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Productivity Enhancement of Radiator Assembly Line Using Lean Tools and Technique

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In current scenario, competitive business environment, every industry is striving to top the performance on customer satisfaction, product quality, speed to complete manufacturing orders, productivity, diversity of product line, and flexibility to manufacture new products. The main objective of this study concentrates on the implementation of lean concepts in a manufacturing organization. The process flow of the entire assembly operation is made a detailed study to over view the non value added activities involved in the process. This is mainly addressed by making use of the tools such as Standard work, Value Stream Mapping (VSM), Kaizen generation and implementation. The continuous improvement activity is the key point in sustenance of any implementation. The results obtained are documented and studied for the further improvements and elimination of non value added activities. The implementation of the lean concepts in the shop floor will improve the shop standards and reduce the variations among the operator's performance as well.

Keywords - radiator; value stream mapping; lean tools; kaizen; kanban.

I. INTRODUCTION

The basic idea behind the lean manufacturing is to eliminating waste. Waste is defined as anything that does not add value to the end product from the customer's perspective. The basic idea of lean manufacturing is to help manufacturers to improve their organizations ability and become more competitive through the execution of different lean manufacturing tools and techniques.

In the current scenario, industries are developing new tools and techniques to manufacture products to compete and survive in the market. The most intimidating issue faced by manufacturers is how to deliver good quality products or materials at low cost. Lean manufacturing plays a vital role in addressing this issue. Lean manufacturing simply known as lean is production practice, which regards the use of resources for any work other than the creation for the end customer, is waste, and thus a target for elimination. Simply, Lean manufacturing is the set of "tools" that help in the identification of non value added activities. The main tools used in this study are Visual management, Value Stream Mapping (VSM), Changeover reduction. Visual management is used to indicate whether a production line is running according to production plan, Value stream mapping is to establishing flow, eliminating waste, and adding value to the products and Changeover reduction is mainly to reduce the lead time. The main objective of this study is to observe the effectiveness of the implementation of Lean tools in Fluid Power Machines Pvt. Ltd., Coimbatore.

II. BRIEF LITERATURE REVIEW

The implementation of a lean manufacturing strategy allows strengthening the phase sequence that leads to operational excellence, a continuous improvement, and the elimination of non-value-added activities [1]. Thus, the influence of lean practices contributes substantially with the operating performance of plants [2, 3] and the use of lean tools allows the improvement of results [4]. The tool value stream mapping (VSM) is applied as a way to progress toward lean manufacturing and as a formula to lead the activities of improvement [5–9].Therefore, it is a measure of the ability to deliver on time and it is generally a good indicator of the effectiveness of lean initiatives to improve the flow.

In recent years, a plethora of literature has extensively documented the implementation of lean philosophy into various manufacturing sectors. Houshmand and Jamshidnezhad [10] suggested a hierarchical structure in their research to model the design process of a lean production system, which consisted of design parameters and process variables. They also asserted about the generic nature of this architecture. Cagliano et al. [11] made a comparison of the manufacturing performance among lean, agile, and traditional supply chains. Further, they have taken into account the supply strategies of European manufacturing firms and concluded that lean and agile strategies outperform other methods. Shah and Ward [12] studied the effects of three factors, plant size, plant age, and unionization status, on the feasibility of implementing the key facets of lean production systems. They were able to substantiate a strong support for the influence of plant size on lean implementation. The results also indicate that lean implementation contributes significantly to the operating performance of plants. Bamber and Dale [13] delineated the application of lean manufacturing to a traditional aerospace manufacturing industry. However, they revealed that a number of methods of lean production were found to be not as effective as in the motor manufacturing sector; the reasons for this included the dominant position of the company and the customer demand characteristics.

Haque and James-Moore [14,15] applied lean thinking to new product introduction (NPI). They illustrated that concurrent engineering, so far, is implemented to improve NPI, but there is a shortfall in improvement. Moreover, they revealed that this shortfall can be abridged through the implementations of lean thinking to NPI.

Soderquist and Motwani [16] successfully mapped the quality management concepts of lean production in a French automotive parts supplier company. They outlined an integrated approach for quality, including managerial back-up, customer relationships, and operations, and, thereby, achieving a competitive advantage for automotive manufacturers.

Pavnaskary et al. [17] have proposed a classification scheme to serve as a link between manufacturing waste and lean manufacturing tools. The proposed scheme classifies all well-known lean manufacturing tools and metrics. Also, it suggests the tools and metrics that will help to meet manufacturing problems. A customer-focused manufacturing strategy may be seen as comprising the cost, quality, flexibility, and supply dependability dimensions [18-19].

The achievement of high employee utilization, however, does not often require investment[20-22]. Obstacles, such as fluctuations in customer or order frequency, without flexible employee assignments lead to utilization losses. The time determination of processes e.g. in production areas to evaluate the performance level opposes these obstacles efficiently. In particular a neutral and valid base to evaluate performance is required to achieve increases in productivity[24]. Value Stream Mapping does not just contribute to reducing lead times by reducing and avoiding waste, it also contributes to increasing effectiveness and efficiency by improving work methods and the organization of work, thereby raising productivity [25]. Hence from the literature survey it is revealed that the model of lean methodology helps in improving the productivity.

III. METHODOLOGY

In this study Radiator assembly is selected to observe the effectiveness of the implementation of Lean tools.

A. *Product Details*

Radiators are heat exchangers used to transfer heat energy from one source to another for the purpose of cooling and it has wide application in automobiles, agriculture equipment's, mechanical industries.

A radiators uses brass tubes to connect the upper and lower tanks, copper fins for increasing the contact header plates, filler caps, brass necks, brass pipes and mild surface area for improving the heat transfer rate, brass tanks to collect the coolant, brass steel brackets to avoid the fin damage and filler cap to fill the coolant and maintain the constant pressure. Figure 1 shows the Schematic arrangement of Radiator with all its accessories.

Figure 1. Radiator

B. *Process Details*

This study deals with the entire assembly process of the radiator. The major process steps in assembly are Fins making, Tube making, Core assembly, Heater plate assembly, Leak Testing, Neck and pipe assembly, Tank assembly, Pre Dispatch Inspection (PDI), Painting, Final Inspection, Packing and dispatch. Figure 2 shows the process flow chart for the process carried out in the shop floor.

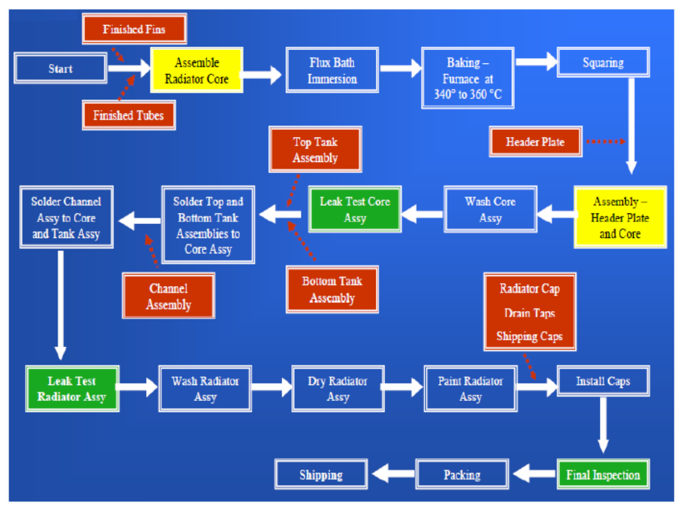


Figure 2. Process flow chart

C. *Problem Definition*

The problem formulated in this study originates from practical problem that organization faced which are difficult in production activity and performance. Preliminary discussion with the organization in the project formulation phase revealed that there are some variations in production execution, where production using different work method, production sequencing, manpower engagement, resulting different output of product in each shift along although available time is the same.

The project charter as shown in Figure 3 clearly indicates the objective of the project and actions to be carried out. The action plan shows the time line in weeks for the carried project work and the actions done respectively.

Project Title: Productivity enhancement of radiator assembly line using lean tools and techniques

Business Case	Opportunity Statement
This project enhances better line balancing with in the flow of process in manufacturing radiators of different mix.	Pain: The current cycle time of radiator models in the month of Oct'16 is 169.5 min, which is not balanced with the flow of the process. **Impact of pain in Rs.(or soft):** Production improvement : 20 nos per day Cycle time reduction: 55 min

Goal statement				Project scope
Metric	*Current level*	*Goal / Target*	*Target date*	Process under improvement: Header plate assembly, Core assembly, Tube subassembly, Header plate assembly, Packing and inspection Starts with: Receiving raw materials from suppliers. Ends with: Delivery of radiators to customers. Inclusion: Standard radiator models only.
Radiator assembly– Total Cycle time	169.5 min	114.5 min	Apr 2017	

Project plan				Team Selection
Phase	*Start*	*End*	*Remarks*	
Define	01/10/2016	20/10/2016	20 days	
Measure	21/10/2016	11/11/2016	20 days	
Analyze	12/11/2016	12/12/2016	30 days	
Improve	13/12/2016	23/01/2017	41 days	
Control	24/01/2017	01/03/2017	35 days	

Figure 3. Project Charter

IV. CURRENT VALUE STREAM MAPPING

All data for the current state map were collected according to the approach recommended. Data collection for the material flow started at the shipping department, and worked backward all the way to the assembly process, gathering snapshot data such as inventory levels before each process, process cycle times, number of workers. The small boxes in the map represent the process and the number inside the box is the number of workers at each process. Also, each process has a data box below, which contains the process CT, the number of shifts, and the change over time. It should be noted that this data was collected whilst walking the shop floor and talking to the operators at each work station. The processing and set-up times are all based on the average of historical data with giving standard allowances. After collecting all the information and material flows, they are connected as indicated by arrows in the map, representing how each work station receives its schedule from business planning.

A. *Takt Time*

For this particular product, the work needs to be accomplished in a nine hour work day and an average of 25 days per month, with 30 minutes of break and clean-up. For a day 50 radiators must complete to meet the customer demand, or the production schedule. The takt time calculation is shown in the following Table I and the current state map is followed by the Figure 4.

TABLE I. TAKT TIME CALCULATION

Time per shift / day	9 hours = 540 minutes
Break time	30 minutes
Total available time per day	510 minutes
Customer demand per day	50 units
Takt time = Available time / Customer demand	
Takt time in minutes	510 / 50 = 10.2 minutes

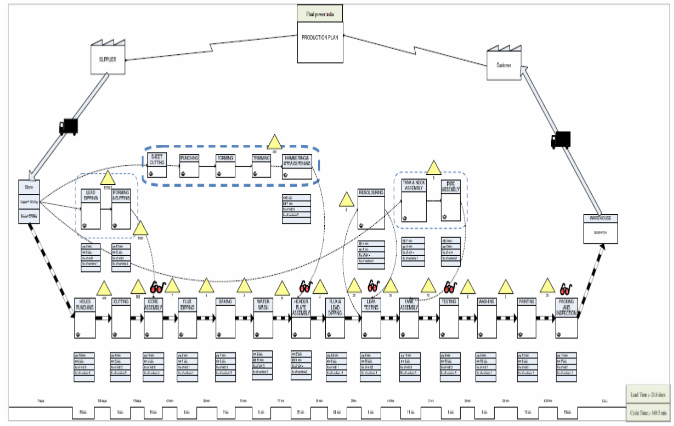


Figure 4. Current value stream mapping

B. *Line Balancing*

The cycle times of the assembly operations within this production line were documented as shown in Table 2 showing what was being done at each operation and the amount of time required for performing the different tasks. The line balancing is shown in Table II. Total cycle time is 169.5 min and total lead time is 21.6 days.

TABLE II. CYCLE TIME FOR EACH STAGE

Sl. No	STAGE	CYCLE TIME (Min)
1	Holes punching	10
2	Cutting	9
3	Core Assembly	16
4	Flux Dipping	6
5	Baking	7
6	Water wash	5
7	Header plate sub assembly	5
8	Tubes Subassembly	17
9	Tank, Neck, Tube Subassembly	10
10	Header plate Assembly	21
11	Flux and lead dipping	6.5
12	Leak testing	6
13	Tank Assembly	11
14	Testing	8
15	Washing	5
16	Painting	12
17	Packing and Inspection	15
TAKT TIME		**10.2**

V. KAIZEN IMPROVEMENT

The kaizen workshop is conducted and kaizens are being developed and their feasibility study is taken before implementation. The kitting process makes the material storage easier and searching of materials time is reduced. This is shown in the Figure 5.

(Before) (After)

Figure 5. Material storage

The pneumatic line feeders cutting are done in line with the process and that makes more time and this can be overcome by taking the master dimensions of pneumatic lines with allowances and they are done offline to match with the line balancing. This reduces the cycle time of almost 80 minutes, This is shown in the Figure 6.

(Before) (After)

Figure 6. Pneumatic Lines

The storage of fins and tube coils is modified for easier identification and easier movement. The before and after design of the storage system for fins and tubes is shown in Figure 7.

(Before) (After)

Figure 7. Stores

The pin card is used as the kanban card for easier retrieval for parts and stock checking and to use the stock as a two bin safety stock system. This is shown in the Figure 8.

(Before) (After)

Figure 8. Storage view

In header plate assembly instead of manual punching a roller gear punch is modified and used which leads to the reduction of the process cycle time. This is shown in the Figure 9.

(Before) (After)

Figure 9. Header Plate

The movement of the foils is made easy by designing a new trolley. But in the old design the foils are moved manually down the floor by bending down. This is shown in the Figure 10.

(Before) (After)

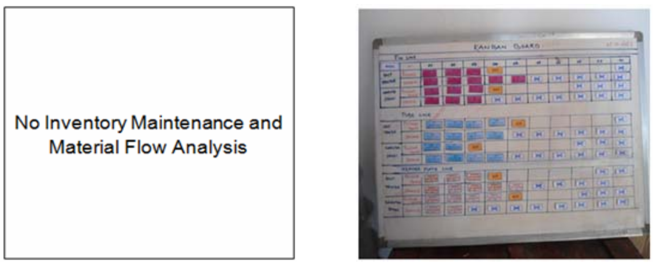
Figure 10. Movement

In fins cutting process, cutting is done manually using scissors but now automation sensors are used to cut the fins which leads to the reduction of lead time, this is shown in the Figure 11.

(Before) (After)

Figure 11. Cutting fins

The material flow can be easily accessed and updated by a lean tool called KANBAN. Before this there is no standardization for the material flow. So KANBAN card and board is implemented for easier identification. This is shown in the Figure 12.



(Before) (After)

Figure 12. KANBAN

In Tube and Neck assembly the holes are made by gas cutting which takes more time. A new type hole hack saw is used to cut the holes which takes only seconds. This is shown in the Figure 13.

(Before) (After)

Figure 13. Tank and neck assembly

VI. FUTURE STATE VALUE STREAM MAPPING

The future state Value Stream mapping is drawn after implementing the kaizen generated. The cycle time has been reduced and the Lead time is also reduced as shown in Figure 14. The clear idea of the results and discussion is shown in the value stream mapping.

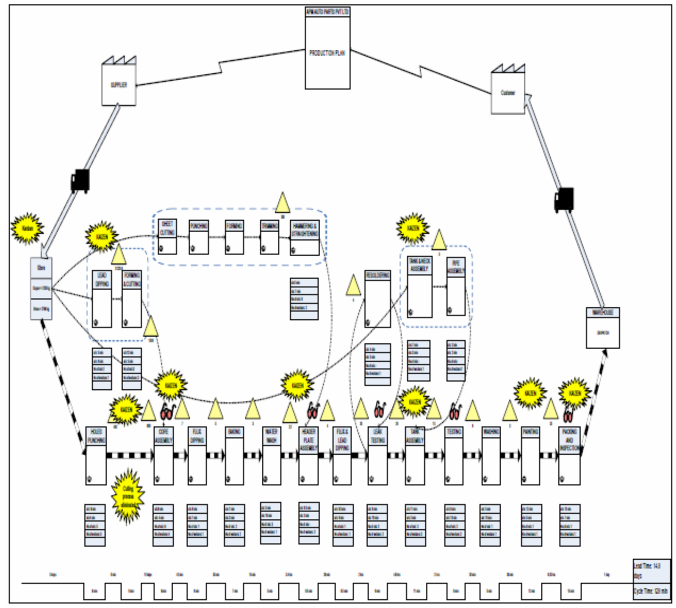


Figure 14. Future state value stream mapping

VII. CYCLE TIME IMPROVEMENTS

The final study on the production process is done by repeating the same methodology used during the current state analysis. The improvements observed after implying these lean concepts are explained in this section

A. Final Time Study

The final time study on the process is done by the video study and giving allowances to each and every sequence the following result is observed and found to be reduced from 169.5 min to 128 min and represented in the graph in Figure 15.

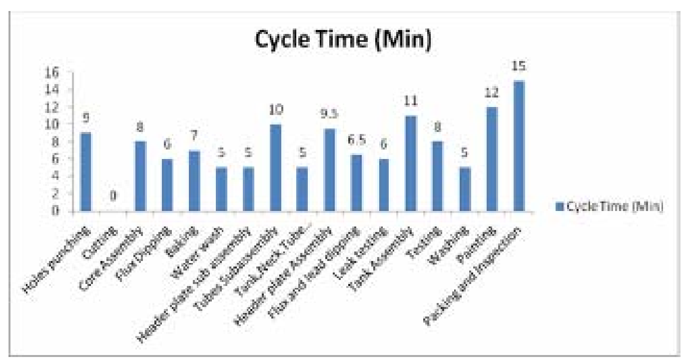
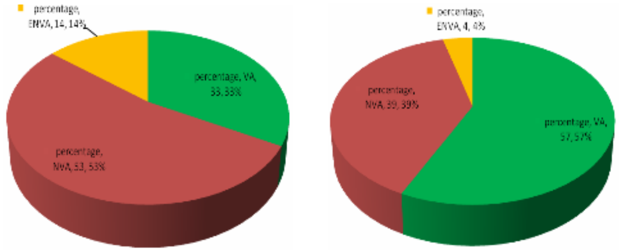


Figure 15. Final cycle time

B. VALUE ANALYSIS

The value analysis to the process before and after is shown in the Figure 16. The improvement in the value added activity is 57% from 33%.



(Before) (After)

Figure 16. Value analysis

C. Cycle Time Comparision

The improvements comparison clearly states that the utilization and implementation of lean concepts has reduced the cycle time from 169.5 minutes to 128 minutes. The cycle time improvement to the process before and after is shown in the Figure 17.

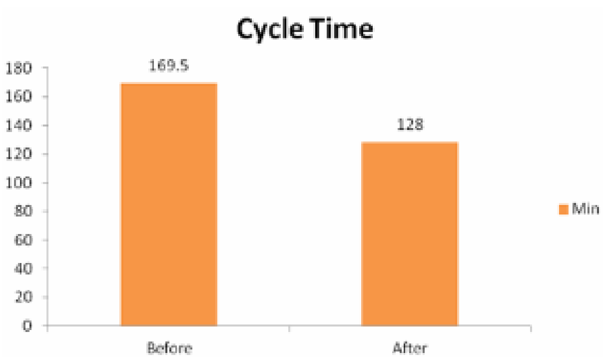


Figure 17. Cycle time comparison

VIII. Conclusions

The lean concepts like work standardization, value stream mapping, Kaizen and Kanban on the selected area of work has led to the following conclusion:

1. Because of the reduction of NVA in each stages, the process flow is found to be smooth thereby reducing the cycle time.
2. By conducting kaizen workshop on regular basis, about 96 kaizens were identified and almost 15 kaizens were implemented, and also the methodology of conducting the kaizen workshop is regularized and followed by the self-managed team.
3. The bottleneck process time is reduced in the line balancing.
4. The overall reduction in the NVA leads to the reduction of cycle time from 169.5 minutes to 128 minutes.
5. The Value added analysis of the process shows that an improvement of 57% from 33%.
6. The non-value added analysis of the process shows that an improvement of 39% from 53%.
7. The production of units based on the improved cycle time show that a productivity improvement of 63 units from 50 units.

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References

[1] MS. Phadke, “Quality engineering using robust design”, Prentice-Hall, Englewood Cliffs, New Jersey, 2009.

[2] L. Bamber and B.G. Dale, “Lean production: a study of application in a traditional manufacturing environment, Production Planning & Control”, vol. 11, no. 3, pp.291-298, 2000.

[3] B. Haque and M. James-Moore, “Applying lean thinking to new product introduction. Journal of Engineering design”, vol. 15, no.1, pp.1-31, 2004.

[4] K. Soderquist and J. Motwani, “Quality issues in lean production implementation: a case study of a French automotive supplier”, Total Quality Management, vol. 10, no. 8, pp.1107-1122, 2009.

[5] S.J. Pavnaskar, J.K. Gershenson and A.B. Jambekar, “Classification scheme for lean manufacturing tools”, International Journal of Production Research, vol. 4, no. 13, pp.3075-3090, 2003.

[6] T. McDonald, E.M. Van Aken and A.F. Rentes, “Utilising simulation to enhance value stream mapping: a manufacturing case application”, International Journal of Logistics, vol. 5, no.2, pp.213-232, 2002.

[7] Y. Monden, “Toyota production system: an integrated approach to just-in-time”, CRC Press, 2011.

[8] JK. Liker, “Becoming lean”, Productivity Press, Portland, 1998.

[9] P. Hines and DH. Taylor, “Going lean: a guide to implementation”, Lean Enterprise Research Center, Cardiff Business School, Cardiff University, Cardiff, UK, 1998.

[10] M. Rother and J. Shook, “Learning to see: value stream mapping to add value and eliminate muda”, The Lean Enterprise Institute, Brookline, Massachusetts, 1999.

[11] S.J. Pavnaskar, J.K. Gershenson and A.B. Jambekar, “Classification scheme for lean manufacturing tools”, International Journal of Production Research, vol. 41, no.13, pp.3075-3090, 2003.

[12] W.G. Sullivan, T.N. McDonald and E.M. Van Aken, “Equipment replacement decisions and lean manufacturing”, Robotics and Computer-Integrated Manufacturing, vol. 18, no.3, pp.255-265, 2002.

[13] JP. Womack and DT. Jones, “Lean thinking: banish waste and create wealth in your corporation”, Simon & Schuster, New York, 1996.

[14] F.A. Abdulmalek and J. Rajgopal, “Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study”, International Journal of production economics, vol. 107, no. 1, pp.223-236, 2007.

[15] I. Serrano, C. Ochoa and RD. Castro, “Evaluation of value stream mapping in manufacturing system redesign”, International Journal of Production Research, vol. 46, no. 16, pp.4409-4430, 2008.

[16] A.K. Sahoo, N.K. Singh, R. Shankar and M.K. Tiwari, “Lean philosophy: implementation in a forging company”, The International Journal of Advanced Manufacturing Technology, vol. 36, no. 5-6, pp.451-462, 2008.

[17] C.L. Lai, W.B. Lee and W.H. Ip, "A study of system dynamics in just-in-time logistics", Journal of Materials Processing Technology, vol. 138, no. 1, pp.265-269, 2003.

[18] F.T.S. Chan, "Effect of kanban size on just-in-time manufacturing systems", Journal of materials processing technology, vol. 116, no. 2, pp.146-160, 2001.

[19] A. Lee-Mortimer, "A lean route to manufacturing survival", Assembly Automation, vol. 26, no. 4, pp.265-272, 2006.

[20] R. Domingo, R. Alvarez, M. Melodía Peña and R. Calvo, "Materials flow improvement in a lean assembly line: a case study", Assembly Automation, vol. 27, no. 2, pp.141-147, 2007.

[21] R. Álvarez, R. Calvo, M.M. Peña, and R. Domingo, "Improvement of parts flow of an assembly line applying lean tools", In Proceedings of the 2nd Manufacturing Engineering Society International Conference (MESIC), Madrid, 2007.

[22] T.R. Browning, and R.D. Heath, "Reconceptualizing the effects of lean on production costs with evidence from the F-22 program", Journal of Operations Management, vol. 27, no. 1, pp.23-44, 2009.

[23] R. Shah and P.T. Ward, "Defining and developing measures of lean production", Journal of operations management, vol. 25, no. 4, pp.785-805, 2007.

[24] C. Sendil Kumar and R. Panneerselvam, "Literature review of JIT-KANBAN system", The International Journal of Advanced Manufacturing Technology, vol. 32, no. 3, pp.393-408, 2007.

[25] J. Srinivasaraghavan and V. Allada, "Application of mahalanobis distance as a lean assessment metric", The International Journal of Advanced Manufacturing Technology, vol. 29, no. 11, pp.1159-1168, 2006.

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