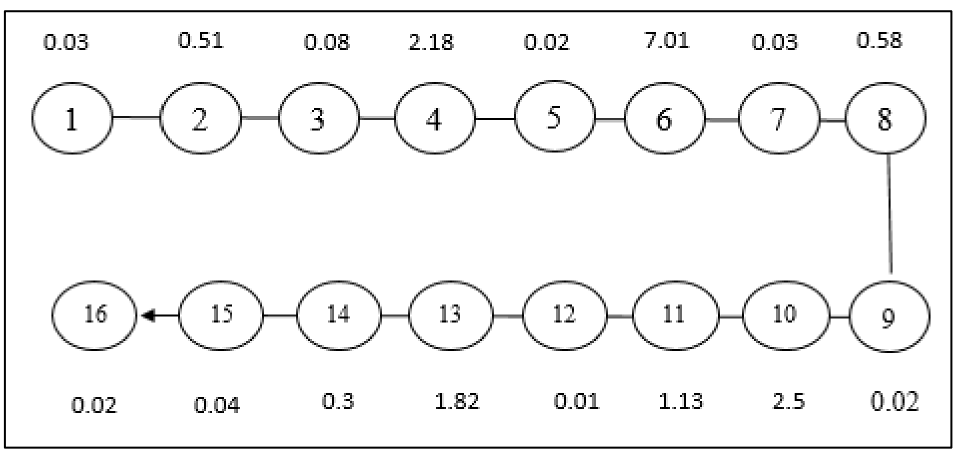

Figure 3: Process Flow Diagram

Table 5 shows the resulted assignment of the elements into workstations. This assignment has resulted in 9 workstations instead of previously 8 stations. This is done so that each workstation does not exceed the Takt time of 1.19 seconds. It also shows that bottleneck occur in workstation 2 and 8. This is due to exceeding the Takt time of 1.19 sec/unit. For the workstation 4 and 6, the time element also exceeded the Takt time. However, the process cannot be improved due to the nature of the process.

Table 5: Assignment of the elements into workstation

Workstation	No	Working Element	Time	Total time	Idle time
1	1	Pour ingredients into mixer	0.03	0.62	0.57
	2	Mix the ingredients	0.51		
	3	Refine the big dough	0.08		
2	4	Dough divider	2.18	2.18	-0.99
3	5	Arrange dough on tray	0.02	0.02	-1.17
4	6	Fermentation room	7.01	7.01	5.82
5	7	Put inside oven	0.03	0.63	0.56
	8	Bake	0.58		
	9	Arrange on trolley rack	0.02		
6	10	Cooling process	2.5	2.5	-1.31
7	11	Take out burger bun from mould	1.13	1.14	0.05
	12	Inspection	0.01		
8	13	Arrange in packaging bag	1.82	1.82	-0.63
9	14	Sealing	0.3	0.36	0.83
	15	Arrange on trolley rack	0.04		
	16	Send to storage	0.02		

Two work elements (as highlighted in Table 5) have been identified with high cycle time and the source for bottleneck and line balance loss. They are work element 13 of the Packaging Process and work element 4 of the Dough Divider workstation. The following section will present the proposed solution in detail to improve the process and activity in the respective workstations.

3.2 Proposed Improvement for Work Element 13 - Packaging

The packaging process consists of three elements, they are inspection which have a cycle time 0.01 seconds, arrange bun in bag which have a cycle time of 1.82 seconds and sealing which have a cycle time of 0.3 seconds. Element arrange bun in bag is selected to be improved as it exceeds the takt time of 1.19sec/unit. The working element is by manual process. So it can be improved through work design.

When a new proposed method is developed, this method is not practiced yet and therefore stopwatch study is not possible. Predetermined Motion Time System (PMTS) will be used to establish the standard time. To enable a fair comparison between the proposed method , the standard time for current method will also be recalculated based on PMTS.

The procedure will be conducted by basic methods-time measurement (MTM-1). The system identifies the basic motion of an operation or manual method. Table 6 shows MTM Analysis of the process using two hand chart.

The highlighted row in Table 6 shows the activity that can be eliminated by redesigning the hand motion so that the left and right hand motions are balanced. The new proposed solution after elimination and rearrangement of activities is shown in Table 7.

The proposed method has improved the standard time from 1.737 seconds to 0.783 seconds. The improvement is achieved by simply rearranging the work layout. Figure 4 shows work layout of the current/existing and the proposed method. By simply providing a packaging bag for each worker rather than sharing, the proposed method was able to eliminate idle time and achieve motion economy.

Table 6 : MTM Analysis Using Two Hand Chart - Current Method

Operator	LH Description	Code	TMU	TMU	Code	RH Description
Arrange burger bun into packaging bag						
Operator 1	Idle	--	--	13.4	R12B	Reach
	Idle	--	--	2.0	G1A	Grasp
	Idle	--	--	13.4	M12B	Move to packaging area
	Open the packaging bag	D1	4.0	4.0	D1	Open the packaging bag
	Hold packaging back	--	--	20.1	R22B	Reach
	Idle	--	--	2.0	G1A	Grasp
	Idle	--	--	19.4	M22B	Move to packaging bag
	Idle	--	--	2	RL1	Release into packaging bag
TMU = 76.3 = 2.75 seconds/2 operator =1.737 sec						

Table 7: MTM Analysis Using Two Hand Chart - Proposed Method

Operator	LH Description	Code	TMU	TMU	Code	RH Description
Arrange burger bun into packaging bag						
Operator 3,4	Reach packaging bag	R3/4B	2.0	20.1	R22B	Reach burger bun
	Grasp	G1A	2.0	2.0	G1A	Grasp
	Open the packaging bag	D1	4.0	19.4	M22B	Move to packaging bag
	Hold packaging back	--	--	2	RL1	Release into packaging bag
Total TMU			TMU= 43.5			
	43.5 ×0.036 seconds = 1.566 seconds 1.566 seconds/2operators = 0.783 sec					

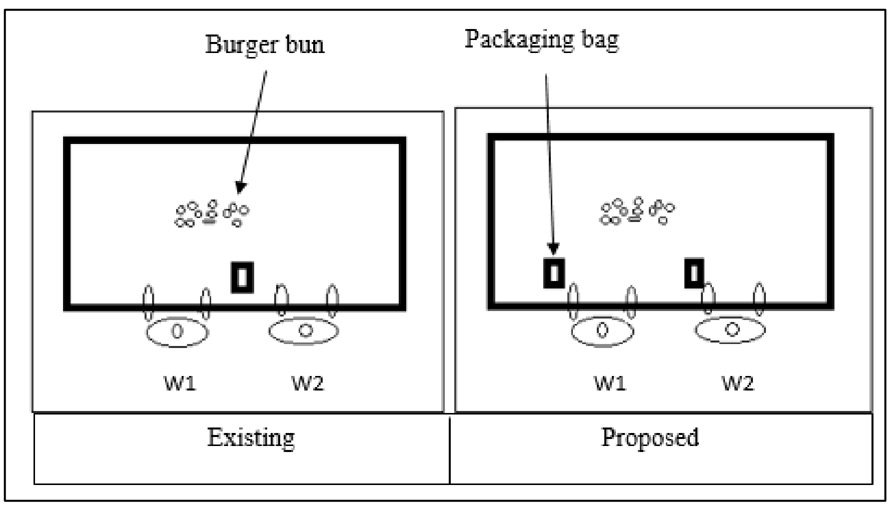

Figure 4: Workstation Layout

The proposed method allows the workers to simultaneously take the packaging bag with their left hand and the bun with the right hand. The packaging bag is easy to open using one hand only. The left hand just holds the packaging bag and right hand will arrange the burger bun until complete.

Based on the calculation, the percentage of time reduce is;

$\frac{1.7374\ sec}{7.989\ sec} \times 100 = 21.75\ \%$ to $\frac{0.783\ sec}{7.989\ sec} \times 100 = 9.8\ \%$

So the improvement is 11.95 %

3.3 Proposed Improvement for Work Element 4 - Dough Divider

Work element 4 does not involve any manual process. The only machine used is dough dividing machine. The existing machine can only produce 5 pieces of dough per batch. That means they undergo the same process at the same time from inserting the big dough until producing 5 pieces of small dough. For the existing machine, only one worker needs to operate the machine. The time taken from the machine to produce adequate amount to fulfill demand without any overtime is impossible. So the workers always have to do overtime to achieve the target demand. It is very costly.

Hence another machine at this workstation should be added. Similar machine but with higher capacity has been identified and recommended. It can produce 8 pieces of dough per batch as compared to existing the machine that can produce 5 pieces of dough only. If the recommended machine is added to this workstation, the company can produce 13 pieces of dough per batch. The new machine proposed can increase the productivity and decrease the time consume for each unit of bun. The average time taken for each pieces of dough to undergo the process is 2.18 seconds per unit. Total time taken for the existing machine to produce 5 pieces of dough is:

2.18 sec × 5 units = 10.9 sec

After adding the new dough dividing machine, the company can actually produce 13 pieces of dough per batch instead of producing 5 pieces of dough per batch in 10.9 sec. Hence, the new average time taken to produce one piece of dough is:

$\frac{10.9\ sec}{13\ pieces\ of\ dough}$ = 0.838 sec per piece of dough

In one shift, the company can only produce 56,670 pieces of dough burger buns using existing machine. So the available time for the worker to work only one shift is:

2.18 sec × 56 670 units = 123,322 seconds

By adding new machine to operate at the same time, at 123,322 seconds, the company can produce a lot more dough as the time taken is reduced:

$\frac{123\ 322\ sec}{0.838\ sec}$ = 147 162.29 ~ 147,162 pieces of dough

Thus, 147,162 pieces of dough can be produced if both machines operated together while if the existing machine there is only 56,670 units only can be produced. If both machines are used, the production is increased from 56,570 units to 147,162 units. Percentage of bun production is increased from:

$\frac{56\ 670\ units}{380\ 000\ units} \times 100 = 14.91\ \%$ to $\frac{147\ 162\ units}{380\ 000\ units} \times 100 = 38.73\ \%$

So there is a 23.82 % increase in production.

4.0 RESULTS AND DISCUSSION

The company faces a high line balance loss of 69% and line efficiency of only 30%. To reduce the LBL the Largest Candidate rule was used. This method has presented a sequential approach for balancing a production line with the objectives of minimization of LBL and increase efficiency. The results however show that two work element namely packaging and dough divider was more than the Takt time of 1.19 sec/unit. The two work element need to be improved to further reduce the LBL and increase efficiency.

Improvement using work design approach was proposed for packaging as it is a manual process. The dough divider is a machine operated process, therefore an additional machine was proposed. The overall workstation achieved the target to have each workstation below the cycle time of 1.19 seconds. Thus, if the suggestion of improvement is applied, using equation (3) and (4) respectively, the efficiency and percentage LBL are as follows;

$$\text{Efficiency} = \frac{\sum t}{nc} \times 100$$
$$= [4.373/ (5 \times 1.143)] \times 100$$
$$= 76.52\%$$

$$\text{Percentage Line Balance Loss (\%LBL)} = \frac{nT_{max} - \sum t_i}{nT_{max}} \times 100$$
$$= \frac{(5)(1.143) - (4.373)}{(5)(1.143)} \times 100$$
$$= 23.48\%$$

Table 8 shows the comparison of production line efficiency and LBL for both current method and the proposed method. The proposed improvements have managed to increase the production line efficiency from 30% to 76% and the LBL has been reduced from 69% to 23%. Thus, both efficiency and Line Balance Loss have been improved by about 45%.

Table 8: Production Line Improvement

	Existing method	Proposed method	Improvement
Efficiency	30.76%	76.52%	45.76%
Line Balance Loss	69.24 %	23.48%	45.76%

5.0 CONCLUSION

The objective of this study is to identify the main problem in the production line for a product with the highest demand and increase the production and efficiency. Production line is balanced by work improvement method in work design and adding new machine that have been proposed for selected workstation. It have successfully minimized the main problem of the current production line, which is poor line balancing. Evaluation has shown that the proposed solutions can increase the efficiency and productivity of the production.

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