Assembly Line Design

DESIGN AND LINE BALANCING OF U-SHAPED ASSEMBLY LINE

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Introduction

Turbo Energy Limited (TEL) is a leading manufacturer of turbochargers in India, catering to the requirements of Internal Combustion engine industry. TEL is equipped with state of the art technology and skilled manpower to consistently deliver quality products.

History:

TEL is part of the TVS Group of Companies. The TVS Group traces its origins to a rural transport service, founded in 1911 by TV Sundaram Iyengar in Tamil Nadu, India. Today, this renowned business conglomerate remains faithful to its core ideals of trust, values, service and ethics._ With a combined turnover of more than US$ 4 billion, the TVS Group employs a total workforce of close to 25,000. Charting a steady growth path of expansion and diversification, it currently comprises around 30 companies.

About TEL:

Established in 1982 as a joint venture between Brakes India Limited, Sundaram Finance Ltd & BorgWarner Turbo Systems Worldwide Headquarters GmbH (formerly known as Künle, Köpp & Kausch), and TEL is today a leading Turbocharger supplier to all Original Equipment Manufacturer (OEMs) operating in India.

Turbo Energy Ltd (TEL) has established a world-class manufacturing facility on a 75 acres complex in a small village, 100km west of Chennai, South India. The plant manufactures turbochargers of various sizes suitable for engines of 1.5 L capacity to 23 L capacity. TEL is certified for TS 16949: 2002.

TEL supplies turbochargers to top-notch companies like:

Green Initiatives:

The Turbocharger itself is a product which helps in reducing emissions that harm the environment. In addition to that the company has taken several eco-friendly initiatives like harnessing the solar energy, wind energy and rain water harvesting.

- **TEL Green Building:**
  - Double wall with stabilized soil cement foundry sand bricks & Aerocon Block with 2 inch thick EPS insulation in between. This combination has U- Value of 0.054 Btu / hr.ft2. Which is much lower than required U-value of 0.124 Btu / hr.ft2.
  - Albido Paint on the Roof with Reflectivity of 82% and EPS under deck insulation with shading effect by solar reflective collector.
  - Energy Efficient Double Glazing with Low –e Coating. This glazing has U Factor = 0.586 Btu / hr.ft2. SHGC = 0.24, High LTC, Has Day light & vision windows. Hardly uses artificial light during day.
  - Building has both Ceiling and Task Lighting Building requires 0.6 Watt / sq. in Open office and 0.7 Watt /Sq. in rest of area against standards of 1.0 watt / sq.
    Outside lighting minimized to reduce night glow and impact on nocturnal environment

- **Solar Air Condition System**:
  - First Time a centralized solar air – conditioning system of 90TR has been installed in India. Parabolic dish reflectors generate pressurized hot water at a temperature of 140 Deg.C. This is fed into a Pressurized Hot Water Fired Vapour Absorption Chiller generates chilled water used for air conditioning the building.
- **Renewable Energy:**
  - **PV cells:** 1200 W of Photo voltaic cells to generate electricity from solar energy to for lighting of the office.
  - **Wind Turbine:** 1 Nos., 5 kW mini wind turbine generates electricity. PV cells Wind Turbine Hybrid System for ups, lighting offices on cloudy days.
  - **Solar Lighting:** Solar based street lighting. 150 no's of solar street light in the main roads.
- Transfers well water to tanks for horticultural use, by harnessing wind energy

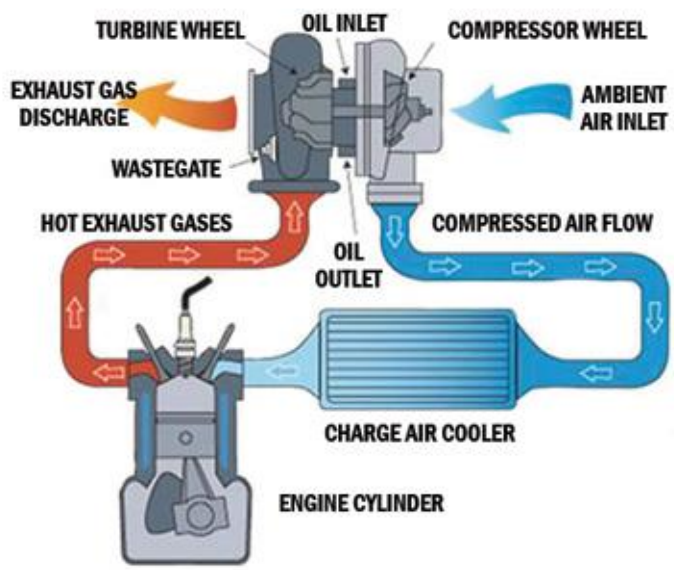
- **Zero Ozone Depletion Effect:**

- Central AC plant does not use CFC or CHFC, but Lithium Bromide and water as refrigerant

The net effect of this is the reduction of carbon-foot print up to 1000 tons/ annum and ₹ 30 lakhs is saved on total energy cost.

What is a Turbocharger?

In exhaust gas turbo charging, part of exhaust gas energy, which would normally be wasted is used to drive a turbine. The turbine shaft is connected to a compressor, which draws in combustion air, compresses it, and then supplies it to the engine. The increased air supply enables more fuel to be burnt; hence the engine develops higher power. Increased air availability improves combustion of fuel, thus leading to lower fuel consumption and less emission.



The advantages of modern turbocharged engine, compared to naturally aspirated engines of identical power output are as follows:

1. Better power and torque characteristics
2. Lower emission
3. Lower weight and a smaller engine package
4. Lower fuel consumption
5. Lower engine noise
6. Reduced power loss at high altitude

Turbocharger Technology

Non Waste gated Turbocharger:

Basic Turbocharger without boost control. Mainly used in Industrial and off-highway engines and in some commercial vehicles.

Waste gated Turbocharger:

Turbocharger with Max. Boost pressure control. Currently used in Passenger cars, M U Vehicles and commercial vehicles.

Turbocharger with integrated exhaust manifold:

The Engine exhaust manifold and turbine housing of the turbocharger is made in single piece. This eliminates joints and facilitates ease of assembly onto the engine.

VTG Turbocharger:

Variable Turbine Geometry (VTG) Turbocharger provides boost on demand due to its unique control mechanism. Mainly used in new generation Passenger cars and M U Vehicles meeting BS IV and above Emission norms.

R2S Turbocharger:

Regulated two stage Turbocharger (R2S), this system uses one low pressure turbocharger and one high pressure turbocharger i.e. two turbocharger for one engine to obtain high density power. This system offers possibility in downsizing the engine

to meet future Emission norms while meeting the customer drivability requirements.

Gasoline Turbocharger:

Gasoline (Petrol) Turbocharger is similar to that of diesel engine turbocharger in its working. However, the materials used are special and will have additional features like water cooled bearing housing and recirculation valve to meet specific gasoline engine operating requirements.

Turbocharger Range

TEL has wide range of products to suit different applications. The selection of TC is based on customer requirement and its application.

The table below provides the current TEL Product range:

Series	**KP**			**K0**			**K1**		**K2**			**K3**		
Size	KP31	KP35	KP39	K03	TR43	K04	K14	K16	K24	K26	K27	K33	K36	K37
Non Waste gate TC		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Waste gate TC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Variable Turbine Geometry		✓		✓										

TC														

Manufacturing Activities:

Assembly

The turbocharger assembly mainly has the following stages:

1. Core assembly
2. Balancing
3. Assembly of Housings
4. Waste Gate Actuator setting
5. Final Inspection

The individual components are stored in Heavy duty storage Rack systems & automated Vertical storage systems. These parts are moved to the assembly using conveyors systems and other lean management material handling systems.

Core Assembly

Core assembly can be called as a heart of the Turbocharger, The Core assembly provides supports for the journal bearings and provides lubrication to the rotary parts. There are semi-automatic core assembly stations with special controls for error proofing.
TEL is also equipped with automatic core assembly line for passenger cars which has higher operational speed. There are controls at each stage for ensuring Zero defects.

Balancing

In addition to individual component level balancing, based on the application

balancing is also done as a core assembly. The balancing helps in reducing the vibrations and noise levels during operation. TEL has facility for fully automatic high speed core balancing and semi-automatic balancing. These machines are a master piece demonstration of the collaboration's technological competence. The cores can be balanced to higher speeds up to 200,000 RPM based on the application requirement.

Assembly of Housings

The Core Assemblies are mounted and fastened at required orientation on the Compressor housing & turbine housing. These operations are done in individual work stations with error proofing control. TEL also has a semi-automatic conveyor assembly line for assembling the housings to the core assembly .This has pallet mechanism for feeding the materials and assembly is done on the pallet. The traceability is established by interfacing 2D readers which reads the unique turbocharger serial no. at each station and records the parameters and values at that stage. The tightening process is controlled with a DC tightening tool, the feedback is monitored and the torque values are stored in the data base. The assembly line also has sensors and vision systems to detect the presence of various components.

Waste Gate Actuator setting

The Waste Gate Actuator setting is done to enable the waste gate flap to open at the required operational boost pressure. TEL uses a custom built Setting Rig made by the technology development wing for performing this operation. There are various controls like data traceability, characteristic monitoring, error proofing control etc. in these rigs. TEL also has the state of art Flow setting rig for Variable geometry Turbochargers

Final Inspection

Final Inspection of turbochargers is carried out at the End of each line to ensure the compliance of the Turbocharger to the specified requirements. Final Inspection acts as a firewall to improve the rapid detection and control mechanism. Final Inspection is done manually by trained personals and with the aid of automated vision system.

KP35 Linear Assembly Line (Current)

The KP 35 assembly line is a linear line which has the capacity to produce 40000 turbochargers a month. This assembly line consists of a total of 7 stations, 2 of which are completely automated, and requires a minimum of 4 operators to man the remaining stations. The length of the assembly line equals 8 meters and the total floor space used by the line is 6 sq. meter. The material feeding is done manually. The line is designed in such a manner that such that flexibility becomes an advantage. This line also has extremely high productivity.

The assembly line consists of 7 stations, in which one or more operations can take place. The various operations taking place in each assembly line are as follows:

STATION 1:

This station, which requires an operator, includes loading of the core assembly, the compressor housing, the turbine housing and the actuator onto the palette. This station also includes the process of mounting the O-ring on the core assembly. The average cycle time that these processes require amounts to 23 seconds. The operator who mans this station needs to work continuously as he sets the pace for the production of the turbocharger.

STATION 2:

This particular station requires an operator and is partially automated. The assembly of the compressor housing and the core takes place at this station. This is done by first loading the core assembly in the gripper. The gripper then mounts the core assembly into the compressor housing. The average cycle time for these processes amounts to 27 seconds. Since the operations in this station take more time than in the first station, after a while, the products begin to stack up in this station. Hence this station can be described as a waiting stage.

STATION 3:

Station 3 involves assembling the actuator followed by the pre-assembly of the central housing side bolts. Both these processes are done manually. The average cycle time for this station equals 21 seconds. The operator at this station enjoys a few moments of idle time as his process requires lesser time.

STATION 4:

This is a fully automated process. This consists of the torqing of the central housing side bolts. This process requires 33 seconds. Since this process takes a longer time than previous operations, once again products get accumulated. Hence this is also a waiting stage.

STATION 5:

This is also an automated process. This is a fairly short process that involves application of grease on turbine housing. The time required for this operation is 15 seconds.

STATION 6:

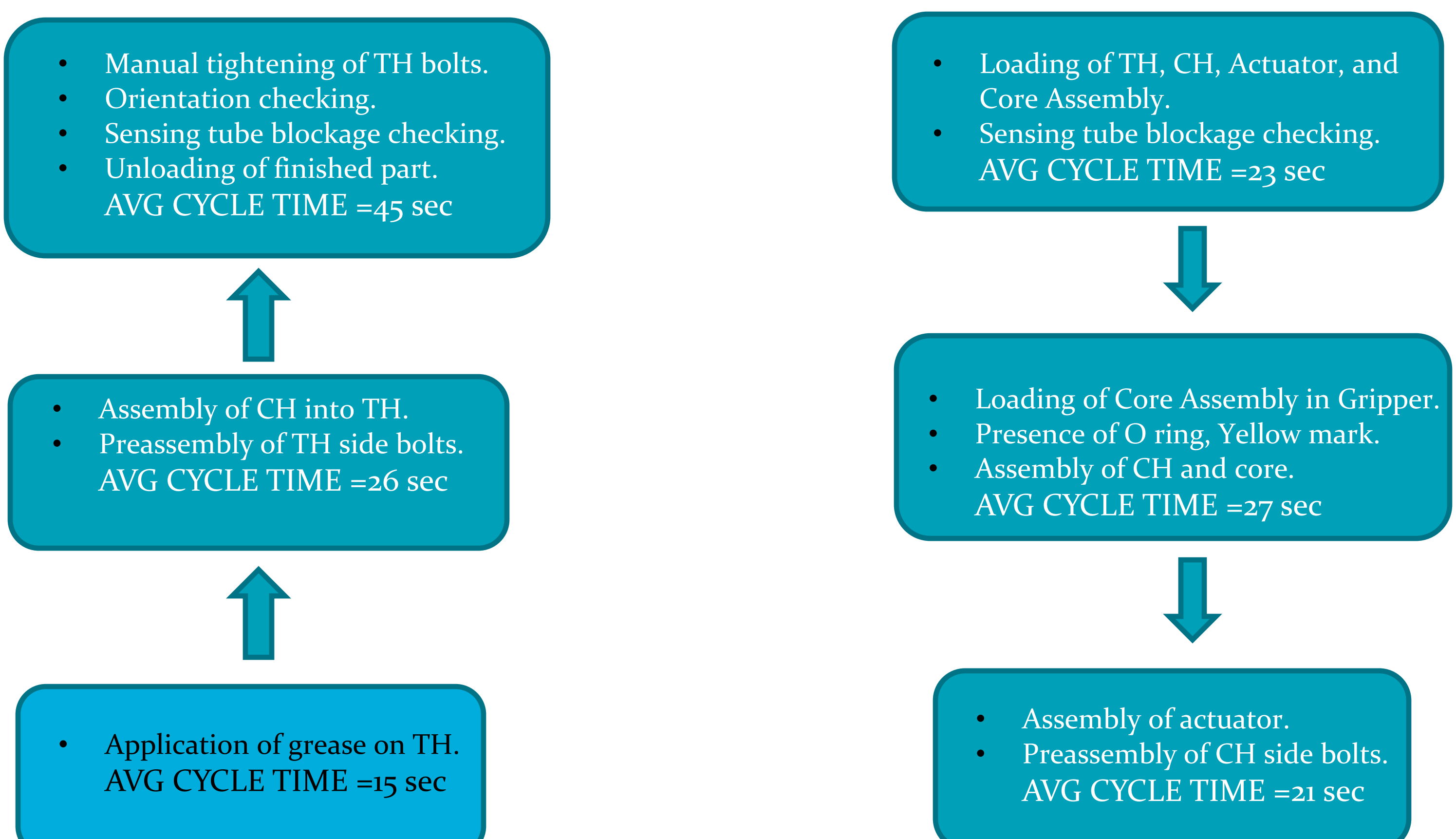
This station consists of assembly of central housing into turbine housing followed by the pre-assembly of the turbine housing bolts, which is done manually. The average cycle time for these processes equals 26 seconds. This is also a waiting stage.

STATION 7:

This station involves manual tightening of the turbine housing bolts, followed by tests and final inspections such as orientation checking, sensing tube blockage checking and unloading of finished part.

This station takes the longest time to finish its process, with an average cycle time of 45 seconds, and hence this process determines the cycle time of the entire operation.

Flow Diagram of Operations:

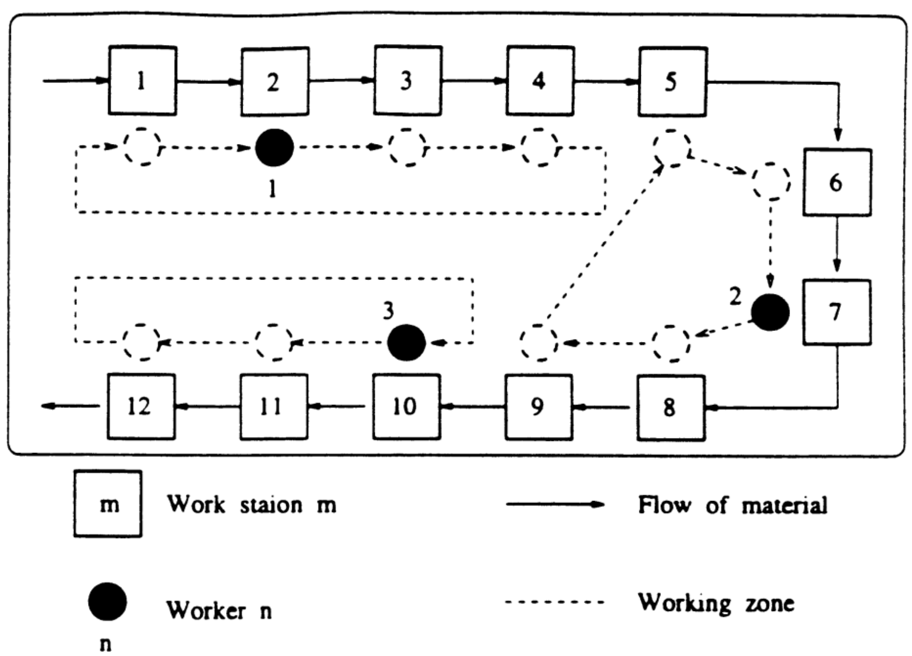


Proposed Assembly-Line (U-shaped)

The proposed assembly line layout for the KP35 model in order to improve the efficiency of its production process is a Machine oriented U-shaped assembly line with static and mixed working zones.

Why U-shaped?

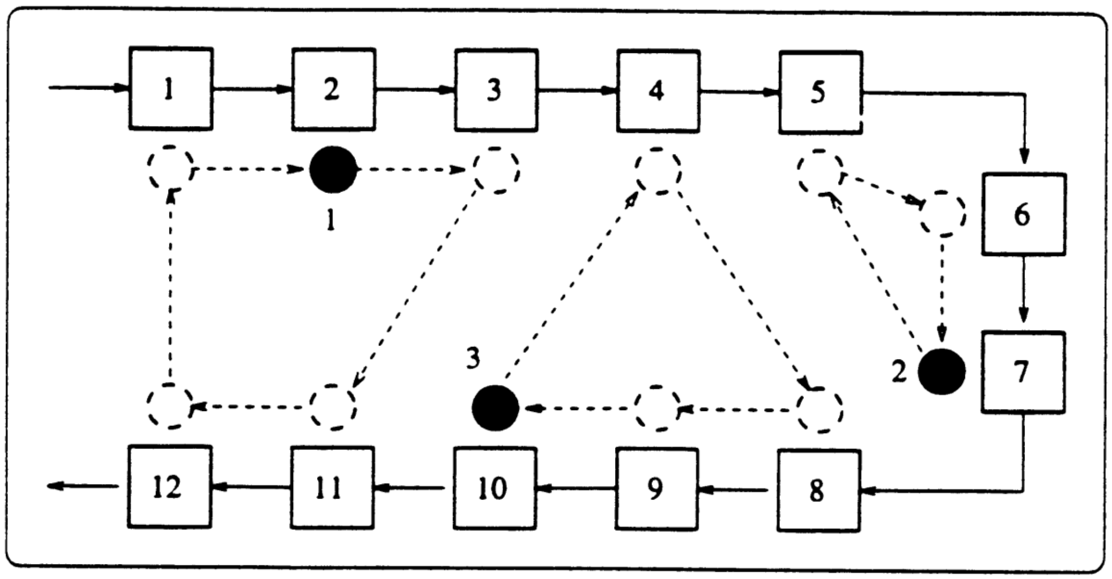
A U-shaped assembly line is a production or assembly in which there are machines or tools available to perform 'N' different operations on an item (all items that enter the system require the sequence of operation from 1,2……N)in a line which is usually configured in a U-shaped. The number of workers in this system are lesser than the number of workstations present in the system.



A U-shaped line with $N = 12$ work stations and $M = 3$ workers.

A static working zone is one in which the sets of machine assigned to each operators are mutually exclusive and therefore the, the operators working zones have no common area i.e. only one specific worker is allows to work in a given workstation. Static working zone has an advantage over dynamic working zones since it does not require the operator to have knowledge about process handled other workstations.

A mixed working zone is where the workstations assigned to given operator need not be consecutive workstation. A mixed working zone has greater flexibility with regard to movement of the worker as a result it helps in balancing the amount of workload assigned to each worker more effectively.



The U-shaped Assembly line has several advantages over the traditional assembly lines which make them more suitable as a production layout for a given product .These advantages are

- Flexibility to increase or decrease the number of workers when adapting to changes in production quantities due to the fluctuations in the demand of the given product
- Having multi-functional workers rotating through stations in the lines allow more workers to participate in efforts to improve the process
- Workers stay more alert by rotating through a variety of tasks compared to repeating a single short cycle task
- The number of stations is always less or equal to that required on a traditional line because there are more possibilities to group tasks into a station in a U-shaped line
- The walking time between workstations are reduced
- Provides a better material flow
- Suitable for better supervision and control

- It is more suitable to have a U-shaped line when we have mixed working zones since the distance between workstation is usually lesser than that in straight assembly line which is also responsible for reduction in walking time between stations
- Restriction in the movement of the operator is greatly reduced in a U-shaped assembly line when compared to that in linear assembly line and hence balancing is more efficient in the U-shaped assembly line
- Communication between workers is easier in a U-shaped Assembly line when compared to a linear assembly line

KP35 U-Shaped Assembly Line (Proposed)

The proposed U shaped assembly line has some similar characteristics with the linear line. It has the same capacity as the linear line. The main difference is the U-shaped requires one less worker and has one less station, i.e., requires 6 stations, 2 of which are automated, and requires 3 operators. Another difference is the station which was used for mounting the various objects onto the palette has been eliminated. The operators will be provided with the various objects as and when they need them. The length of the assembly line equals 6.9 meters and the total floor space used by the line is 7.25 sq. meter. The material feeding is done manually. The flexibility of this line is much higher than that of the linear line.

The assembly line consists of 6 stations, in which one or more operations can take place. The various operations taking place in each assembly line are as follows:

STATION 1:

This particular station requires an operator and is partially automated. The assembly of the compressor housing and the core takes place at this station followed by the assembly of the actuator. This is done by first loading the core assembly in the gripper. The gripper then mounts the core assembly into the compressor housing. The actuator is assembled manually onto the assembly. The average cycle time for these processes amounts to 34 seconds.

STATION 2:

Station 2 involves the pre-assembly of the central housing side bolts. This process requires a cycle time of 5 seconds. This station has been assigned a small job so that the operator who mans this station can also take care of the proceedings in the 5^{th} station. Since the operator of this station looks after the processes which are going on in 2 stations, product tends to get stacked up at this station. Hence this station is a waiting stage.

STATION 3:

This is a fully automated process. This consists of the torqing of the central housing side bolts. This process requires 33 seconds.

STATION 4:

This is also an automated process. This is a fairly short process that involves application of grease on turbine housing. The time required for this operation is 15 seconds.

STATION 5:

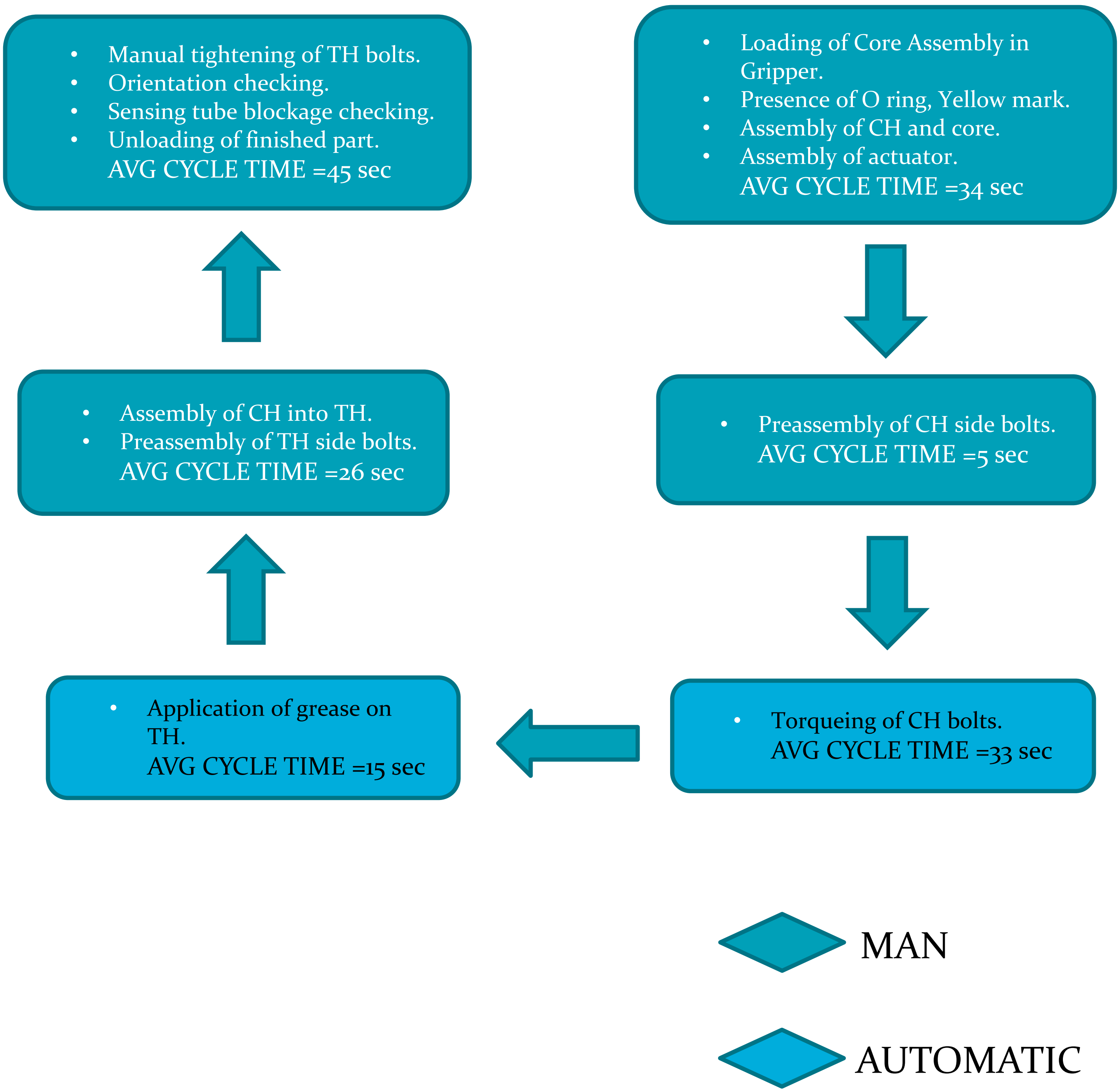
This station consists of assembly of central housing into turbine housing followed by the pre-assembly of the turbine housing bolts, which is done manually. The operator who looks after this station is the same one who looks after station 2 as well. The average cycle time for these processes equals 26 seconds.

STATION 6:

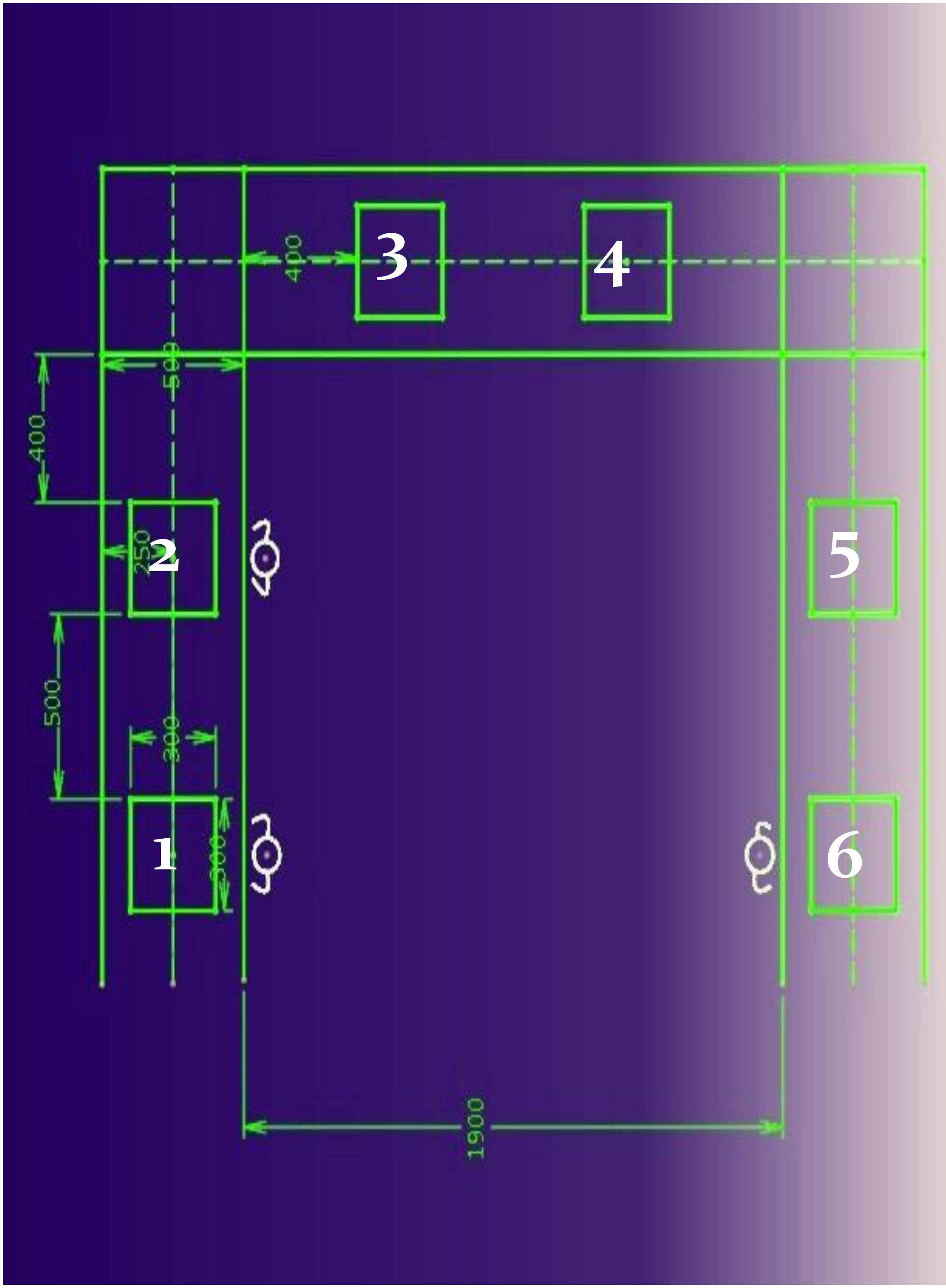
This station involves manual tightening of the turbine housing bolts, followed by tests and final inspections such as orientation checking, sensing tube blockage checking and unloading of finished part.

This station takes the longest time to finish its process, with an average cycle time of 45 seconds, and hence this process determines the cycle time of the entire operation.

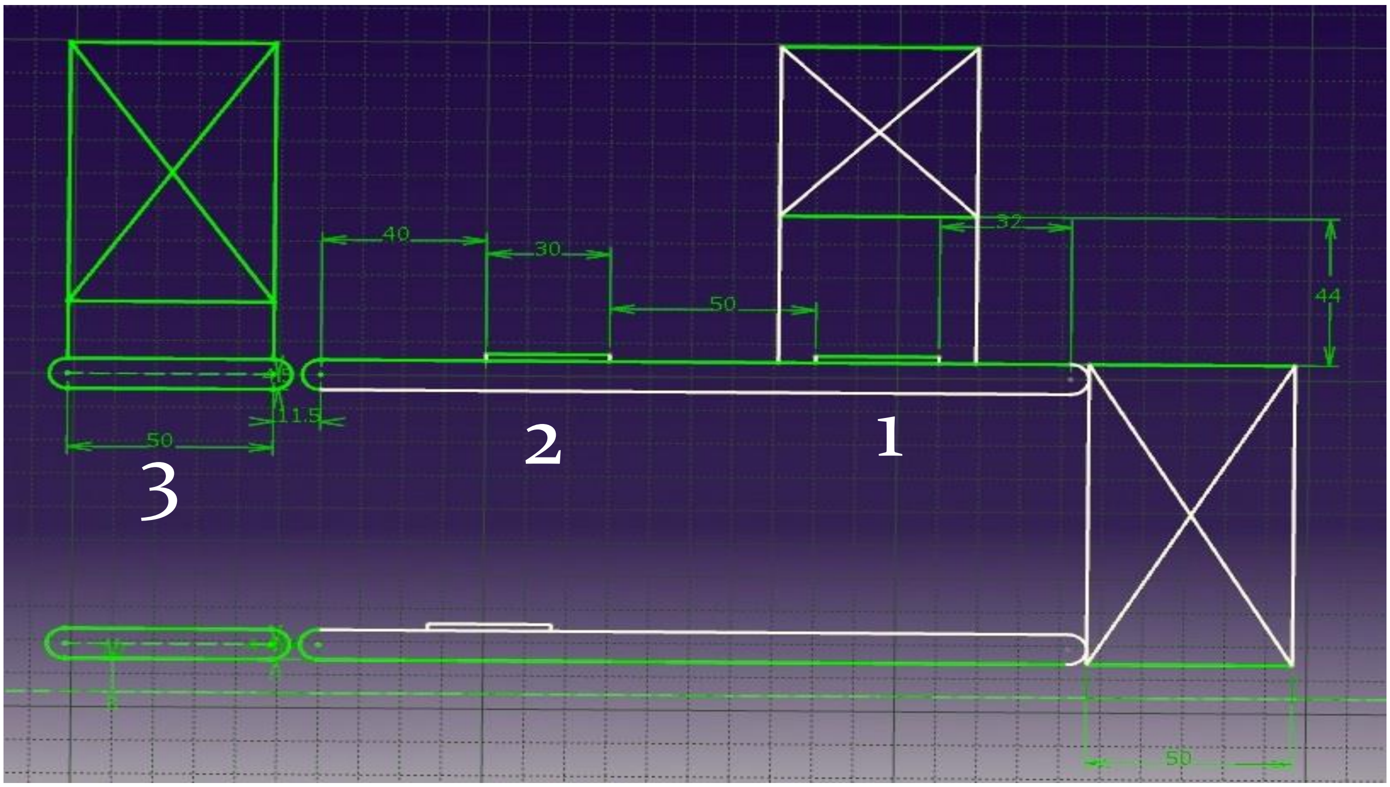
Flow Diagram of Operations



Top View



Side View



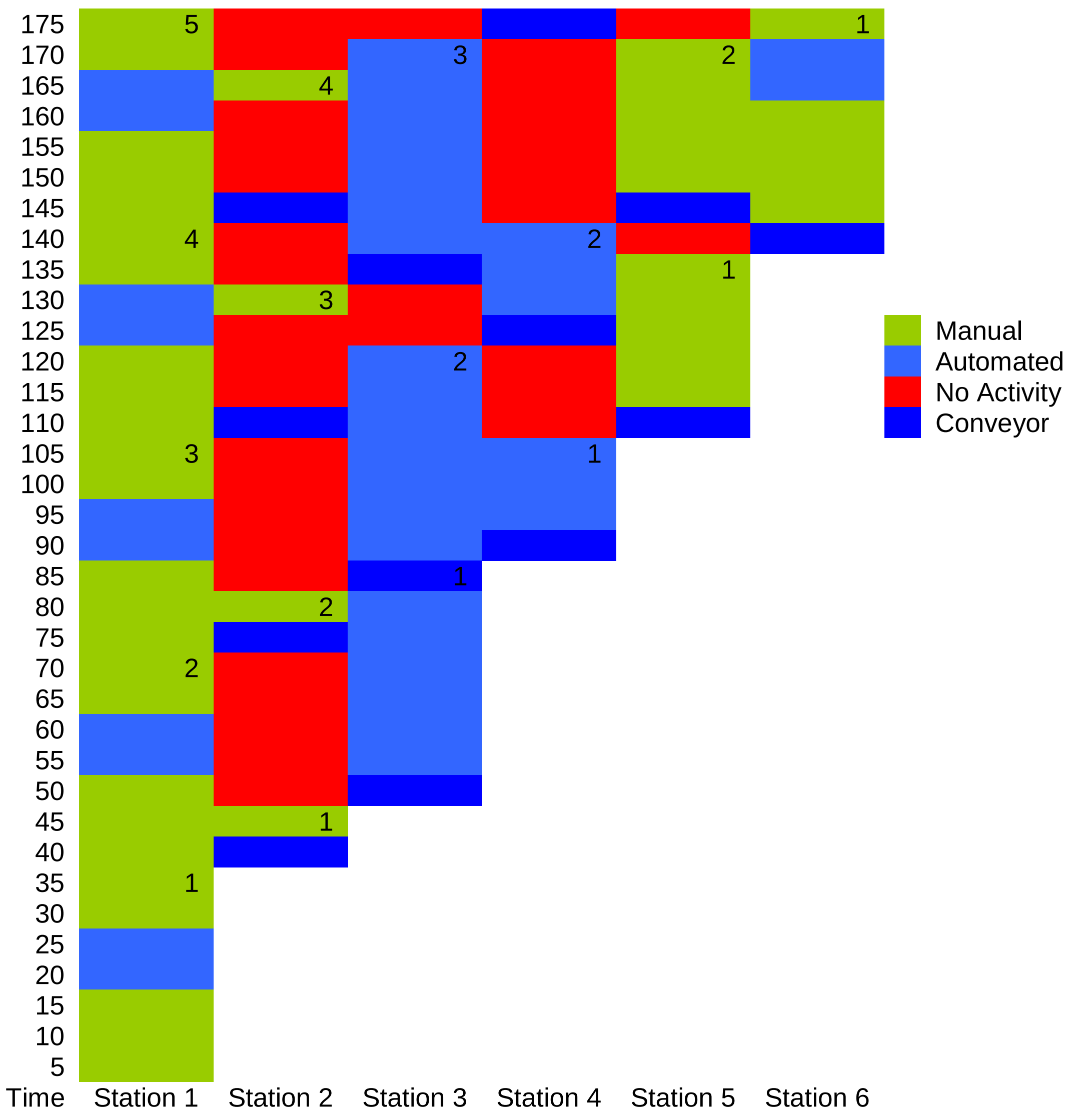
Simulation of U-shaped assembly line

Product No.		1	2	3	4	5	6	7	8	9	10	11
	Start	00:00	00:34	01:08	01:42	02:16	02:50	03:24	03:58	04:32	05:06	05:40
	Processes Time (s)	34	34	34	34	34	34	34	34	34	34	34
Station 1	**End**	00:34	01:08	01:42	02:16	02:50	03:24	03:58	04:32	05:06	05:40	06:14
		00:37	01:11	01:45	02:19	02:53	03:27	04:01	04:35	05:09	05:43	06:17
	Start	00:37	01:11	02:05	02:42	03:33	04:10	05:01	05:38	06:29	07:06	07:57
	Processes Time (s)	5	5	5	5	5	5	5	5	5	5	5
Station 2	**End**	00:42	01:16	02:10	02:47	03:38	04:15	05:06	05:43	06:34	07:11	08:02
	Start	00:45	01:19	02:13	02:50	03:41	04:18	05:09	05:46	06:37	07:14	08:05
	Processes Time (s)	33	33	33	33	33	33	33	33	33	33	33
Station 3	**End**	01:18	01:52	02:46	03:23	04:14	04:51	05:42	06:19	07:10	07:47	08:38
	Start	01:21	01:55	02:49	03:26	04:17	04:54	05:45	06:22	07:13	07:50	08:41
	Processes Time (s)	15	15	15	15	15	15	15	15	15	15	15
Station 4	**End**	01:36	02:10	03:04	03:41	04:32	05:09	06:00	06:37	07:28	08:05	08:56
	Start	01:39	02:13	03:07	03:44	04:35	05:12	06:03	06:40	07:31	08:08	08:59
	Processes Time (s)	26	26	26	26	26	26	26	26	26	26	26
Station 5	**End**	02:05	02:39	03:33	04:10	05:01	05:38	06:29	07:06	07:57	08:34	09:25
		02:08	02:42	03:36	04:13	05:04	05:41	06:32	07:09	08:00	08:37	09:28
	Start	02:08	02:53	03:38	04:23	05:08	05:53	06:38	07:23	08:08	08:53	09:38
	Processes Time (s)	45	45	45	45	45	45	45	45	45	45	45
Station 6	**End**	02:53	03:38	04:23	05:08	05:53	06:38	07:23	08:08	08:53	09:38	10:23
Cycle time			00:45	00:45	00:45	00:45	00:45	00:45	00:45	00:45	00:45	00:45
Production lead-time		02:53	03:04	03:15	03:26	03:37	03:48	03:59	04:10	04:21	04:32	04:43

A time study for 10 cycles of the production line, i.e., the assembly of 10 products, was conducted. Assuming that the assembly of the first product began at 00:00 min, the cycle time for each station was added to signify that the process was completed. For example , if the first process took 34 seconds, then the time at the end of the first station would be 00:34 min. Assuming 3 seconds for the product to pass from first station to second station, the second process would begin at 00:37 min. This study was repeated for 10 complete cycles. In the case of the operator manning the second station, who also mans the fifth station, consideration has to be given as to whether he's finished his operation at one station when the product reaches the other station. For example, if the product reaches station 2 at 01:45 min and the operator finishes his operation at the fifth station only at 02:02 min, then the second process for this particular cycle can begin only at 02:05 min (3 sec assumed for operator to travel from 2nd to 5th station). After all these considerations, the cycle time was found to be 45 seconds with stations 2 and 6 being waiting stages.

Man-Machine Chart

The man-machine chart provides an accurate description of the levels of activity at a particular station, i.e. how much time an operator works, a machine works, how much time goes by without any work done etc. It helps us determine the station activity time and standby time. If an operator is found to be over-worked, his workload can be eased or a rotation of operators can be done.



Conveyor Systems (Proposed)

The common requirements for conveyors systems are to transport product between successive steps in the order fulfillment process, and to provide accumulation buffers throughout the process to allow for workflow balancing when considering the different processing rates associated with each step in the process.

While choosing a conveyor system for the given assembly line the following characteristics were taken into consideration

- Modularity: A conveyor system with pre-engineered sections and modules and components which facilitate its reconfiguration is said to be modular
- Flexibility: A conveyor system which can accommodate different product sizes, higher loads and can operate at different speeds is said to have flexibility
- Safety: Conveyor which include built in safety features so as to reduce the hazardous nature of a given process are usually preferred over systems without such safety equipment
- Ergonomics: A conveyor system designed with proper ergonomics creates a better work environment, increases productivity and reduces operator injuries
- Reliability
- Maintainability: A conveyor system which has features that makes its maintenance easier is said to have greater maintainability
- Energy efficiency: A conveyor system that uses least energy for a given cycle is said to be the most energy efficient. While certain conveyors use less energy than others, energy efficient principles can be applied to all types of conveyors. Something as simple as programming individual conveyors or parts of the system to shut down or enter "sleep" mode during periods of inactivity can result in significant cost savings. Sequential or staggered start-up of motors in a large system can also help limit the peak power draw.

Based on the above characteristics FlexLink XK Pallet Handling System was used for the given assembly line. The table given below specifies some of its features

Pallet sizes (W×L)	300x300
Maximum load on pallet	30 Kg
Maximum accumulated weight on conveyor at 5 m/min	800 Kg
Maximum conveyor length	50m
Maximum conveyor speed	50m/minute

In addition to the mentioned characteristics it has few additional characteristics that facilitate the production process

- **RFID track and trace**
  All pallets are equipped with sockets for RFID chips. System components for automatic pallet handling are available. These RFID chips track a given pallet so that the pallet can be traced to a given location in production cycle
- **Pallet elevator**
  The pallet elevator allows lifting all standard pallets up- or downwards between two different levels. The lifting unit consists of a short XK-compact conveyor, transporting the pallet into or out of the elevator. Two elevator heights can be ordered: low and high elevator.

A Comparative Study: Linear vs. U-shaped

General	Present	Proposed
Type	Linear Line	U-shaped
Man Power	4	3
Floor Space usage (mxm)	.75 x 8 = 6.0	7.25
No. of Stations	7	6
No. of Waiting Stage	4	2
Cycle time in second	45	45
Qty/Day at 80% efficiency	1024	1024
Qty/operator	256	341
Material Feeding	Manual	Manual
Line Capacity	0.02222	0.02222
Production Lead Time Difference	22 sec	11 sec

	# Loading of TH, Ch, Actuator, Core Assembly		# Loading of Core Assembly in the Gripper
	# Sensing tube blockage checking		# Presence checking of O ring, Yellow mark
			# Assembly of CH and Core
Station :1	**# Avg Cycle time : 23 sec**		# Assembly of Actuator
	# Loading of Core Assembly in the Gripper	**Station :1**	**# Expected Avg Cycle time : 34 sec**
	# Presence checking of O ring, Yellow mark		
	# Assembly of CH and Core		# Pre assembly of CH side bolts
Station :2	**# Avg Cycle time :27 sec**	**Station :2**	**# Expected Avg Cycle time : 5 sec**
	# Assembly of Actuator		# Torquing of CH bolts – Automatic
	# Pre assembly of CH side bolts		
		Station :3	**# Expected Avg Cycle time : 33 sec**
Station :3	**# Avg Cycle time :21 sec**		

			# Application grease on TH
	# Torquing of CH bolts – Automatic		
		Station :4	**# Expected Avg Cycle time : 15 sec**
Station :4	**# Avg Cycle time : 33 sec**		
	# Application grease on TH		# Assembly of CH into TH
			# Pre assembly of TH side bolts
Station :5	**# Avg Cycle time : 15 sec**		
		Station :5	**# Expected Avg Cycle time : 26 sec**
	# Assembly of CH into TH		
	# Pre assembly of TH side bolts		# Manual tightening of TH bolts
			# Orientation checking
Station :6	**# Avg Cycle time : 26 sec**		# Sensing tube blockage checking
			# Unloading of finished part
	# Manual tightening of TH bolts		
	# Orientation checking	**Station :6**	**# Expected Avg Cycle time : 45 sec**
	# Sensing tube blockage checking		
	# Unloading of finished part		
Station :7	**# Avg Cycle time : 45 sec**		

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