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Value Stream Mapping in a Manufacturing Company

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***Abstract*— The value stream refers to all activities involved in designing, producing and delivering goods and services to customers. Value stream maps are special type of process maps which represent all the actions, both value added and non-value added currently required to bring a product through the main flows essential to every product. The main objective of the study was to draw the current state map for the product molded case circuit breaker which is manufactured in one of leading companies in India, to identify and reduce the non valued added activities and propose a future state to reduce the production lead time and improve the value added time.**

Keywords;Current state Map (CSM), Future state map (FSM), Production lead time ,Value added time.

I. INTRODUCTION

The research study was carried out in a unit based in Mumbai, India which manufactures molded case circuit breaker also known as MCCB. We have taken two types of MCCB's in our product family based on its current rating.

a) MCCB – Type A

b) MCCB –Type B

Both of these MCCB's undergo through the same processing steps as shown in Table.1

TABLE.1PROCESSING STEPS FOR MCCB

S.No.	Process Steps	C/T (sec.)	C/O	Uptime	Operators	Av. Time (sec.)	Inventory (Days/Units)
1	Release Assembly	360	0	100%	1	25200	5 days
2	Assembly 1	125	0	100%	2	25200	180 units
3	Assembly 2	170	0	100%	1	25200	150 units
4	OT Testing	140	0	100%	1	25200	300 units
5	Thermal/Magnetic Calibration	350	0	90%	1	25200	150 units
6	Reset Force testing	180	0	95%	1	25200	200 units
7	milliVolt/High Volt Testing	150	0	95%	1	25200	200 units
8	Packing/Finishing	110	0	100%	2	25200	350 units

The objectives for the implementation of the lean in the company are as follows:

- To study the Current State map by collecting the data from the shop floor
- To identify the problems faced by the company in terms of Non Value Added time and minimise the waste.

To propose Future State Value Map which can reduce Production lead time, increase the Value added time and reduce non value added time

II. LITERATURE SURVEY

The importance and implementation of Value Stream mapping has been studied in detail by pioneers like Taiichi Ohno (1988), Womack et al (1990), Womack and Jones (1998, 2005), Daniel. T. Jones (2006), Rother and Shook (1999), Kevin J Duggan (2002) and Peter Hines and Nick Rich (1997).Taiichi Ohno (1988) could not see waste at a glance (especially across a geographical area). He developed Material and Information Flow Mapping (VSM) as a standard method for mapping the flows visually and it became the standard basis for designing improvements at Toyota - as a common language. It became one of their business planning tools. VSM is now utilized throughout the world, in many businesses to strategically plan and it is the starting point to any lean transformation and implementation.

Womack and Jones (1998) and Moore (2006) have stated that, the organizations of many types are implementing lean manufacturing, or lean production, practices to respond to competitive challenges. They have mentioned that lean initiatives can be taken up in the fields of automotive sector, aerospace, and consumer goods industries around the world. Moore has discussed various implementation tools of Lean Manufacturing, which can be incorporated in the industries.

Rother and Harris (2001) have clearly mentioned the importance of levelling the mix .Producing large batches of one product family variant in the cell makes it hard to supply the customer with a variety of products in a short lead time without holding extra finished goods To minimize batching, surges and upstream inventory, you need to level the product mix of your cell. You can measure the degree of batching in any process by looking at its `EPE` which means ``every-part-every-day`` .EPE indicates how often a process can produce each of the high-running product types it makes.

Yang-Hua and Valandeghem (2002) describe, Value stream mapping as a mapping tool that is used to describe supply chain networks. It maps not only material flows but also information flows that signal and control the material flows. The material flow path of the product is traced back from the final operation in its routing to the storage location for raw material. This visual representation facilitates the process of lean implementation by helping to identify the value-added steps in a value stream, and eliminating the non-value added steps / waste (muda).

Duggan (2006) has explained the application of value stream mapping and lean concepts to Mixed model production. Mixed Model production means producing a variety or mix of products or product variations through the same value stream at the pull of the customer. This means to build and deliver the right quantity of a specific product. In the Mixed model production, a group of products are determined to be a product family and are treated as one.

Ramesh et al (2008) et al mentions the value stream mapping as a technique which involves flowcharting steps, activities, material flows, communications and other process elements that are involved with process or transformation. Value stream mapping helps an organization to identify the non-value-adding elements in a target process and brings a product or a group of products that uses the same resources through main flows, from raw materials to the arms of the customer.

Martichenko and Grabe (2010) are of the opinion that a level flow show be created throughout the process. Level flow reduces variation in processes and tries to spread activities equally over working time. This minimizes the peaks and valleys in movement that creates unevenness and overburden, which result in waste. Use pull systems when level flow is not possible. A pull system is an inventory-replenishment method in which each downstream activity signals its need to the next upstream activity. Pull system reduces wasteful complexity in planning and overproduction.

III. STEPS ADOPTED FOR THE STUDY

As the company was manufacturing many products, our team in consultation with management decided to undertake a study in the molded circuit breaker unit. The following steps was adopted for carrying out value stream mapping in the company

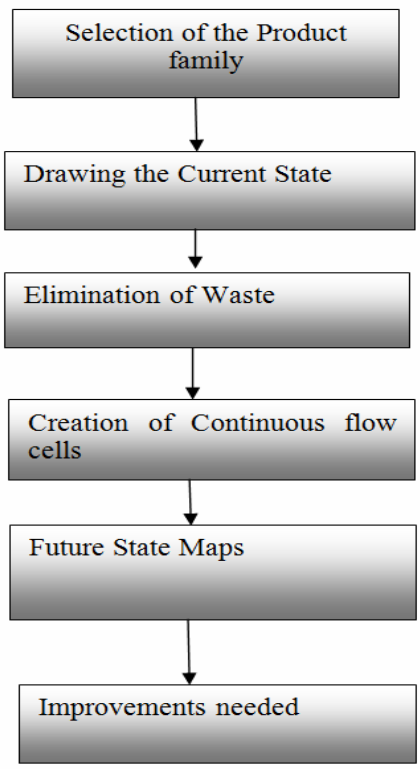

Fig. 1 Steps for Value Stream Mapping

A. Selection of the Product family

The Product which we selected is called molded case Circuit Breaker also known as MCCB. We have taken two types of MCCB's in our product family based on its current rating a) MCCB – Type A b) MCCB –Type B

B. Drawing the Current State

This is an important step in Value Stream Mapping Process. The data is collected while walking along the shop floor and studying material and information flow. The data collection begins at the shipping end (Downstream end) and work towards the upstream.

C. Elimination of Waste

After analyzing the current state map we found that there is a huge difference between production lead time and the actual processing time. So there are good opportunities to eliminate waste from the production line.

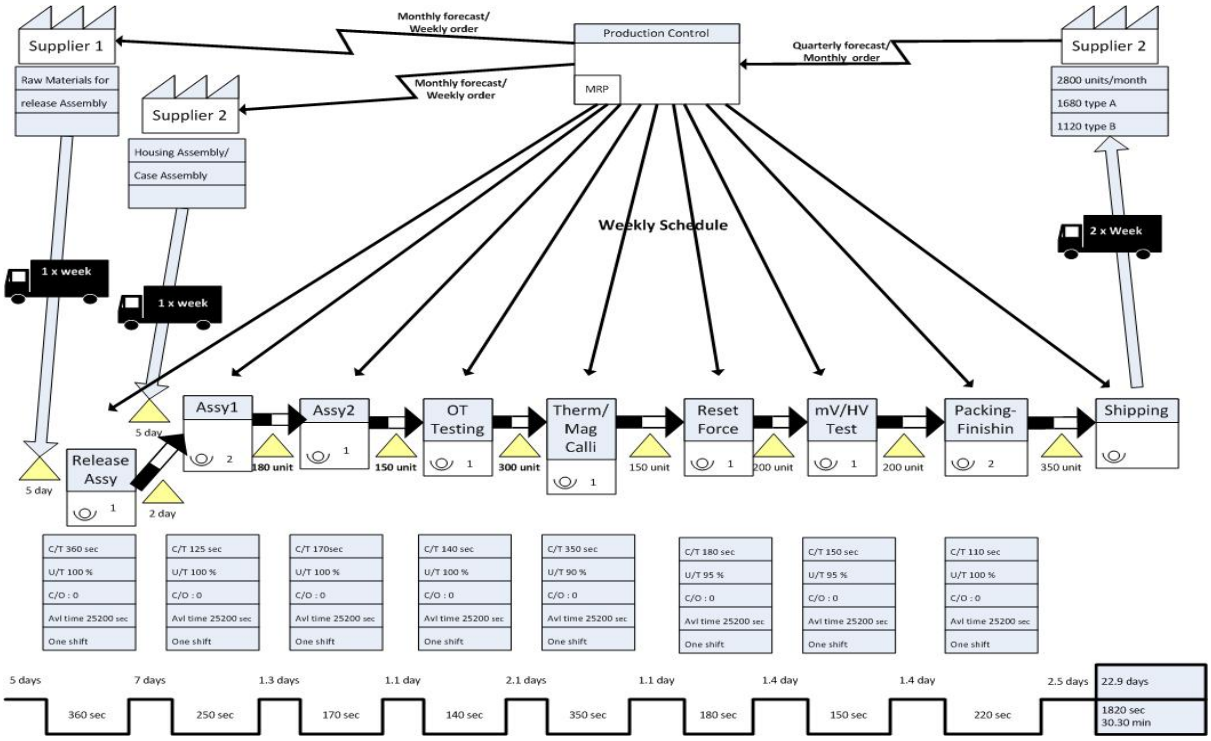

Fig. 2 Creation of current state

D. Creation of Continuous flow cells

The continuous flow cells are created to introduce a continuous flow in the value stream.

E. Future State Maps

The purpose of value stream mapping is to identify and eliminate sources of waste by implementing a future-state value stream that can become a reality within a short time. The goal is to build a chain of production where the individual processes are linked to their customer(s) either by continuous flow or pull, and each process gets as close as possible to producing only what its customer(s) need when they need it.

F. Improvements needed

Suggesting possible improvements in the future

IV. CASE STUDY – ANALYZING THE CURRENT STATE

The Customer gets the shipment twice a week. The Production control department gets the demand forecast every four month and orders monthly. The Production control department sends monthly forecast and weekly orders to the suppliers.

There are two Suppliers:

Supplier 1: It supplies the raw materials for the release assembly.

Supplier 2: It supplies the basic housing assembly (Case Assembly) which will be assembled with release assembly at the next station – Assembly 1

1. Release Assembly Station: At this station, the release assembly is made which further goes into the housing assembly at the next station.

2. Station Assembly 1: The housing assembly is assembled with release assembly.

3. Station Assembly 2: The electrical contacts are assembled to the MCCB.

4. Over Travel Testing (OT Testing): At this station, the over travel between the electrical contacts and its contact pressure is tested.

5. Thermal-Magnetic Calibration: At this station, the MCCB is tested and calibrated for overload and short-circuit faults.

6. Reset Force Testing: At this station, the MCCB is tested for the force required to reset the MCCB.

7. millivolt/High Volt testing (mV/HV testing): The internal electric resistance of MCCB is tested in terms of milli-Voltage and High Voltage drop.

8. Packing & Finishing: The final packing and finishing is done at this station.

We started our value stream mapping from the downstream process which is the Packing and finishing process and travelled upstream towards the Release assembly process. The following information of each process was collected.

- *Calculating the Work in process(WIP) at each work cell*
- *Calculate the Cycle time, Change over time and Utilization percentage of each process*
- *Available time for production in each shift.*
- *Creating Current state based on the Data collected.*

V. CREATION OF CURRENT STATE

After drawing the current state we could find out that the following observations

- The total processing time(production lead time) is 20.9 days and the value added time is 30.30 min.Which meant the total time required to produce one product took approximately 21 days which was relatively very high.
- We could also find considerable amount of Inventory tied up between each process,which was also a great serious of concern.Which in turn prolonged the production process.
- Further we could see the utilization rates of process Therm/magcalli,Reset force,mv/HV test were only 90%,95% and 95 % respectively.Our future goal was to increase it to 100 %.

This meant there were lot of scope to eliminate waste from the production line. In this scenario the authors decided to apply Lean principles and concepts to reduce the production lead time and increase the value added time.

VI ANALYSIS AND CREATION OF FUTURE STATE

After analyzing the current state map we found that there is a huge difference between production lead time and the actual processing time. So there are good opportunities to eliminate waste from the production line. We have observed that Assembly 1, Assembly 2 and OT testing stations are having similar cycle times. So we can form continuous flow cell including these three processes. The Release assembly station cannot be included in the cell because of two reasons:
a) High Cycle time
b) There is a break in flow due to Supplier 2.
We will call this cell 1.
Similarly we can make another continuous flow cell (cell 2) which includes Reset force testing, mv/HV testing and final finishing and Packing. We cannot include thermal magnetic calibration in our Flow cell because it has very high cycle time.

We propose to provide supermarkets in between processes where continuous flow is possible. We will also provide supermarkets for the raw materials to introduce the pull system.

A. Finished Goods Supermarket

As we can see from the 4 months of the demand that there is considerable variation in the monthly demand. So we propose to provide finished goods supermarket before the shipment to take care of these variations. But our ultimate goal will be to eliminate this supermarket in future after the stabilization of internal processes.

B. Calculation of Takt time

"Takt time" is how often one product or part should be produced, based on the rate of sales, to meet customer requirements. Takt is a German word which means pace.
Takt time is calculated by dividing customer demand rate per shift (in units), into the available working time per shift (in seconds).
Available Working Time per shift = 25200 sec
Daily demand = 140 units.
Takt = Available Working Time per shift/ Daily demand
= 25200/140
= 180 sec
= 3 min

TABLE.2 DESIGN OF CONTINUOUS FLOW CELL

Processes Included	**Processing Time (sec.)**
Assembly 1	250
Assembly 2	170
OT Testing	140
Total	560

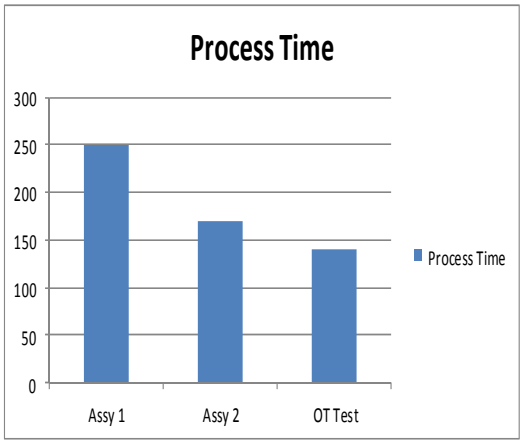

Fig. 3 Process time v/s Workstation

$$No.Of\ operators = \frac{Total\ processing\ time}{Takt\ Time} \quad (1)$$

$$= \frac{560}{180} = 3.11$$

We propose to take 3 operators, Proposed Cycle time = 90 % of Takt time,

= .90x 180 = 162 sec.

So total work content with proposed cycle time with 3 operators = 3x162 = 486 sec.

Difference between current and proposed processing time = 560 -486 = 74 sec.

TABLE 3 DESIGN OF CONTINOUS FLOW CELL 2

Processes Included	Processing Time (sec.)
Reset Force Testing	180
mV/HV testing	150
Packing and Finishing	220
Total	550

To implement this continuous flow cell we need to reduce the total work content by 74 sec i.e. we need to identify and eliminate the total waste equivalent to

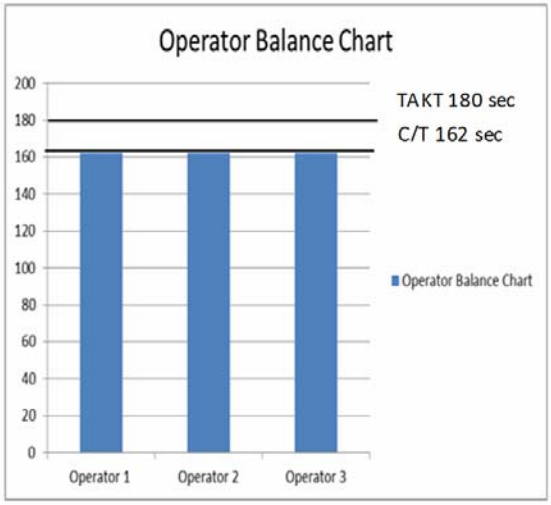

Fig. 4 Operator Balance Chart

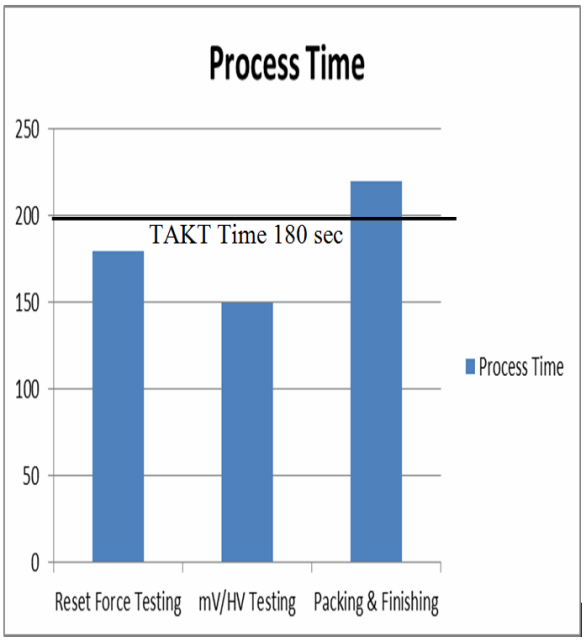

Fig 5 Process time v/s Work station

74 sec of the work content. This will be done by using process kaizen methodology.

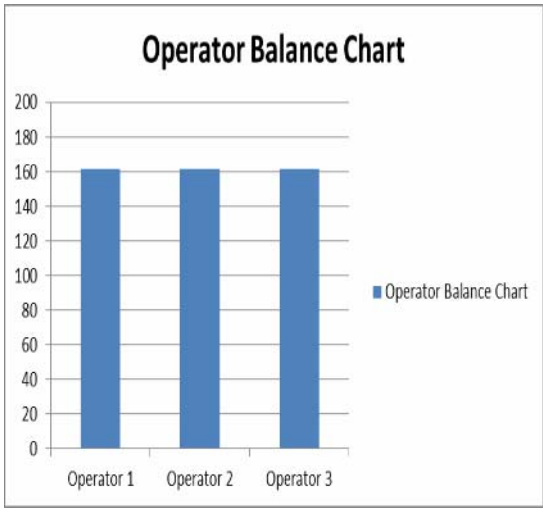

Fig 6 Operator Balance Chart

To implement this continuous flow cell we need to reduce the total work content by 64 sec i.e. we need to identify and eliminate the total waste equivalent to 64 sec of the work content.
This will be done by using process kaizen methodology.

C. Calculation of Finished Goods Supermarket

We are proposing to daily shipment to the customer.
Product Demand for four months:
Month 1 = 2950 units, Daily average demand = 147.5
Month 2 = 2750 units, Daily average demand = 137.5
Month 3 = 2825 units, Daily average demand = 141.25
Month 4 = 2675 units, Daily average demand = 133.75

Average Monthly demand = 11200/4 = 2800 units
Average Daily Demand considering 20 working days per month = 2800/20 = 140 units = Mean daily demand

Standard Deviation of Daily demand, σ = 5.86

For 97.7 % fill rate, Z= 2
By using,

$$Z = \frac{X - Mean}{\sigma} \quad (2)$$

X = 151.72 = 152 units = (Cycle stock + Buffer Stock)
Consider 10 % variation in the internal processes,
So, Safety stock = 10% of X = 0.1 * 152 = 15.2 = 16 units
So Finished Goods Supermarket size = Cycle stock + Buffer stock + Safety stock

= X + Safety stock
= 152 + 16 = 168 units =1.2 days

But as we are going to implement lean for the first time, so we will keep Finished Goods inventory of 1.5 days in supermarket to take care of initial variations.

D. Raw Material Supermarket

As we are going to receive raw material daily on milk run, so ideally we should keep one day inventory in the raw material supermarket, But initially we will keep 1.5 days of raw material to take care of initial variations with ultimate goal to reduce it to one day inventory

E. Assembly Cell Super markets

As we are making every part every day (EPEI= 1 day), We should keep only one day of WIP in the supermarkets, but in the initial stage of Lean implementation, we will start with 1.5 days inventory with the ultimate goal of reducing it to one day .

F Thermal Magnetic Calibration Station

The total testing time = 350 sec
Available time = 25200 sec
Number of MCCB tested = 25200/350 = 72 units
But our daily demand is 140 units,
So we have two options here to take care of this issue:

Option 1: Run this particular station for two shifts daily
In this case, the total available time = 2x25200 = 50400 sec.
Number of breaker tested = 50400/350 = 144 units

Option 2: Add one more testing machine to this station
In this case we will get 2 MCCB tested at a time in 350 sec.
So effective cycle time will be 350/2 = 175 sec
So total MCCB tested in one shift (25200 sec) = 25200/175 = 144 units

As we can see, in both the options, we are able to take care of the daily demand, but which option to be selected, depends upon the company policy.

As we see from the future state map, that the shipping department gets the order from the Production Control, So the pacemaker in our case would be the Shipping Department.

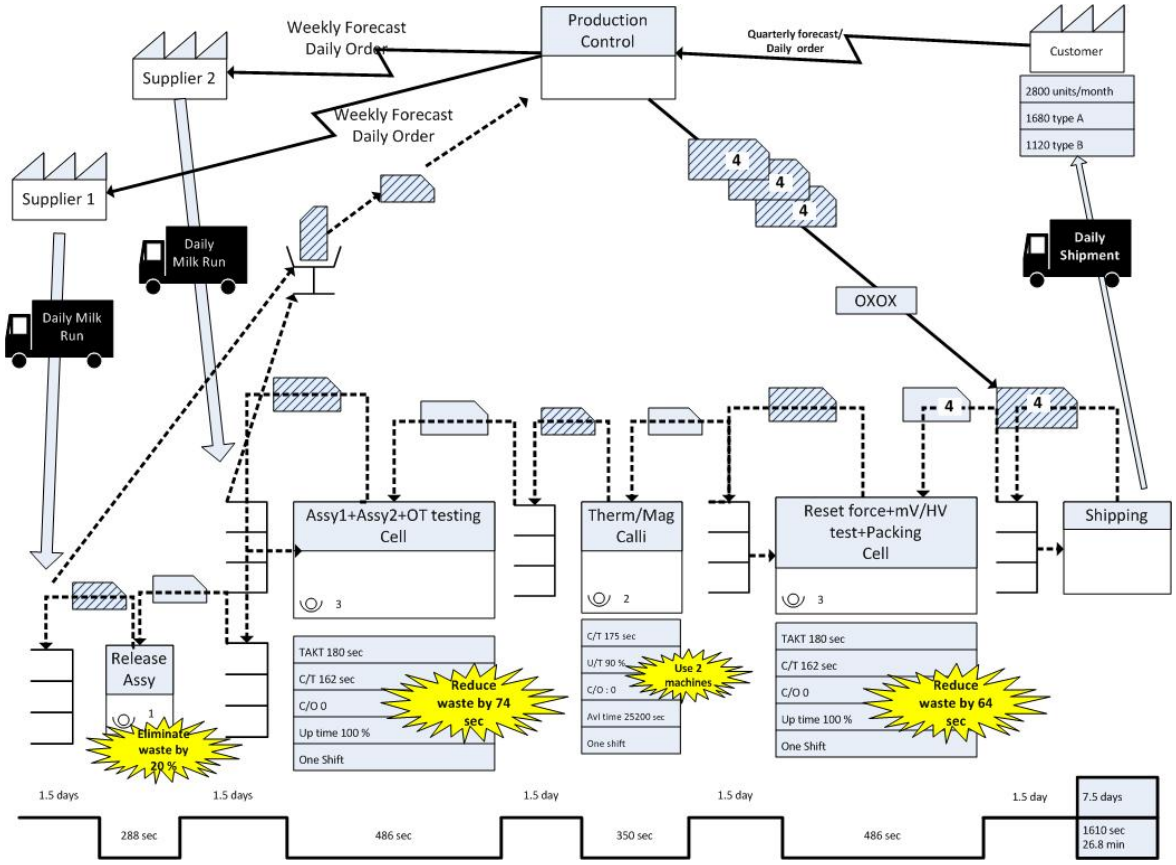

Fig. 7 Creation of Future State

The Production Control department levels the products with the help of the Heijunka Box. The Withdrawal kanbans are pulled one by one by shipping department from the Heijunka Box. After this process a Production kanban is issued to Cell 2.

Similarly if the Thermal/ Magnetic Calibration cell withdraw products from the supermarket with help of the withdrawal kanban, a production kanban is issued to the Cell 1.When Cell 1 withdraws the products from the super market a production kanban is issued to the Release assembly cell. Finally when the release assembly cell withdraws the raw materials from the supermarket the withdrawal kanban is transferred to a signal post from where it is transferred to the production control department.

G. Pacemaker

H. *Pitch*

The Packing size is four numbers of MCCBs per pack.

So Pitch = 4x Takt Time =4x180 = 720 second = 12 minutes

This means every withdrawal/Instruction Kanban for MCCB will be of 4 numbers of MCCB.

Now, we have total available working time = 25200 sec = 420 minutes

So, Number of available Pitch intervals = 420/12 = 35

Pitch intervals available for Type A = 60% of 35 = 21 intervals

Pitch intervals available for Type B = 40% of 35 = 14 intervals

Now as we have to run the production for one shift only and our EPEI is one day, so we will try to level the production of both the types evenly during the available pitch intervals.

TABLE 4. LEVELLING THE PRODUCTION MIX

Pitch intervals	1	2	3	4	5	Tea(9:00 to 9:15)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Lunch(12:03 to 12:33)
Shift time	8:00	8:12	8:24	8:36	8:48		9:15	9:27	9:39	9:51	10:03	10:15	10:27	10:39	10:51	11:03	11:15	11:27	11:39	11:51	
MCCB Type	A	B	A	B	A		B	A	B	A	B	A	B	A	B	A	B	A	B	A	

Pitch intervals	20	21	22	23	24	25	Tea(13:45 to 14:00)	26	27	28	29	30	31	32	33	34	35	Shift Ends here
Shift time	12:33	12:45	12:57	13:09	13:21	13:33		14:00	14:12	14:24	14:36	14:48	15:00	15:12	15:24	15:36	15:48	16:00
MCCB Type	B	A	B	A	B	A		B	A	B	A	A	A	A	A	A	A	

I. Improvements Proposed

TABLE. 4 IMPROVEMENTS AFTER IMPLEMENTING THE FUTURE STATE

	Current state	Future state	Improvement
Operators	10	9	10%
Lead Time	20.9 days	7.5 days	64.10%
Processing time	30.3 minutes	28 minutes	7.60%

1. As we can see that earlier we used total 10 operators but now we need only 9 operators, so there is saving of one operator's cost.
2. Earlier the total Lead time was 20.9 days which has now come down to 7.5 days.
3. The total processing time was 30.3 minutes which has come down to 28 minutes now.

We will make the plan for future state implementation step by step by introduction of different loops in the future state map for our convenience:

J. Implementation Plan

- **Pacemaker Loop**

1. Develop continuous flow cell-2 , from Reset force testing to the packing station
2. Operate the Continuous flow cell-2 with only 3 operators with C/T= 162 sec
3. Kaizen work elements to reduce the total processing time to 486 sec i.e. reduction by 64 sec.

- Pacemaker Loop
- Flow cell & Thermal/magnetic Calibration Loop
- Supplier Loop

4. Improve the up time at Reset force testing and mV/HV testing stations
5. Develop Pull system by introduction of FG supermarket
6. Keep only 1.5 days of finished goods in the supermarket

1. Develop continuous flow cell-1 from assembly-1 to Over travel (OT) testing stations
2. Operate the Continuous flow cell-1 with only 3 operators with C/T= 162 sec
3. Kaizen work elements to reduce the total processing time to 486 sec i.e. reduction by 74 sec
4. Introduce pull system by introducing supermarkets between Flow cell 1, Thermal/magnetic Calibration and Flow cell 2
5. Keep two machines for Thermal/magnetic calibration station to reduce cycle time to 175 sec from 350 sec
6. Keep 1.5 days inventory in the supermarkets

Achieving the Future state:

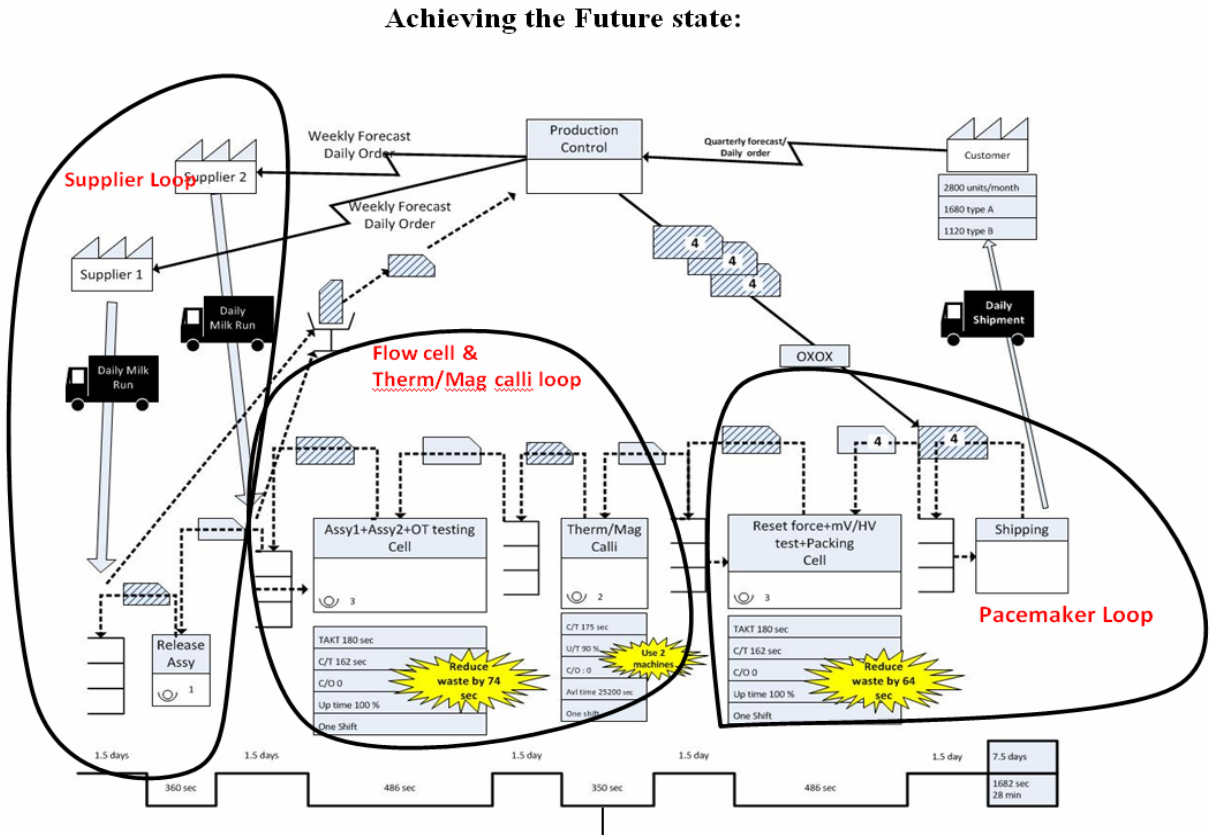

Fig. 8 Achieving the Future State

- **Flow cell & Thermal/magnetic Calibration Loop**

- **Supplier Loop:**

  1. Develop pull system by introducing Raw Material
  2. Supermarket
  3. Introduce Daily delivery of raw materials(Milk Run) from the suppliers
  4. Keep 1.5 days inventory of raw materials at the supermarket

VII. CONCLUSION:

We selected one Product Family and tried to develop a Lean system for the same. We suggested changes in the system based on the required average demand rate to ensure the continuous Pull system. We need to maintain this continuous flow and level pull by monitoring the system and following the standards and rules. After implementing lean system to this product family, we need to concentrate on other product families also to achieve the similar targets based on following the same principles of lean. We may need to use additional resources such as equipment and operators in that case. Developing value stream for all other product families will be more complicated and will need a very well planned strategy to achieve this goal.

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