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Productivity Improvement through Time Study (Work Measurement) and Line Balancing at Automotive Seat Belts Manufacturer

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ABSTRACT: Assembly Line Balancing is an effective tool to improve the throughput of the assembly line by minimizing the number of workstations, non-value added activities and cycle time in an efficient manner to achieve effective utilization of human resources and machine. High efficiency benefits the company with proper utilization of men, raw material, machines, and space. Markets are affected by diverse customer needs, which demands the product at high quality, shorter delivery time and lower price. Accounting the problem, Line Balancing and Kaizen (continuous improvement) are the only practical approaches to improve efficiency, productivity, and quality. This paper mainly focuses on improving the overall productivity of 'Rear Seat Belt' assembly line by working on cycle time, non-value added activities, distribution of workload at each workstation by line balancing technique. With these improvements, the company managed to reduce the total time required to complete 2300 product units per day, from 170.54 seconds down to 162.26 seconds. This study also proposes assembly line improvements, by focusing on a Material Handling Operator solution. The material handling operator moves around the assembly line for a standard time to replenish the raw assembly parts and transfer the boxed containers of the assembled parts at the needed workstations, so that the operators at each workstations can concentrate on their own tasks.

KEYWORDS: Assembly Line Balancing, Non-Value Added Activities, Cycle Time, Quality, Line Efficiency

I. INTRODUCTION

Assembly Line is a flow-oriented production system. Assembly lines are production systems developed to meet the requirements of humankind. The demand for higher product variability and shorter life cycles has caused traditional production methods to be replaced with assembly lines. These systems aim to manufacture products at production rates quicker in time, in the most productive way, cheaply and with the quality required.

Quality product and capability of coping with customer demands are vital aspects that should take into account especially for small and medium industry. Companies should have the understanding that the performance solely depends on the output of the production line. Thus, the primary focus of line balancing is on minimizing waste related to over-production, inventory defects, transportation, motion, waiting. Production process improvement becomes obligatory to gauge as well as improvise the current production scenario and hence, the advent of Kaizen plays a chief role.

In an assembly line, the main issues are cycle time at each station, work in process inventory and number of workstations. All organizations strive to design and manage the assembly line which is perfect and with maximum productivity and operational efficiency, to have the best utilization of available resources. Assembly line balancing also provides flexibility to the employees, thereby reducing the monotonous activity and thus improving job satisfaction. Besides this assembly line balancing is also useful.

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II. LITERATURE REVIEW

Assembly line balancing is a method of assigning various tasks to the workstations while optimizing one or more objectives without violating any restrictions imposed on the line. Assembly line balancing problem has been an active field of research over the past decades due to its relevancy to diversified industries such as an automobile, garment, footwear, and electronics. Ghosh [1] as well as Erel and Sarin [2] provided detailed reviews on the topic. Configurations of assembly lines for single and multiple products could be divided by three line types, single-model, mixed-model and multi-model. Single-model assembles only one product, mixed-model assembles multiple products and multi-model produces a sequence of batches with intermediate setup operations by Becker [3]. This paper solves a single model line balancing problem.

C Merengo *et al.* [4] presents new balancing and production sequencing methodologies which states the goals of minimizing the rate of incomplete jobs or the probability of blocking events, reducing 'Work in Process.' The balancing methodology also aims at minimizing the number of stations on the line, uniform parts usage, which is a typical goal in 'Just in Time' production systems.

Gautham J. *et al.* [5] concentrated on improving the overall efficiency of a single model assembly line can be improved by reducing the non-value added activities, cycle time and distribution of workload at each station by line balancing. The methodology adopted for the operation includes calculation of process cycle time, identifying non-value adding activities and calculating total workload on each station and distributing it by line balancing to improve the efficiency of the assembly line.

Yamazumi chart is a stacked bar chart that shows the balance of cycle time and takt time in every station by Laraia *et al.*[6]. Takt time is net time available to work divided by required units of production. This step is the systematic process of developing the efficient work center in the establishment of time standards which can be calculated as :

$$\text{STANDARD TIME} = \text{NORMAL TIME} \times (1 + \text{ALLOWANCE})$$

(1)

Sarvesh Kumar Srivastava *et al.* [7] states that Kaizen (continuous improvement) is a lean tool used in the manufacturing industry for the productivity improvement, fatigue reduction and reduction in the chances of injury. Womack *et al.* [8] developed from the massively successful Toyota Production System, focuses on the removal of all forms of waste from the system. Krafcik [9] describes the Japanese style manufacturing process pioneered by Toyota uses a range of techniques including JIT inventory systems continuous improvement and quality circles.

III. METHODOLOGY

The methodology of this research work is a time study conducted on 'Rear Seat Belt Assembly Line' at a seatbelt manufacturer. Data collection is an important stage in identifying the problem in a production line. During the observation of each process in different workstations, direct time study is carried out. In this research work stopwatch is the major equipment used for recording the elemental time of each operation. The procedure for carrying out the study is as follows: Identify the workstations of the model line and divide them into work elements and recording each elements' time through stopwatch for at least ten iterations. After taking ten iterations, the average value is taken which accounts for the observed time of the workstations. There is a significant thing to note that the work elements which are performed by the operator during the machine time, are excluded from the observed time.

The elemental time for each workstation is measured from starting of picking the part up until it has been located at the next workstation. To enhance the reliability of the data obtained, the video camera is also used to record the tasks elemental time. After comparing the stopwatch time data and video recording data, accurate data of study is concluded.

Yamazumi Chart is also used in the study. It is used as a tool to proceed Kaizen for line balancing. Yamazumi chart is a well-arranged bar chart that shows the total cycle time for each operation when performing their process in the production flow. It facilitates the work balancing, the isolation and elimination of non-value added work elements.

There are specific terms which are used to exaggerate the entire time study are as follows:

1) NORMAL TIME- The time for a particular operation which is rated against the average job element time is called the normal time.

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$$\text{NORMAL TIME} = \text{JOB ELEMENTAL TIME} \times \text{PERFORMANCE RATING}$$

(2)

PERFORMANCE RATING describes the pace at which the worker should work considering his delays. This rating holds no mathematical formula; it is determined from judgment, or expert judgment might be the appropriate word.

2) **STANDARD TIME**- Standard time is the time needed to complete an operation by an operator working at 100% efficiency with unavoidable delays (allowances). Standard allowance of 10% is taken in this study.

$$\text{STANDARD TIME} = \text{NORMAL TIME} + \text{ALLOWANCES}$$

(3)

3) **CYCLE TIME**- The time required to complete one cycle of an operation is called cycle time.

$$\text{CYCLE TIME} = \text{STANDARD TIME} + \text{MACHINE TIME}$$

(4)

4) **TAKT TIME**- The takt time determines the production pace within the available time in which the product should be manufactured in order to meet the customer demand.

$$\text{TAKT TIME} = \frac{\text{TOTAL TIME AVAILABLE}}{\text{UNITS OF CUSTOMER DEMAND}}$$

(5)

$$\text{5) LINE CAPACITY} = \frac{(\text{AVAILABLE TIME} - \text{MATERIAL HANDLING DELAYS})}{(\text{CYCLE TIME} + \text{MATERIAL HANDLING FREQUENCY})}$$

(6)

IV. PROBLEM STATEMENT

The system analyzed in this study is an assembly line for the product 'Rear Seat Belt'. The model line is U-Shaped. There are 16 workstations in the assembly line, namely Ratchet Assembly (WS-1), Sensor Sub Assembly (WS2), Spool Assembly (WS-3), Spring Winding (WS-4), Mach Cover Assembly (WS-5), Belt Pin Sewing (WS-6), Web Pulling (WS-7), Tilt Lock Testing (WS-8), Sash Guide Assembly (WS-9), Anchor Plate Assembly (WS-10), Hardware Assembly (WS-11), Label and Anchor Sewing (WS-12), Button Riveting (WS-13), Sled Test (WS-14), Manual Inspection (WS-15), Dust Cover Assembly (WS-16). Each workstation is managed by one workstation operator.

The productivity of the model line is unsatisfactory and fails to achieve its target output. Therefore, a line balancing technique is used in this study to determine the problems. To perform line balancing, cycle time is needed. In this study, ten iterations of cycle times are recorded for each workstation, and their averages are noted. The total cycle time is 170.54 seconds (Table 1). The working time per day of the model line is 8.5 hours, including rest time, while the demand for the product is 2300 units per day. The takt time is 13.3 seconds per unit. It was observed that the process bottleneck occurred at Tilt Lock Testing Machine (WS8) because it could only produce 2204 units per day, compared to the demand, thereby reducing the line efficiency to an alarming figure of 77%.

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Table 1. Detailed study of Rear Seat Belt Assembly Line (Before Improvement)

REAR SEAT BELT ASSEMBLY LINE STUDY (BEFORE IMPROVEMENT)														
Sr. No.	STATION/ASSEMBLY NAME	MANUAL TIME (SEC)	AUTO TIME (SEC)	OBSERVED TIME (SEC)	PERF. RATING	NORMAL TIME (SEC)	ALLOWANCE	STANDARD TIME (SEC)	CYCLE TIME (SEC)	STATION CAPACITY/DAY	STATION CAPACITY/HRS	DELAYS FREQ.	DELAY TIME (SEC)	AVAILABLE TIME (SEC)
1	RATCHET ASSEMBLY	4.52	5	9.52	105%	4.75	10%	5.22	10.22	2969	349	20	260	30340
2	SENSOR SUB ASSEMBLY	4.36	6.44	10.8	89%	3.88	10%	4.27	10.71	2822	332	21	378	30222
3	SPOOL ASSEMBLY	5.15	4	9.15	97%	5.00	10%	5.50	9.50	3154	371	47	652	29948
4	SPRING WINDING	7.72	5.02	12.74	88%	6.79	10%	7.47	12.49	2406	283	23	539	30061
5	MACH COVER ASSEMBLY	8.01	4.42	12.43	93%	7.45	10%	8.19	12.61	2401	282	28	311	30289
6	BELT PIN SEWING	4.14	4.65	8.79	93%	3.85	10%	4.24	8.89	3314	390	42	1157	29443
7	WEB PULLING	9.33	2	11.33	88%	8.21	10%	9.03	11.03	2774	326	0	0	30600
8	TILT LOCK TESTING	3.24	10.5	13.74	95%	3.08	10%	3.39	13.89	2204	259	0	0	30600
9	SASH GUIDE ASSY.	6.84	2	8.84	110%	7.52	10%	8.28	10.28	2938	346	36	410	30190
10	ANCHOR PLATE ASSY.	9.94	0	9.94	80%	7.95	10%	8.75	8.75	3479	409	16	166	30434
11	HARDWARE ASSEMBLY	12.02	0	12.02	94%	11.30	10%	12.43	12.43	2452	288	12	125	30475
12	LABEL AND ANCHOR	2.61	5.89	8.5	90%	2.35	10%	2.58	8.47	3496	411	51	971	29629
13	BUTTON RIVETING	6.37	4	10.37	88%	5.61	10%	6.17	10.17	3004	353	4	60	30540
14	SLED TESTING	6.32	6.44	12.76	93%	5.88	10%	6.47	12.91	2371	279	0	0	30600
15	MANUAL INSPECTION	9.35	0	9.35	95%	8.88	10%	9.77	9.77	3132	368	0	0	30600
16	DUST COVER AND PACKING	7.83	0	7.83	98%	7.67	10%	8.44	8.44	3601	424	21	205	30395
							100.1663		110.2	170.54				

Another issue which counts the loss of productivity is material handling at each workstation is done by work operator. The operators themselves need to get the required parts for assembly from the trolleys present outside the assembly line and are also required to manually deliver the assembled components to the other workstations for the next assembly, which may cause bottlenecks at some workstations. Workstations become idle every time their operators walk away to deliver assembled parts or get material from the trolleys. This tasking mitigates the ability of the operator to achieve the production target within the available working time (which is of 8.5 hours). Material handling is a kind of excess motion, which marks a big reason for overtime and tagged as a **WASTE**. The delay time of material handling has been subtracted from the available time, according to the frequency of the days.

V. PROPOSED MODIFICATIONS OF THE EXISTING SYSTEM

In order to reduce the cycle time, a Yamazumi chart is constructed (Figure 1). From the chart non-value added activities can be identified and completely removed. Room for improvement can be made by balancing the work content among the workstations. The workers are required to complete 2300 product units in the shift time of 8.5 hours (including breaks). However, the process time for the WS-8 is higher than the takt time, thus making it a bottleneck process station. Looking at the analysis of work study the line capacity till the shift time is 2204. For fulfilling the customer requirement of 2300 units/day, the operators need to work overtime, consequently, increasing the company cost.

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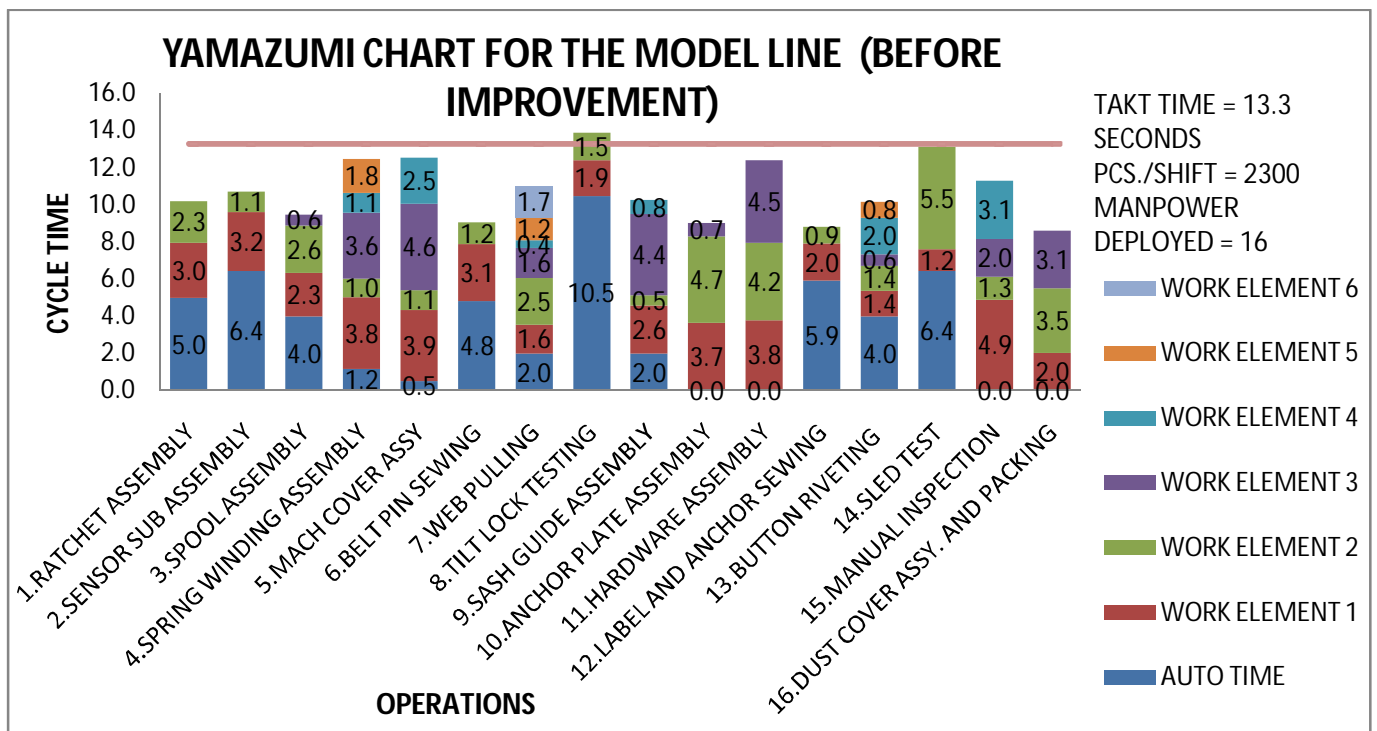


Figure 1. Yamazumi Chart for the Model Line (Before Improvement)

As we observe the chart, it is evident that Tilt Lock Testing station is the bottleneck process of the entire line. The takt time of the assembly line is 13.3 seconds but the cycle time for the process is 13.8 seconds. The process needs re-analysis; also there are three more workstations, that is, Belt Pin Sewing (WS-6), Anchor Plate Assembly (WS-10) and Dust Cover Assembly (WS-16), whose work elements need to be redistributed. Out of these, Anchor Plate Assembly and Dust Cover Assembly involve only hardware assembling of parts, without the negligible involvement of machine operation. Thus, the work elements from each of the two workstations can be re-distributed among other processes to balance the entire line and enhance its efficiency. The idea adopted for balancing the tasks is identifying the workstations whose operators are in a 'waiting' mode during the machine operation, which is realized as a waste and a significant cause of line balance loss. It costs the company and a delay in customer requirement. The time study sheet of WS-10 and WS-16 is as follows:

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Table 2. Time Study of Anchor Plate Assembly workstation (WS-10)

ANCHOR PLATE ASSEMBLY												
Sr. No.	WORK ELEMENT	OBSERVED TIME (IN SECONDS)										AVERAGE
1	PICKS AND ASSEMBLE THE BOLT IN THE ANCHOR PLATE WITH CS RING	4.4	4.5	3.4	4	4.2	4.2	4.3	4.1	4.2	4.2	4.15
2	ASSEMBLE THE BOLT IN SEAT BELT FRAME WITH CS RING	5.3	5.1	5.3	5.3	5.5	5.3	5.2	5.3	5.3	5.3	5.29
3	PUT THE ASSEMBLED PART FOR LABEL AND ANCHOR SEWING	0.6	0.8	0.8	1	0.9	0.6	0.8	1.1	0.8	0.9	0.83
CYCLE TIME (SECONDS)												10.27

Table 3. Time Study of Dust Cover Assembly workstation (WS-16)

DUST COVER ASSEMBLY												
Sr. No.	WORK ELEMENT	OBSERVED TIME (IN SECONDS)										AVERAGE
1	PICKS THE SEAT BELT AND DUST COVER	1.8	1.8	2.0	1.6	1.8	1.9	2.0	2.0	1.7	1.8	1.8
2	ADJUST DUST COVER OVER SEAT BELT	3.0	3.2	3.2	3.5	2.8	3.0	3.2	3.3	3.1	3.3	3.2
3	PICKS THE DUST COVER ASSEMBLED SEAT BELT AND PACKS IT INTO THE BIN	2.7	3.0	2.8	2.5	2.8	3.0	2.7	3.2	2.9	2.7	2.8
CYCLE TIME (SECONDS)												7.83

The elemental time study sheet for the identified stations is as follows:

1. Belt Pin Sewing

This is the sixth workstation. It consists of five work elements. The first two work elements (marked yellow) are covered in 3.77 seconds, compensating the machine time of the operation. The work time of the station is balanced by adjusting the first work element of the Anchor Plate Assembly (WS-10), that is, 'Assembling the bolt in anchor plate with CS ring' in the machine time of the Belt Pin Sewing (WS-6) station (marked in golden), thereby, reducing a worker on the assembly line and enhancing the overall efficiency and increasing space of the assembly line. This re-distribution of tasks doesn't have any effect on assembly of the seat belt at latter workstations.

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Table 4. Time Study of Belt Pin Sewing workstation (WS-6) (Before Improvement)

BELT PIN SEWING												
Sr. No.	WORK ELEMENT	OBSERVED TIME (IN SECONDS)										AVERAGE
1	PICKS THE WEBBING AND HOUSING	1.5	1.9	1.6	1.8	1.6	2.7	1.4	1.7	1.5	1.9	1.76
2	INSERTS WEBBING IN FRAME THROUGH SPOOL AND PULLS IT	1.9	2	2.5	1.6	2.1	1.5	1.8	2	2.5	2.2	2.01
3	FOLDS THE WEB AND INSERTS THE BELT PIN IN FOLDED REGION AND SEWS IT	2.1	3	2.7	3.6	4	2.6	3.1	2.9	3	3	3
4	AUTO TIME	4.8	4.8	5	4.8	4.9	4.8	4.8	4.8	4.8	4.8	4.83
5	REMOVE WEBBING FROM MACHINE & PLACE RETRACTOR ON NEXT STATION	1.2	1.1	1.1	1.3	1.1	1.2	1.1	1	1.1	1.2	1.14
CYCLE TIME (SECONDS)												8.97

Table 5. Time Study of Belt Pin Sewing workstation (WS-6) (After Improvement)

BELT PIN SEWING												
Sr. No.	WORK ELEMENT	OBSERVED TIME (IN SECONDS)										AVERAGE
1	PICKS THE WEBBING AND HOUSING	1.5	1.9	1.6	1.8	1.6	1.7	1.6	1.7	1.5	1.9	1.68
2	INSERTS WEBBING IN FRAME THROUGH SPOOL AND PULLS IT	1.8	2	2	1.9	2.1	1.9	1.8	1.9	2	1.9	1.93
3	FOLDS THE WEB AND INSERTS THE BELT PIN IN FOLDED REGION AND SEWS IT	2.5	2.3	2.5	2.5	2.4	2.4	2.5	2.5	2.5	2.4	2.45
4	AUTO TIME	4.8	4.8	4.7	4.8	4.9	4.8	4.8	4.8	4.8	4.8	4.8
5	PICKS AND ASSEMBLE THE BOLT IN THE ANCHOR PLATE WITH CS RING	4.4	4.5	3.4	4	4.2	4.2	4.3	4.1	4.2	4.2	4.15
6	KEEP THE SEAT BELT FOR WEB PULLING	1.2	1.1	1.1	1.3	1.1	1.2	1.1	1	1.1	1.2	1.14
CYCLE TIME (SECONDS)												12

2. Tilt Lock Testing

There are six work elements of this process. During the course of the machine cycle, the operator completes the first two elements (as marked in yellow) in 4.41 seconds, whereas the remaining 6.09 seconds are wasted in waiting for the machine to cover its operation. The waiting process is regarded as a waste in terms of lean management. As a result, some changes are made in the testing machine by the maintenance professionals. The process time of the device is

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reduced to 9.7 seconds from 10.5 seconds. Moreover, to handle the waste of 'Waiting', a work element from Anchor Plate Assembly (WS-10) of assembling the bolt in frame hole of the seat belt, is adjusted in the waiting time of Tilt Lock Assembly station.

Table 6. Time Study of Tilt Lock Testing workstation (WS-8) (Before Improvement)

TILT LOCK TESTING												
Sr. No.	WORK ELEMENT	OBSERVED TIME (IN SECONDS)										AVERAGE
1	MARKS INSPECTION MARK ON MACH COVER	1	0.8	0.9	1.1	1.2	0.9	1	0.8	1	0.9	0.96
2	PICKS THE WEB PULLED SEAT BELT AND CHECKS IT BY PULLING THE WEB (MANUALLY); IF THE SEAT BELT REMAINS UNLOCK AT 0°	3.5	3.8	3.5	3.6	3.1	3.3	3.4	3.5	3.5	3.3	3.45
3	WAIT	4.8	4.5	4.8	4.2	5	4.7	4.7	5	4.8	5	4.75
4	MOUNTS THE SEAT BELT OVER THE MACHINE FIXTURE FOR TILT LOCK TESTING	1.6	1.8	2	1.7	1.6	1.8	2.3	1.7	2.1	1.8	1.84
5	AUTO TIME	10.5	10.5	10.5	10.4	10.5	10.6	10.5	10.5	10.5	10.5	10.5
6	PICKS THE TILT TESTED PART AND PUT FOR HARDWARE ASSY.	1.4	1.5	1.3	1.5	1.3	1.5	1.3	1.5	1.3	1.4	1.4
CYCLE TIME (SECONDS)												13.74

Table 7. Time Study of Tilt Lock Testing workstation (WS-8) (After Improvement)

TILT LOCK TESTING												
Sr. No.	WORK ELEMENT	OBSERVED TIME (IN SECONDS)										AVERAGE
1	MARKS INSPECTION MARK ON MACH COVER WITH WHITE PENCIL	1	0.8	0.9	1.1	1.2	0.9	1	0.8	1	0.9	0.96
2	PICKS THE WEB PULLED SEAT BELT AND CHECKS IT BY PULLING THE WEB (MANUALLY); IF THE SEAT BELT REMAINS UNLOCK AT 0°	3.5	3.8	3.5	3.6	3.1	3.3	3.4	3.5	3.5	3.3	3.45
3	ASSEMBLE THE BOLT IN SEAT BELT FRAME WITH CS RING (TO BE DONE IN WAITING TIME)	5.3	5.1	5.3	5.3	5.5	5.3	5.2	5.3	5.3	5.3	5.29
4	MOUNTS THE SEAT BELT OVER THE MACHINE FIXTURE FOR TILT LOCK TESTING	1.6	1.8	2	1.7	1.6	1.8	2.3	1.7	2.1	1.8	1.84
5	AUTO TIME	9.8	9.6	9.8	9.8	9.7	9.7	9.7	9.7	9.6	9.6	9.7
6	PICKS THE TILT TESTED PART AND PUTS IT OVER THE HARDWARE ASSY. RAIL	1.4	1.5	1.3	1.5	1.3	1.5	1.3	1.5	1.3	1.4	1.4
CYCLE TIME (SECONDS)												12.94

3. Label and Anchor Sewing

Other steps that can be re-distributed are assembling the dust cover on the seat belt, which was executed at the Dust Cover Assembly (WS-16) workstation, the last workstation. Previously, this task was done with a cycle time 8.84 seconds; re-distributing it in the machine time of Label and Anchor Sewing (WS-12) process, undoubtedly, increases the cycle time of the workstation to 12.96 seconds but also eliminates a worker from the assembly line. The elimination of the worker saves the company cost, enhances the efficiency of the line and increases space.

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Table 8. Time Study of Label and anchor Sewing workstation (WS-12) (Before Improvement)

LABEL AND ANCHOR SEWING												
Sr. No.	WORK ELEMENT	OBSERVED TIME (IN SECONDS)										AVERAGE
1	PICKS THE HARDWARE ASSEMBLED SEAT BELT AND ADJUST THE WEBBING FROM ANCHOR PLATE SIDE	2.6	3.5	3.7	2.4	2.1	3	3	2.3	3.3	3.2	2.91
2	FOLDS THE WEBBING (A LITTLE BIT) AND KEEPS WEBBING UNDER SEWING MACHINE	2.4	2.4	2.6	3	3.1	2.7	2.6	2	2.8	2.5	2.61
3	PICKS THE HOMOLOGATION LABEL AND SEW IT IN THE FOLDED REGION	1.6	1.8	2	1.8	1.8	1.8	2.2	2.6	2.4	2.4	2.04
4	AUTO TIME	5.8	5.8	6	6	5.7	6	6	5.9	6	6	5.92
5	KEEP SEAT BELT FOR BUTTON RIVETING	1	1	0.8	0.7	0.8	1	1.1	0.6	0.8	1	0.88
CYCLE TIME (SECONDS)												8.84

Table 9. Time Study of Label and anchor Sewing workstation (WS-12) (After Improvement)

LABEL AND ANCHOR SEWING												
Sr. No.	WORK ELEMENT	OBSERVED TIME (IN SECONDS)										AVERAGE
1	PICKS THE HARDWARE ASSEMBLED SEAT BELT AND ADJUST THE WEBBING FROM ANCHOR PLATE SIDE	2.6	2.7	2.5	2.4	2.3	2.6	2.7	2.5	2.5	2.8	2.56
2	FOLDS THE WEBBING (A LITTLE BIT) AND KEEPS WEBBING UNDER SEWING MACHINE	2.4	2.4	2.6	3	2.8	2.7	2.6	2.5	2.5	2.5	2.61
3	PICKS THE HOMOLOGATION LABEL AND INSERT A BIT OF THE LABEL IN THE FOLDED	1.6	1.8	2	1.6	1.8	1.8	2.2	2	2.1	1.8	1.87
4	AUTO TIME	5.8	5.8	5.8	6	5.8	6	6	5.9	6	5.8	5.92
5	PICKS THE SEAT BELT AND DUST COVER	1.8	1.8	2	1.6	1.8	1.9	2	2	1.7	1.8	1.84
6	ADJUST DUST COVER OVER SEAT BELT	3	3.2	3.2	3.5	2.8	3	3.2	3.3	3.1	3.3	3.16
7	KEEP SEAT BELT FOR BUTTON RIVETING	1	1	0.8	0.8	0.8	1	1.1	0.9	0.8	1	0.92
CYCLE TIME (SECONDS)												12.96

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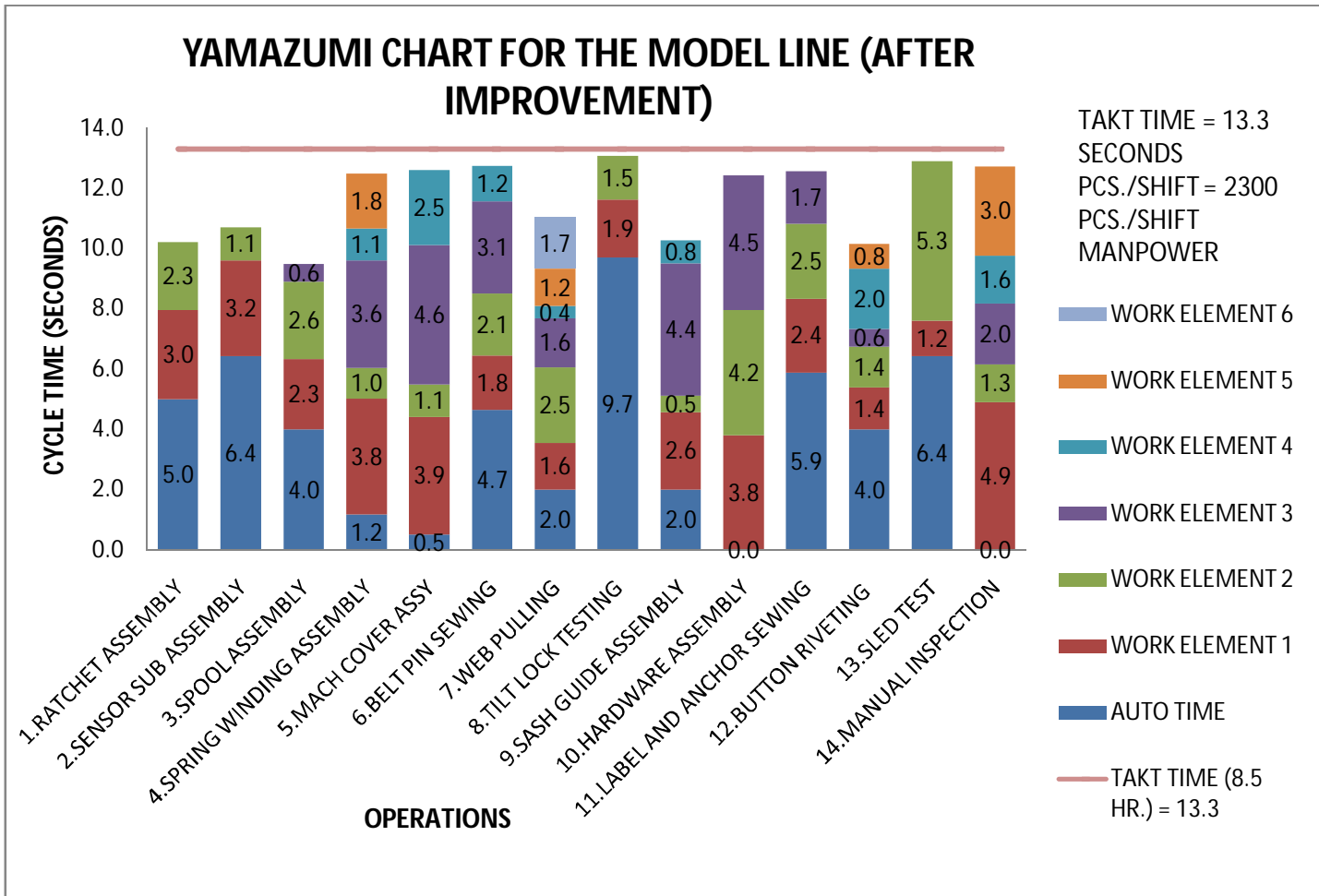


Figure 2. Yamazumi Chart for the Model Line (After Improvement)

An illustration of the enhanced assembly line activities can be seen in the Yamazumi chart. With these improved activities, the company managed to reduce the total cycle time required to complete 2300 product units per day to 162.26 seconds from 170.54 seconds. The line efficiency of the assembly line is increased to 89% from 77%. (Table 10)

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Table 10. Detailed study of the Rear Seat Belt Assembly line (After Improvement)

REAR SEAT BELT ASSEMBLY LINE STUDY (AFTER IMPROVEMENT)												
Sr. No.	STATION/ASSEMBLY NAME	MANUAL TIME (SEC)	AUTO TIME (SEC)	OBSERVED TIME (SEC)	PERF. RATING	NORMAL TIME (SEC)	ALLOWANCE	STANDARD TIME (SEC)	CYCLE TIME (SEC)	STATION CAPACITY/DAY	STATION CAPACITY/HRS	AVAILABLE TIME (SEC)
1	RATCHET ASSEMBLY	4.52	5	9.52	105%	4.75	10%	5.22	10.22	2994	352	30600
2	SENSOR SUB ASSEMBLY	4.36	6.44	10.8	89%	3.88	10%	4.27	10.71	2858	336	30600
3	SPOOL ASSEMBLY	5.15	4	9.15	97%	5.00	10%	5.50	9.50	3223	379	30600
4	SPRING WINDING	7.72	5.02	12.74	88%	6.79	10%	7.47	12.49	2449	288	30600
5	MACH COVER ASSEMBLY	8.01	4.42	12.43	93%	7.45	10%	8.19	12.61	2426	285	30600
6	BELT PIN SEWING	6.77	4.65	11.42	93%	6.30	10%	6.93	11.58	2643	311	30600
7	WEB PULLING	9.33	2	11.33	88%	8.21	10%	9.03	11.03	2774	326	30600
8	TILT LOCK TESTING	3.24	9.7	12.94	95%	3.08	10%	3.39	13.09	2338	275	30600
9	SASH GUIDE ASSY.	6.84	2	8.84	110%	7.52	10%	8.28	10.28	2978	350	30600
10	HARDWARE ASSEMBLY	12.02	0	12.02	94%	11.30	10%	12.43	12.43	2462	290	30600
11	LABEL AND ANCHOR	6.71	5.89	12.6	90%	6.04	10%	6.64	12.53	2442	287	30600
12	BUTTON RIVETING	6.37	4	10.37	88%	5.61	10%	6.17	10.17	3010	354	30600
13	SLED TESTING	6.32	6.44	12.76	93%	5.88	10%	6.47	12.91	2371	279	30600
14	MANUAL INSPECTION	12.18	0	12.18	95%	11.57	10%	12.73	12.73	2404	283	30600
						93.37		102.70	162.26			

The manpower deployed at each workstation is reduced to 14, eliminating two workstations, saving the company cost and improving the overall efficiency. The cost analysis of the assembly line is shown:

Table 11. Cost Analysis of the Model Line

COST ANALYSIS OF REAR SEAT BELT ASSEMBLY LINE	
VOLUME (PER DAY)	2300 PCS.
NUMBER OF WORKING DAYS	248
VOLUME (PER YEAR)	2300*248= 5,70,400
NUMBER OF OPERATORS	14
AVERAGE SALARY PER OPERATOR (PER MONTH)	₹ 20,000
AVERAGE SALARY FOR TWO OPERATORS (PER MONTH)	₹ 40,000
AVRAGE SALARY PER YEAR FOR TWO OPERATORS	` 4,80,000
SAVING PER PART	480000/570400 = 0.84 = 84 PAISE/PART
SAVING PER DAY	0.84*2300 = ` 1932
SAVING PER YEAR	1932*248 = ` 4,79,136

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VI. MATERIAL HANDLING SOLUTIONS ON THE ASSEMBLY LINE

It is estimated that the material handling systems delineate much of the total cost of manufacturing a product. It is, therefore, a vital area that can be improved in a production line, in order to increase productivity. Operators are required to manually deliver the assembled parts to the next workstation, which may cause bottlenecks at some workstations. Moreover, the operators are required to get the raw assembly parts from the trolley kept outside the assembly line. Workstations become idle every time their operators walk to deliver the boxed containers to the next station or get the raw assembly material from the trolley outside the line, which may cause bottlenecks at some workstations. Material handling is a kind of excess motion, refuting the operators from achieving the production target in the stipulated time. Therefore, practical solutions are required to improve the performance of the production line.

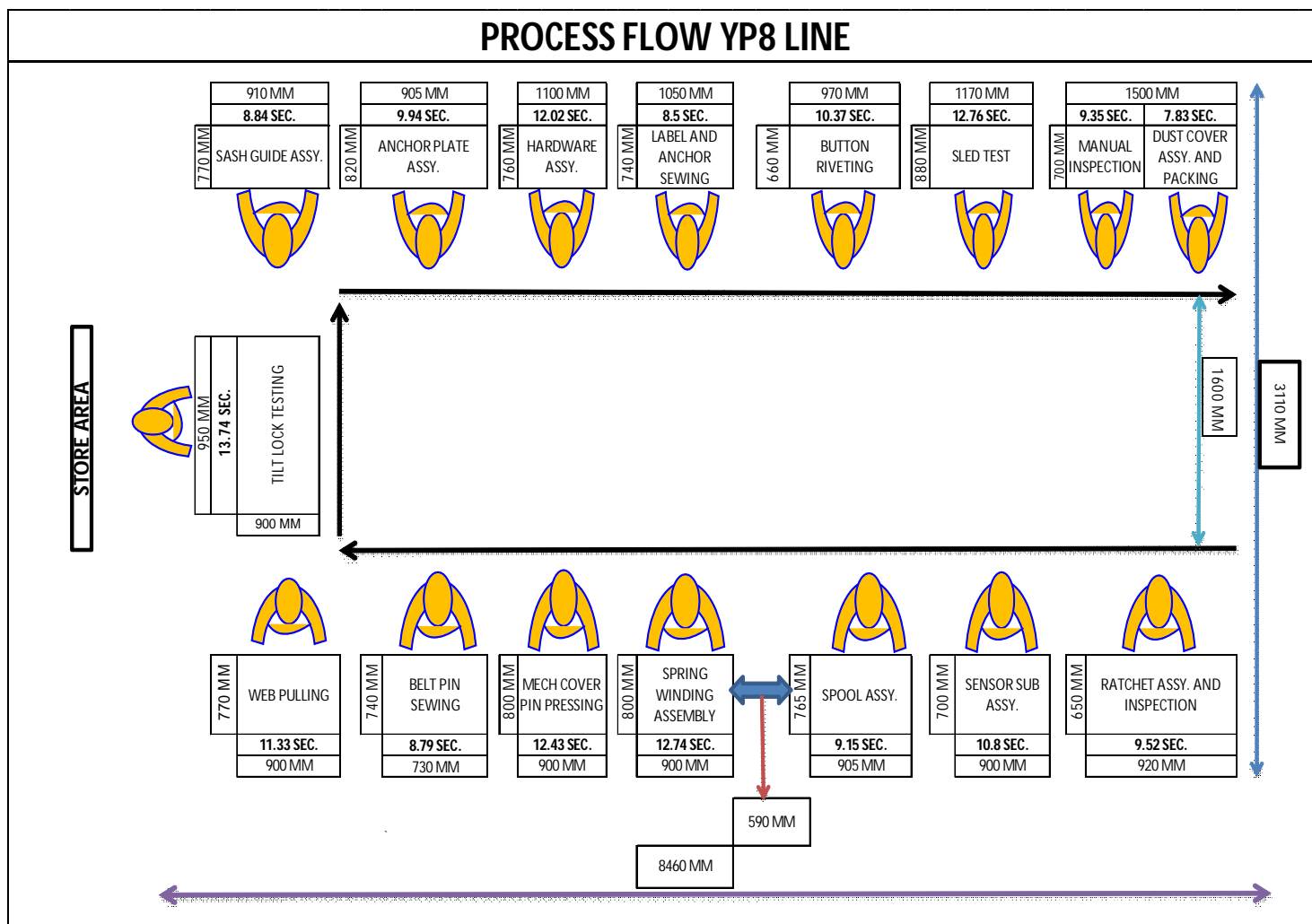


Figure 3. Existing Layout of the Rear Seat Belt Assembly Line.

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The solution focuses on assigning a material handling operator for replenishment of raw assembly material and transfers the assembled parts' boxed containers from one station to another. As a result, the operators at each workstation can continue to concentrate on their assembly task.

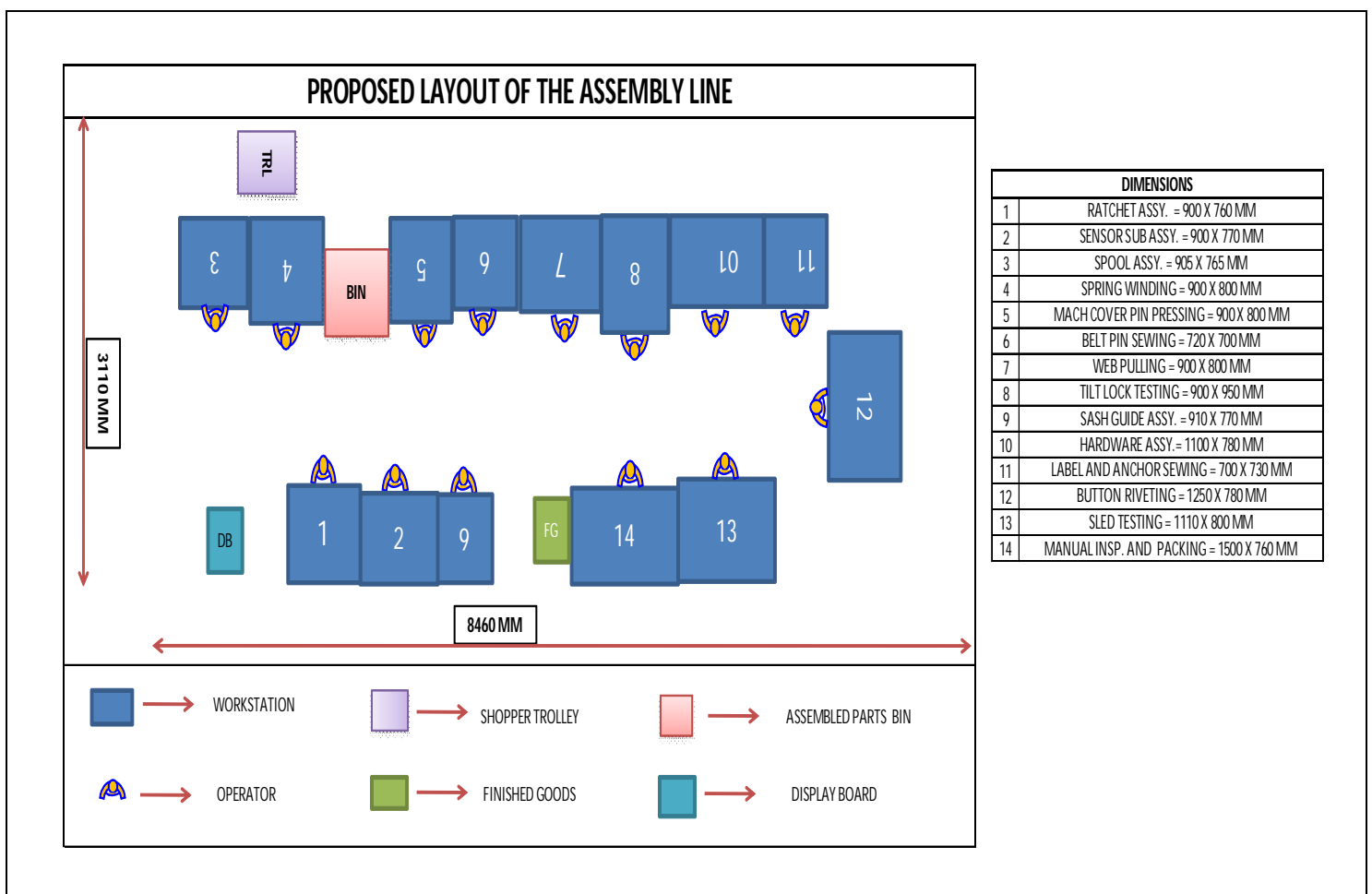


Figure 4. Proposed Layout of the Assembly Line

The above figure shows an overview of the proposed layout of the assembly line. The workstations 1, 2 and 9 are independent, as these doesn't have any direct requirement in the seat belt frame assembly. The Ratchet Assembly (WS-1) is required in Spring Winding Assembly (WS-4), Sensor Sub Assembly (WS-2) is fitted with Mach Cover Assembly (WS-5) and Sash Guide Assembly (WS-9) is required in Hardware Assembly (WS-10). The space around the assembly line is utilized to arrange a shopper trolley. The material handling operator moves around the assembly line for a standard time and replenish the raw assembly parts at the needed workstations and also transfer the boxed containers of the assembled parts to the required workstations, so that the operators don't have to leave their workstations and can concentrate on their parts assembly task.

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VI. CONCLUSION

The productivity of the company for seat belt assembly line was successfully increased using a line balancing method. The company managed to reduce the total time required to complete 2300 product units per day, from 170.54 seconds to 162.26 seconds; and that too within the takt time. The line efficiency increased to 89% from 77%. There is a reduction in two workstations, following this, elimination of two operators is there, benefiting the company by 4,80,000 annually, in terms of cost. This study also describes an overview of the material handling issue in the assembly line and considers a Material Handling Operator to rectify the problem. The proposed layout of the assembly line is designed according to the available floor space, material handling operator's flexibility to utilize the space between the two lines. The material handling operator moves around the assembly line to replenish the assembly parts and transfer the boxed containers of the assembled parts at the needed workstations, so that the operators don't have to leave their workstations.

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