Automated Assembly Systems

L-26

Contents

Automated Assembly

- The term automated assembly refers to the use of mechanized and automated devices to perform the various assembly tasks in an assembly line or cell
- Industrial robots are sometimes used as components in automated assembly systems
- Automated assembly systems is in category of fixed automation
- Most automated assembly systems are designed to perform a fixed sequence of assembly steps on specific product.
- Automated assembly technology should be considered when following conditions exist:

(i) High product demand
(ii) Stable product design
(iii) The assembly consists of no more than a limited number of components
(iv) The product is designed for automated assembly

1) Fundamentals of Automated Assembly Systems

- Automated assembly system performs a sequence of automated assembly operations to combine multiple components into a single entity. The single entity can be a final product or a subassembly in a larger product.
- A typical automated assembly system consists of the following subsystem:

(1)One or more workstations at which assembly steps are accomplished

(2) Parts feeding devices that deliver the individual components to the workstations

(3) A work handling system for the assembled entity

- Control functions required in automated assembly machines are the same as in the automated processing lines

(1) Sequence control (2) Safety monitoring (3) quality control

a)System Configurations

1) in-line assembly machine
2) Dial type assembly machine
3) Carousel assembly system
4) Single station assembly machine

Types of automated assembly systems

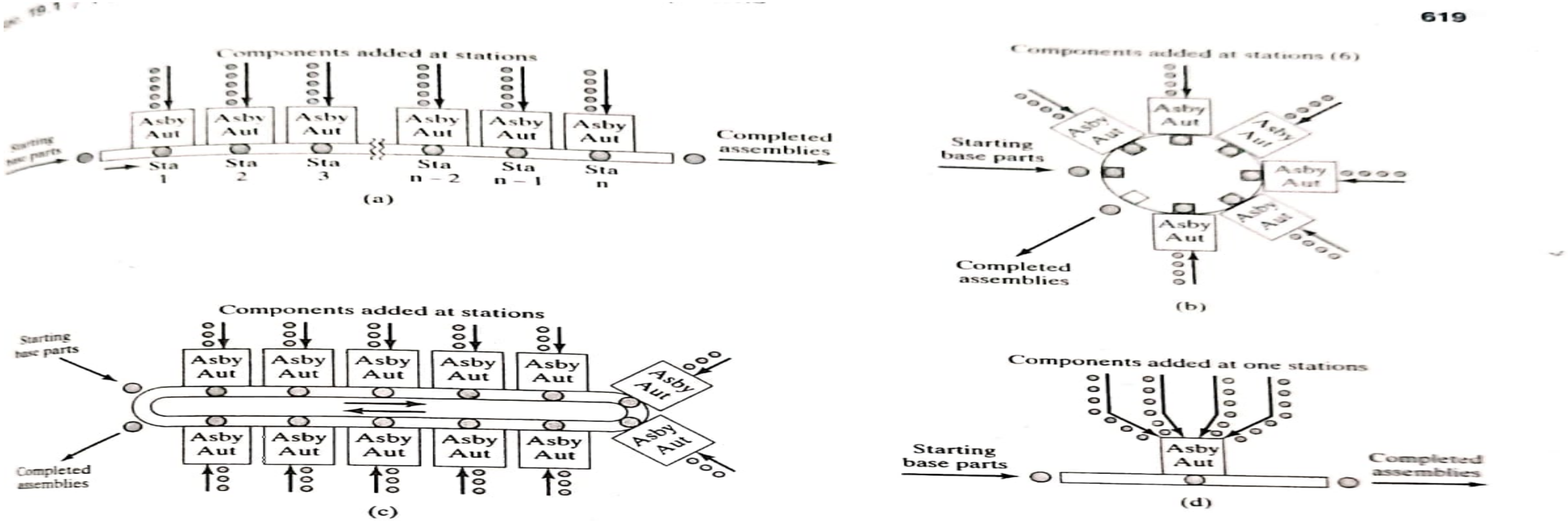


Figure 19.1 Types of automated assembly systems: (a) in-line, (b) dial-type, (c) carousel, and (d) single station.

BLE 19.1 Possible Work Transfer Systems for the Four Assembly System Configurations

		Work Transfer System		
ystem Configuration	*Stationary Base Part*	*Continuous*	*Synchronous*	*Asynchronous*
n-line	No	Unusual	Yes	Yes
Dial-type	No	Unusual	Yes	No
Carousel	No	Unusual	Yes	Yes
Single station	Yes	No	No	No

b) Parts Delivery at Workstations

- The workstation accomplishes one or both of following tasks: (1) a part is delivered to the assembly workhead and added to the existing base part in front of the workhead (2) a fastening or joining operation is performed at the station in which parts added at the workstation or at previous workstations are permanently attached to the existing base part.
- For task (1), a means of delivering the parts to the assembly workhead must be designed. The parts delivery system typically consists of the following hardware

(1) Hopper
(2) Parts feeder
(3) Selector and/or orientor
(4) Feed track
(5) Escapement and placement device

Figures

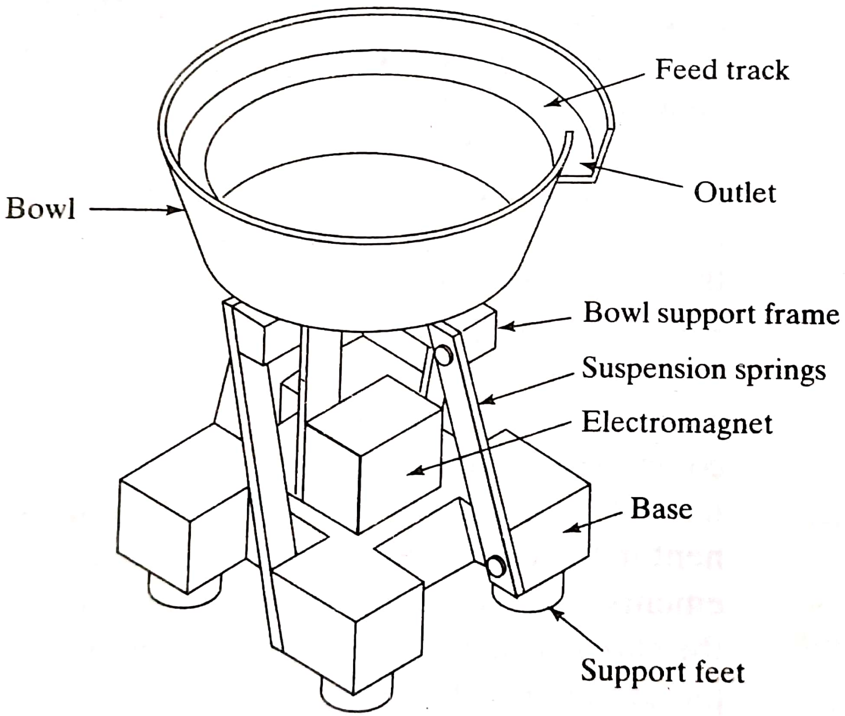


Figure 19.2 Vibratory bowl feeder.

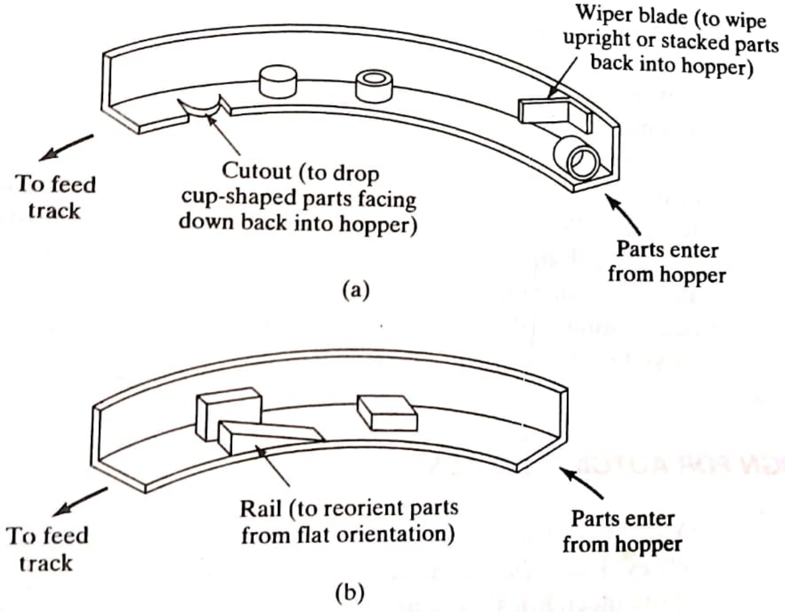
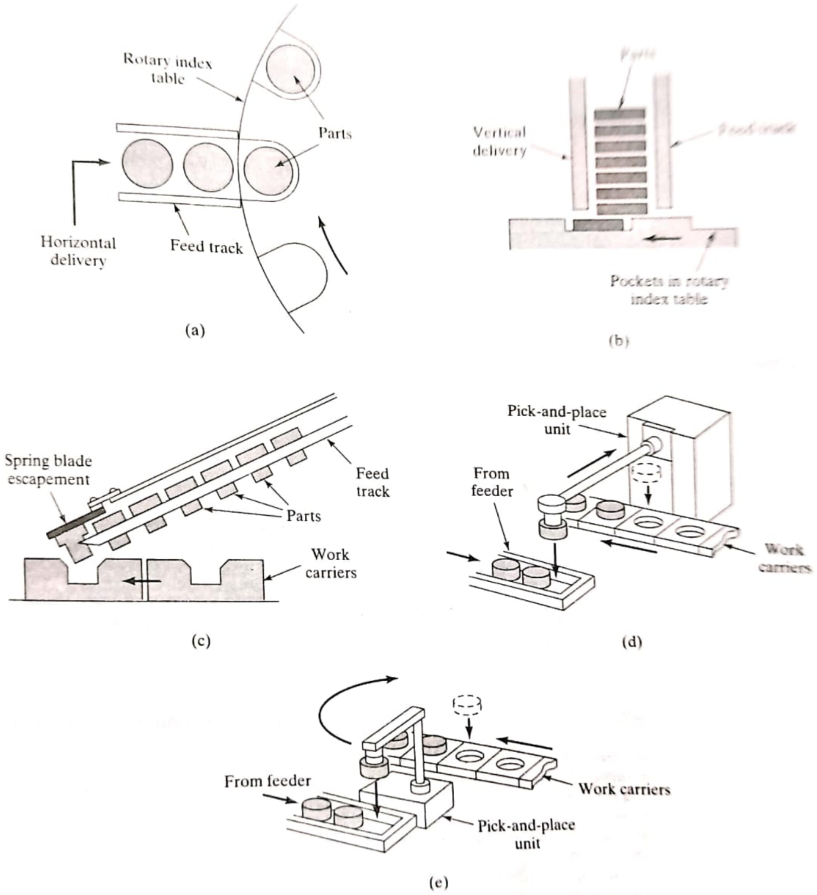


Figure 19.3 (a) Selector and (b) orientor devices used with parts feeders in automated assembly systems.

Various escapement and placement devices used in automated assembly systems



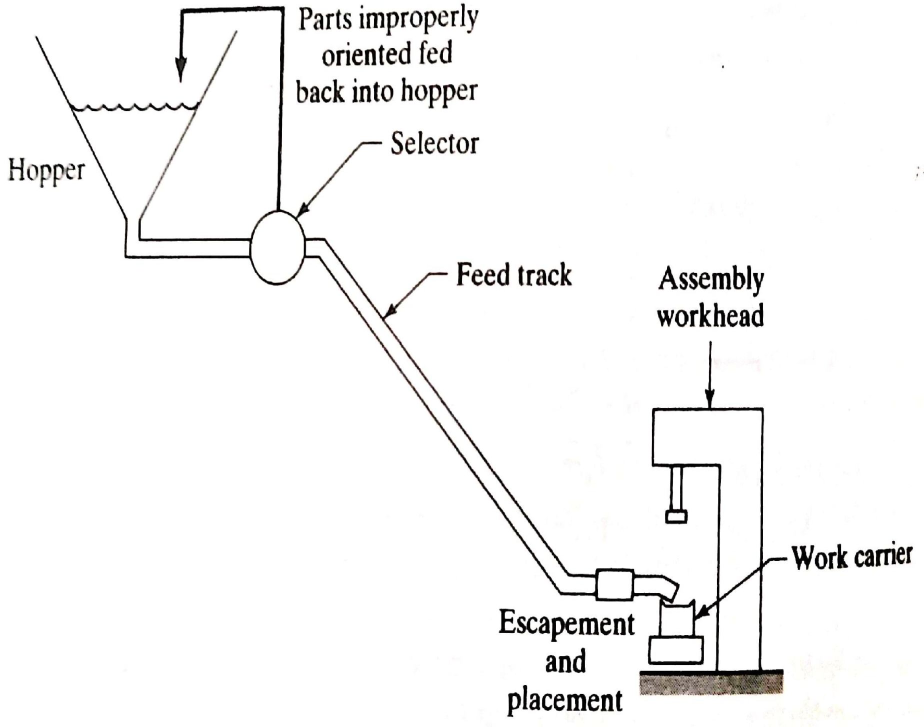


Figure 19.5 Hardware elements of the parts delivery system at an assembly workstation.

C) Applications

- Automated assembly systems are used to produce a wide variety of products and sub-assemblies

TABLE 19.2 Typical Products Made by Automated Assembly

Alarm clocks	Light bulbs
Audio tape cassettes	Locks
Ball bearings	Mechanical pens and pencils
Ball point pens	Printed circuit board assemblies
Cigarette lighters	Pumps for household appliances
Computer diskettes	Small electric motors
Electrical plugs and sockets	Spark plugs
Fuel injectors	Video tape cassettes
Gear boxes	Wrist watches

TABLE 19.3 Some Typical Assembly Processes Used in Automated Assembly Systems

Adhesive bonding (automatic dispensing of adhesive)	
Insertion of components (pin-in-hole printed circuit board assembly)	
Placement of components (surface mount printed circuit board assembly)	
Riveting	
Screw fastening (automatic screwdriver)	
Snap fitting	
Soldering	Screws, bolts & nuts
Spotwelding	
Stapling	
Stitching	

2) Design for Automated Assembly

- For assembly automation to be achieved, fastening procedures must be devised and specified during product design that do not require all of these human capabilities. The following are some recommendation and principles that can be applied in product design to facilitate automated assembly:

(i)Reduce the amount of assembly required

(ii)Use of modular design

(iii)Reduce the number of fasteners required.

(iv) Reduce the need for multiple components to be handled at once

(v) Limit the required directions of access

(iv) High quality required in components

(v) Hopperability

3) Quantitative Analysis of Assembly Systems

The models are develop to analyze the following issues in automated assembly:

a) Parts Delivery System at Workstations

EXAMPLE 19.1 Parts Delivery System in Automatic Assembly

The cycle time for a given assembly workhead = 6 sec. The parts feeder has a feed rate = 50 components/min. The probability that a given component fed by the feeder will pass through the selector is $\theta = 0.25$. The number of parts in the feed track corresponding to the low level sensor is $n_{f1} = 6$. The capacity of the feed track is $n_{f2} = 18$ parts. Determine (a) how long it will take for the supply of parts in the feed track to go from n_{f2} to n_{f1} and (b) how long it will take on average for the supply of parts to go from n_{f1} to n_{f2}.

Solution: (a) $T_c = 6$ sec $= 0.1$ min. The rate of depletion of parts in the feed track, starting from n_{f2}, will be $R_c = 1/0.1 = 10$ parts/min.

$$\text{Time to deplete feed track (time to go from } n_{f2} \text{ to } n_{f1}) = \frac{18 - 6}{10} = 1.2 \text{ min.}$$

(b) The rate of parts increase in the feed track, once the low level sensor has been reached, is $f\theta - R_c = (50)(0.25) - 10 = 12.5 - 10 = 2.5$ parts/min.

$$\text{Time to replenish feed track (time to go from } n_{f1} \text{ to } n_{f2}) = \frac{18 - 6}{2.5} = 4.8 \text{ min.}$$

b) Multi-Station Assembly Machines

Assembly operations at the stations have :

(i)Constant element times, although the times are not necessarily equal at all stations

(ii)Synchronous parts transfer

(iii)No internal storage

There exist the possible events that might occur when the feed mechanism attempts to feed the next component, and the assembly device attempts to join it to the existing assembly at the station. The three events and their associated probabilities are:

(i) The component is defective and causes a station jam
(ii) The component is defective but does not cause a station jam
(iii) The component is not defective

Example

EXAMPLE 19.2 Multi-Station Automated Assembly System

A ten-station in-line assembly machine has an ideal cycle time = 6 sec. The base part is automatically loaded prior to the first station, and components are added at each of the stations. The fraction defect rate at each of the 10 stations is $q = 0.01$, and the probability that a defect will jam is $m = 0.5$. When a jam occurs, the average downtime is 2 min. Cost to operate the assembly machine is \$42.00/hr. Other costs are ignored. Determine: (a) average production rate of all assemblies (asb/hr), (b) yield of good assemblies, (c) average production rate of good product, (d) uptime efficiency of the assembly machine, and (e) cost per unit.

Solution: (a) $T_c = 6$ sec $= 0.1$ min. The average production cycle time is

$$T_p = 0.1 + (10)(.5)(.01)(2.0) = 0.2 \text{ min}$$

The production rate is therefore

$$R_p = \frac{60}{0.2} = 300 \text{ total assemblies/hr}$$

(b) The yield is given by Eq. (19.7):

$$P_{ap} = (1 - .01 + .5 \times .01)^{10} = 0.9511$$

(c) Average production rate of good assemblies is determined by Eq. (19.15):

$$R_{ap} = 300(0.9511) = 285.3 \text{ good asbys/hr}$$

(d) The efficiency of the assembly machine is

$$E = 0.1/0.2 = 0.50 = 50\%$$

(e) Cost to operate the assembly machine C_o = \$42/hr = \$0.70/min.

$$C_{pc} = (\$0.70/\text{min})(0.2 \text{ min/pc})/0.9511 = \$0.147/\text{pc}.$$

C) Single Station Assembly Machines

) or (19.20) using

EXAMPLE 19.5 Single Station Automatic Assembly System

A single station assembly machine performs five work elements to assemble four components to a base part. The elements are listed in the table below, together with the fraction defect rate (q) and probability of a station jam (m) for each of the components added (NA: not applicable).

Element	Operation	Time (sec)	q	m	p
1	Add gear	4	0.02	1.0	
2	Add spacer	3	0.01	0.6	
3	Add gear	4	0.015	0.8	
4	Add gear and mesh	7	0.02	1.0	
5	Fasten	5	0	NA	0.012

Time to load the base part is 3 sec, and time to unload the completed assembly is 4 sec, giving a total load/unload time of $T_h = 7$ sec. When a jam occurs, it takes an average of 1.5 min to clear the jam and restart the machine. Determine: (a) production rate of all product, (b) yield, and (c) production rate of good product, and (d) uptime efficiency of the assembly machine.

Solution: (a) The ideal cycle time of the assembly machine is

$$T_c = 7 + (4 + 3 + 4 + 7 + 5) = 30 \text{ sec} = 0.5 \text{ min}$$

Frequency of downtime occurrences is

$$F = .02 \times 1.0 + .01 \times .6 + .015 \times .8 + .02 \times 1.0 + 0.012 = 0.07$$

Adding the average downtime due to jams,

$$T_p = 0.5 + 0.07(1.5) = 0.5 + 0.105 = 0.605 \text{ min.}$$

Production rate is therefore

$$R_p = 60/0.605 = 99.2 \text{ total assemblies/hr}$$

(b) Yield of good product is

$$P_{ap} = (1.0)(0.996)(0.997)(1.0) = 0.993$$

(c) Production rate of only good assemblies is

$$R_{ap} = 99.2(0.993) = 98.5 \text{ good assemblies/hr}$$

(d) Uptime efficiency is

$$E = 0.5/0.605 = 0.8264 = 82.64\%$$

d) Partial Automation

- Many assembly lines in industry contain a combination of automated and manual work stations. These cases of partially automated production lines occur for two main reasons:

1) Automation is introduced gradually on an existing manual line
2) Certain manual operations are too difficult or too costly to automate

Example

Q1. It has been proposed to replace one of the current manual workstations with an automatic workhead on a ten-station production line. The current line has six

automatic stations and four manual stations. Current cycle time is 30 sec. The limiting process time is at the manual station that is proposed for replacement. Implementing the proposal would allow the cycle time to be reduced to 24 sec. The new station would cost \$0.20/min. Other cost data: C_w = \$0.15/min, C_{as} = \$0.10/min, and C_{at} = \$0.12/min. Breakdowns occur at each automated station with a probability $p = 0.01$. The new automated station is expected to have the same frequency of breakdowns. Average downtime per occurrence $T_d = 3.0$ min, which will be unaffected by the new station. Material costs and tooling costs will be neglected in the analysis. It is desired to compare the current line with the proposed change on the basis of production rate and cost per piece. Assume a yield of 100% good product.

Solution: For the current line, $T_c = 30 \text{ sec} = 0.50 \text{ min}$.

$$T_p = 0.50 + 6(0.01)(3.0) = 0.68 \text{ min}.$$

$$R_p = 1/0.68 = 1.47 \text{ pc/min} = 88.2 \text{ pc/hr}.$$

$$C_o = 0.12 + 4(0.15) + 6(0.10) = \$1.32/\text{min}.$$

$$C_{pc} = 1.32(0.68) = \$0.898/\text{pc}.$$

For the proposed line, $T_c = 24 \text{ sec} = 0.4 \text{ min}$.

$$T_p = 0.40 + 7(0.01)(3.0) = 0.61 \text{ min}.$$

$$R_p = 1/0.61 = 1.64 \text{ pc/min} = 98.4 \text{ pc/hr}.$$

$$C_o = 0.12 + 3(0.15) + 6(0.10) + 1(0.20) = \$1.37/\text{min}.$$

$$C_{pc} = 1.37(0.61) = \$0.836/\text{pc}.$$

Even though the line would be more expensive to operate per unit time, the proposed change would increase production rate and reduce piece cost.

Q2 Example

EXAMPLE 19.7 Storage Buffers on a Partially Automated Line

Considering the current line in Example 19.6, suppose that the ideal cycle time for the automated stations on the current line $T_c = 18$ sec. The longest manual time is 30 sec. Under the method of operation assumed in Example 19.6, both manual and automated stations are out of action when a breakdown occurs at an automated station. Suppose that storage buffers could be provided for each operator to insulate them from breakdowns at automated stations. What effect would this have on production rate and cost per piece?

Solution: Given $T_c = 18$ sec $= 0.3$ min, the average actual production time on the automated stations is computed as follows:

$$T_p = 0.30 + 6(0.01)(3.0) = 0.48 \text{ min.}$$

Since this is less than the longest manual time of 0.50, the manual operations could work independently of the automated stations if storage buffers of sufficient capacity were placed before and after each manual station. Thus, the limiting cycle time on the line would be $T_c = 30$ sec $= 0.50$ min, and the corresponding production rate would be:

$$R_p = R_c = 1/0.50 = 2.0 \text{ pc/min} = 120.0 \text{ pc/hr.}$$

Using the line operating cost from Example 19.6, $C_o = \$1.32/\text{min}$, we have a piece cost of

$$C_{pc} = 1.32(0.50) = \$0.66/\text{pc.}$$

Comparing with Example 19.6, one can see that a dramatic improvement in production rate and unit cost is achieved through the use of storage buffers.

E) What the Equations Tell Us

The equations derived in this section and their application in our examples reveal several practical guidelines for design and operation of automated assembly systems and the products made on such systems. We state these guidelines here:

- The parts delivery system at each station must be designed to deliver components to the assembly operation at a net rate (parts feeder multiplied by pass-through proportion of the selector/orientor) that is greater than or equal to the cycle rate of the assembly workhead. Otherwise, assembly system performance is limited by the parts delivery system rather than by the assembly process technology.
- The quality of components added in an automated assembly system has a significant effect on system performance. The effect of poor quality, as represented by the fraction defect rate, is either to:
  (1) cause jams at stations that stop the entire assembly system, which has adverse effects on production rate, uptime proportion, and cost per unit produced, or
  (2) cause the assembly of defective parts in the product which has adverse effects on yield of good assemblies and product cost.
- As the number of workstations increases in an automated assembly system, uptime efficiency and production rate tend to decrease due to parts quality and station reliability effects. This supports the ***Modularity Principle*** in Design for Automated Assembly (Section 19.2) and reinforces the need to use only the highest quality components on automated assembly systems.
- The cycle time of a multi-station assembly system is determined by the slowest station (longest assembly task) in the system. The number of assembly tasks to be performed is important only insofar as it affects the reliability of the assembly system. By comparison, the cycle time of a single station assembly system is determined by the sum of the assembly element times rather than by the longest assembly element.
- By comparison with a multi-station assembly machine, a single station assembly system with the same number of assembly tasks tends to have a lower production rate but a higher uptime efficiency.

Contd.

- Multi-station assembly systems are appropriate for high production applications and long production runs. By comparison, single station assembly systems have a longer cycle time and are more appropriate for mid-range quantities of product.
- Storage buffers should be used on partially automated production lines to isolate the manual stations from breakdowns of the automated stations. Use of storage buffers will increase production rates and reduce unit product cost.
- An automated station should be substituted for a manual station only if it has the effect of reducing cycle time sufficiently to offset any negative effects of lower reliability.