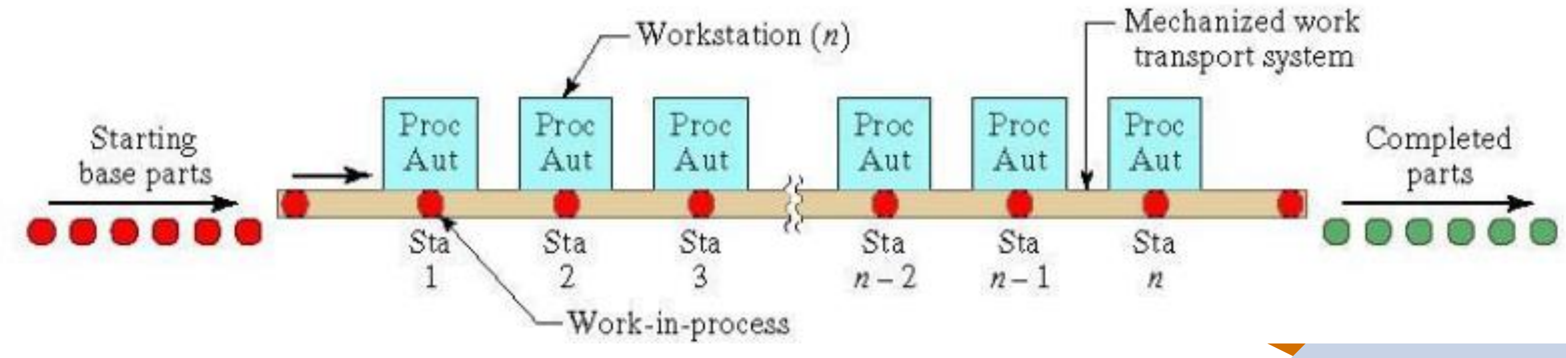
AUTOMATED FLOW LINES

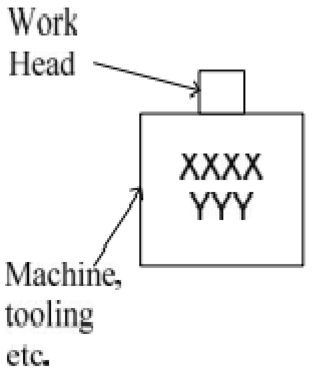
Introduction: Automated Flow Lines

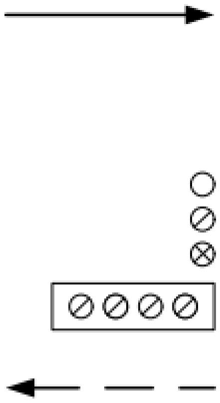
- An automated flow line consists of several machines or workstations which are linked together by work handling devices that transfer parts between the stations.
- The transfer of work parts occurs automatically and the workstations carry out their specialized functions automatically.
- The flow line can be symbolized as shown in Figure



Introduction: Automated Flow Lines

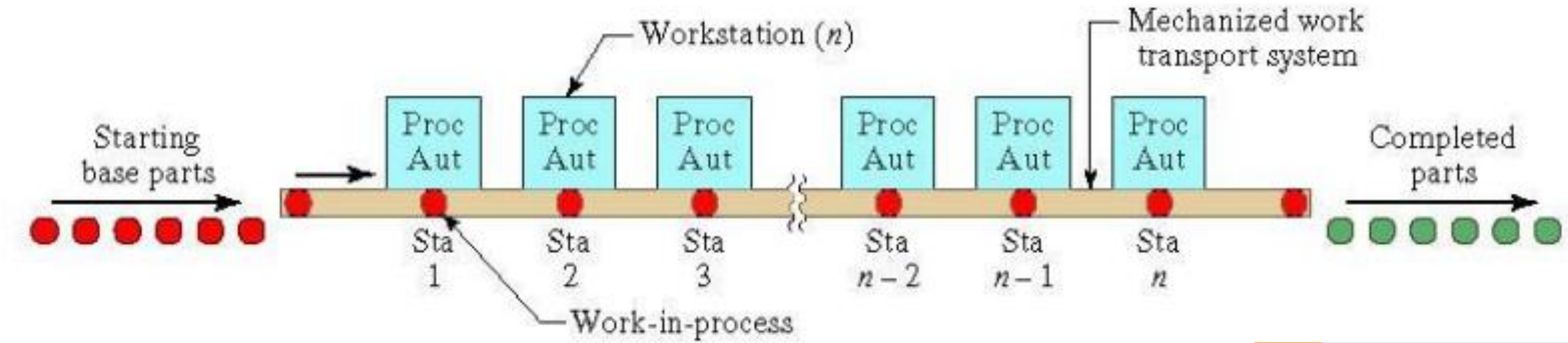
- **The flow line can be symbolized as shown in Figure using the symbols presented in Table.**

SYMBOL	COMPONENT
	• Workstation XXXX: PROC–Processing station ASBY–Assembly station INSP– Inspection station SORT– Sorting station YYY: MAN–Manual AUT–Automated

SYMBOL	COMPONENT
	• Material handling system (Arrow indicates workflow direction) • Workpart Raw workpart Partially processed part Finished part • Storage buffer • Data/Information flow

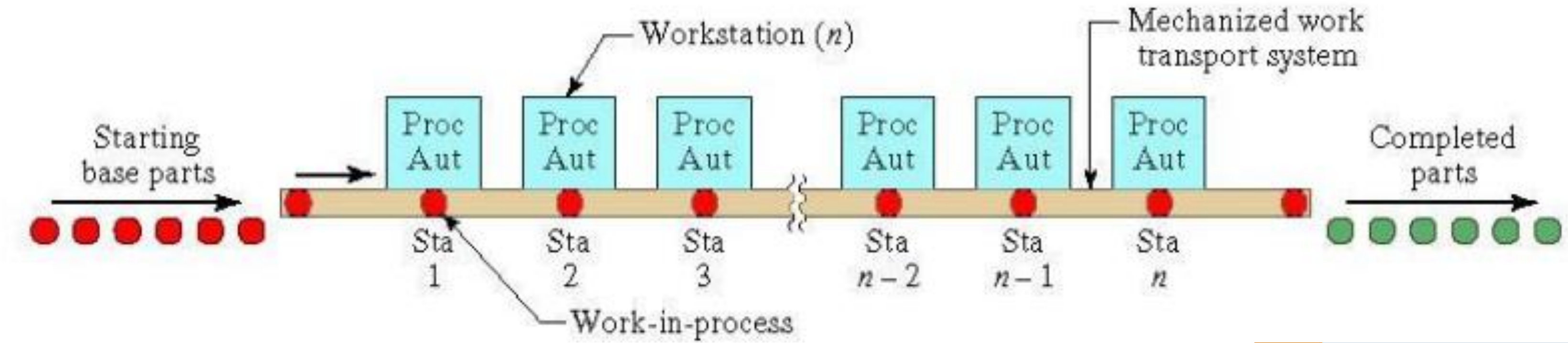
Introduction: Automated Flow Lines

- A raw workpart enters one end of the line and the processing steps are performed sequentially as the part moves from one station to the next.
- It is possible to incorporate buffer storage zones into the flow line, either at a single location or between every workstation.



Introduction: Automated Flow Lines

- It is also possible to include inspection stations in the line to automatically perform intermediate checks on the quality of the workparts.
- Manual stations might also be located along the flow line to perform certain operations which are difficult or uneconomical to automate.



Objectives of Automated Flow Lines

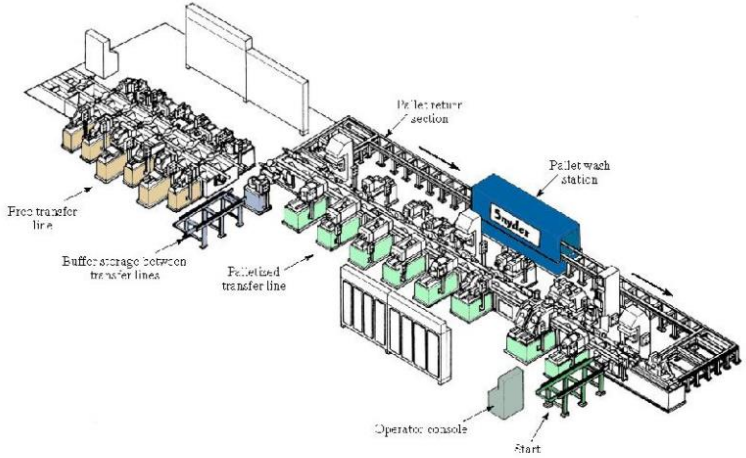
The objectives of the use of flow line automation are, therefore:

- To minimize distances moved between operations
- To achieve specialization of operations
- To achieve integration of operations
- To reduce labor costs
- To increase production rates
- To reduce work-in-process

Configurations of Automated Flow Lines

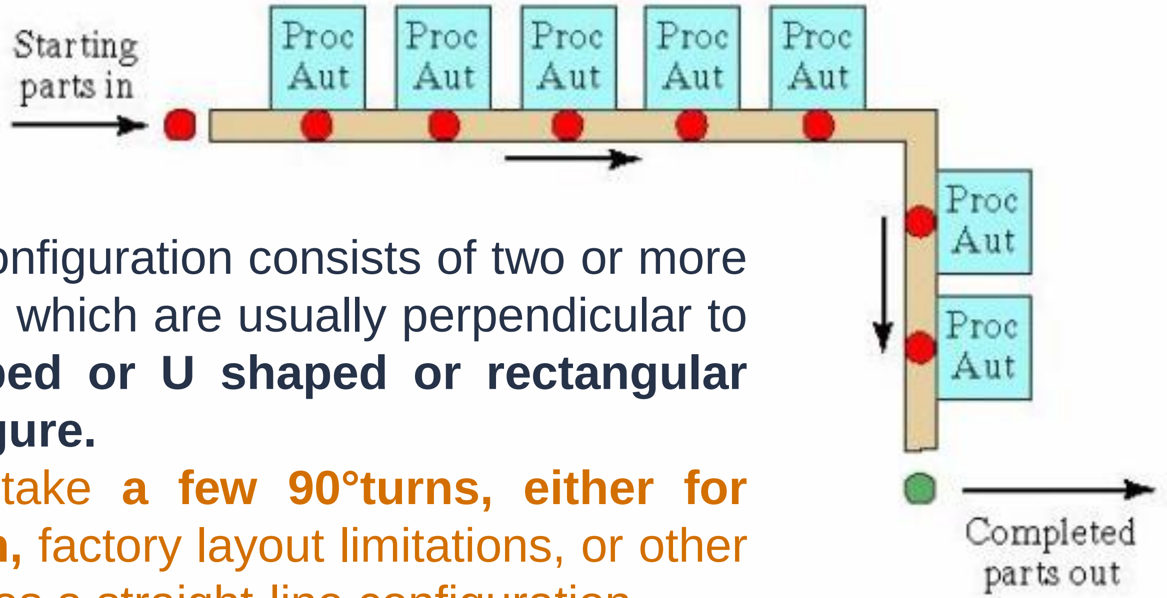
In-line type:

- The in-line configuration consists of a sequence of workstations in a more or less straight line arrangement as shown in Figure.
- An example of an in-line transfer machine used for metal cutting operations



Configurations of Automated Flow Lines

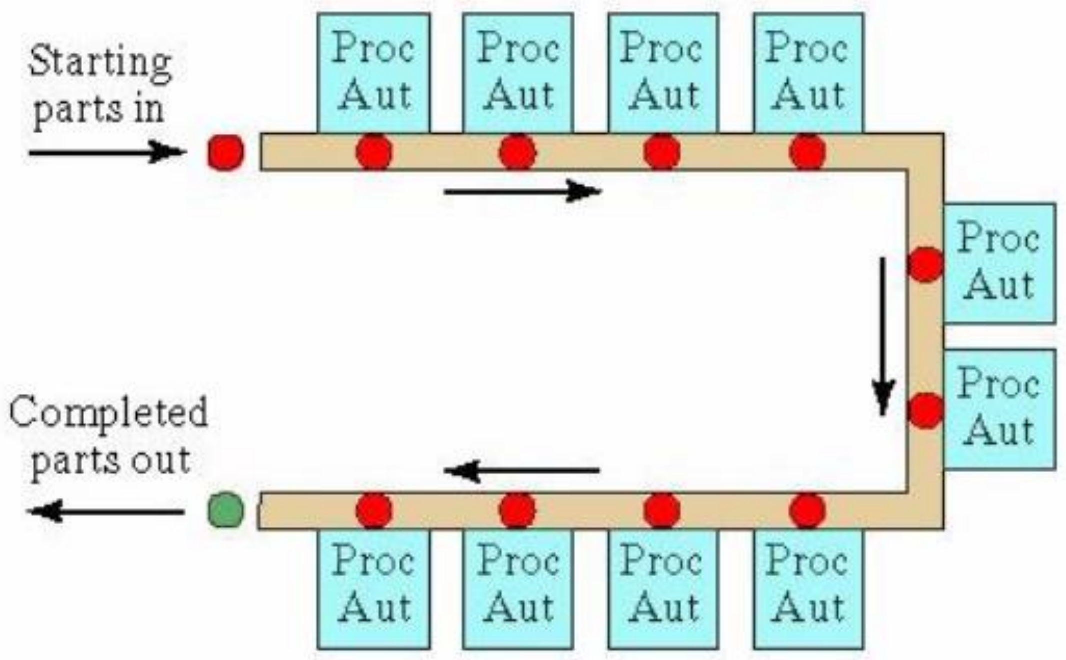
L shaped configuration



Segmented In-line type:

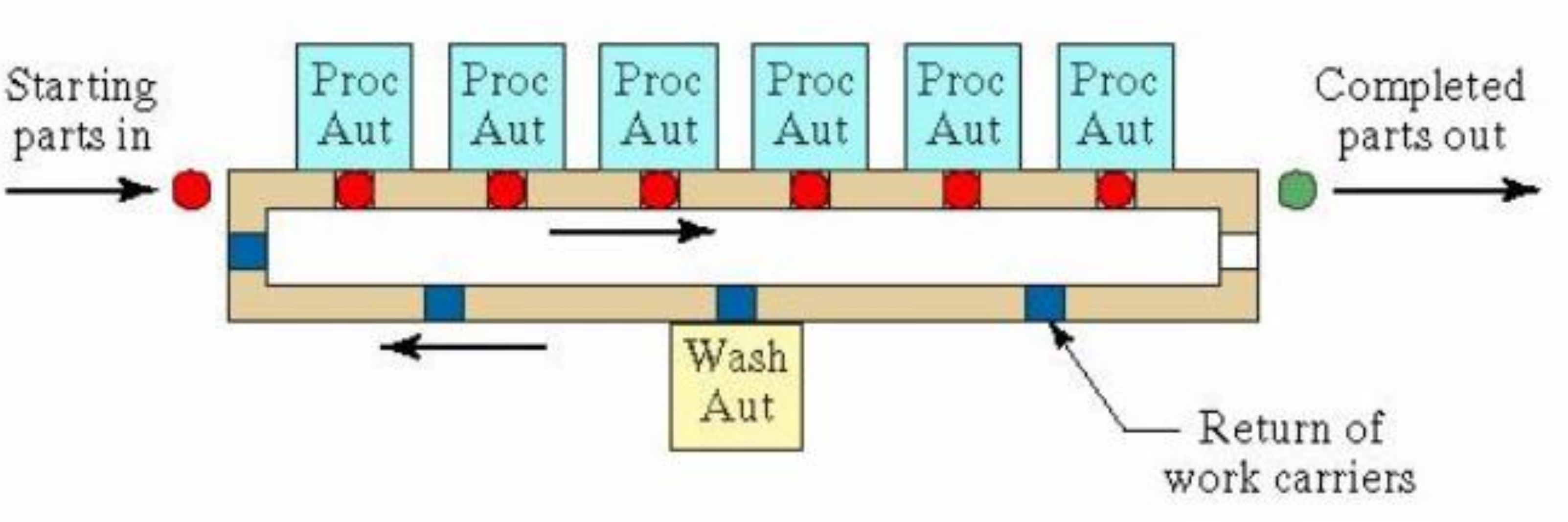
- The segmented in-line configuration consists of two or more straight line arrangement which are usually perpendicular to each other with **L shaped or U shaped or rectangular shaped as shown in Figure.**
- The flow of work can take **a few 90°turns, either for workpiece reorientation,** factory layout limitations, or other reasons, and still qualify as a straight-line configuration

Configurations of Automated Flow Lines



U shaped configuration

Configurations of Automated Flow Lines



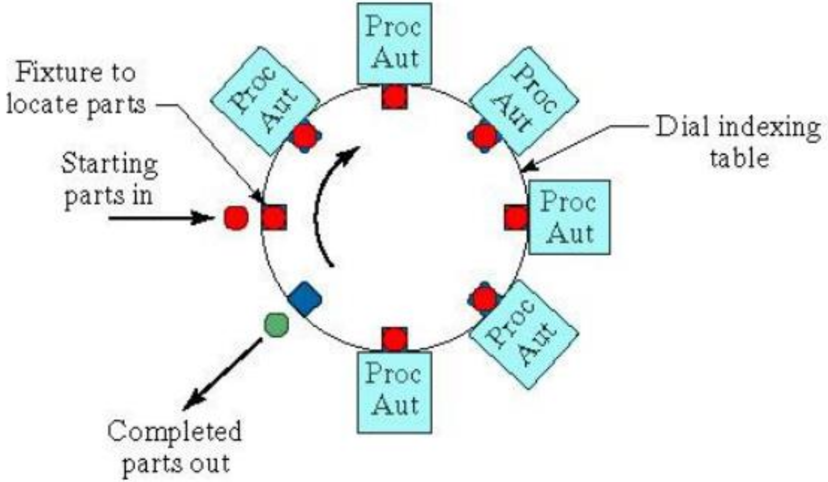
Rectangular shaped configuration

Configurations of Automated Flow Lines

Rotary type:

- In the rotary configuration, the workparts are indexed around a circular table or dial. The workstations are stationary and usually located around the outside periphery of the dial.

- The parts ride on the rotating table and arc registered or positioned, in turn, at each station for its processing or assembly operation.



Configurations of Automated Flow Lines

Rotary type:

- This type of equipment is often referred to as an indexing machine or dial index machine and the configuration is shown in Figure.
- Example of six station rotary shown in Figure.

Methods of workpart transport

- The transfer mechanism of the automated flow line must not only move the partially completed workparts or assemblies between adjacent stations, it must also orient and locate the parts in the correct position for processing at each station.

- The general methods of transporting workpieces on flow lines can be classified into the following three categories:
  - Continuous transfer
  - Intermittent or synchronous transfer
  - Asynchronous or power-and-free transfer

Methods of workpart transport

The most appropriate type of transport system for a given application depends on such factors as:

- The types of operation to be performed
- The number of stations on the line
- The weight and size of the work parts
- Whether manual stations are included on the line
- Production rate requirements
- Balancing the various process times on the line

Methods of workpart transport

Continuous transfer:

- With the continuous method of transfer, the workparts are moved continuously at constant speed.
- This requires the workheads to move during processing in order to maintain continuous registration with the workpart.
- For some types of operations, this movement of the workheads during processing is not feasible. It would be difficult, for example, to use this type of system on a machining transfer line because of inertia problems due to the size and weight of the workheads.
- In othercases, continuous transfer would be very practical.

Methods of workpart transport

Continuous transfer:

- Examples of its use are in beverage bottling operations, packaging, manual assembly operations where the human operator can move with the moving flow line, and relatively simple automatic assembly tasks.
- In some bottling operations, for instance, the bottles are transported around a continuously rotating drum.
- Beverage is discharged into the moving bottles by spouts located at the drum's periphery.
- The advantage of this application is that the liquid beverage is kept moving at a steady speed and hence there are no inertia problems.
- Continuous transfer systems are relatively easy to design and fabricate and can achieve a high rate of production

Methods of workpart transport

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Methods of workpart transport

Intermittent transfer:

- In this method the workpieces are transported with **an intermittent or discontinuous motion.**
- Workstations are fixed in position and the parts are moved between stations and then registered at the proper locations for processing.
- All workparts are transported at the same time and, for this reason, the term **"synchronous transfer system"** is also used to describe this method of workpart transport.

Methods of workpart transport

Asynchronous transfer:

- This system of transfer, also referred to as a **"power-and-free system,"** allows each workpart to move to the next station when processing at the current station has been completed.
- Each part moves independently of other parts. Hence, some parts are being processed on the line at the same time that others are being transported between stations.
- Asynchronous transfer systems offer the opportunity for greater flexibility than do the other two systems, and this flexibility can be a great advantage in certain circumstances.
- In-process storage of workparts can be incorporated into the asynchronous systems with relative ease

Methods of workpart transport

Asynchronous transfer:

- **Power-and-free systems** can also compensate for line balancing problems where there are significant differences in process times between stations.
- **Parallel stations or several series stations** can be used for the longer operations, and single stations can be used for the shorter operations.
- Therefore, the average production rates can be approximately equalized.

Asynchronous lines are often used where there are one or more manually operated stations and cycle-time variations would be a problem on either the continuous or synchronous transport systems

Transfer Mechanism

There are various types of transfer mechanisms used to move parts between stations.

These mechanisms can be grouped into two types:

- those used to provide **linear travel for in-line machines**
- those used to provide **rotary motion for dial indexing machines.**

Linear transfer mechanisms

- The commonly used linear transfer mechanisms are
    - Walking beam transfer bar system
    - Powered roller conveyor system
    - Chain-drive conveyor system.

Linear Transfer Mechanism

Walking beam transfer bar system

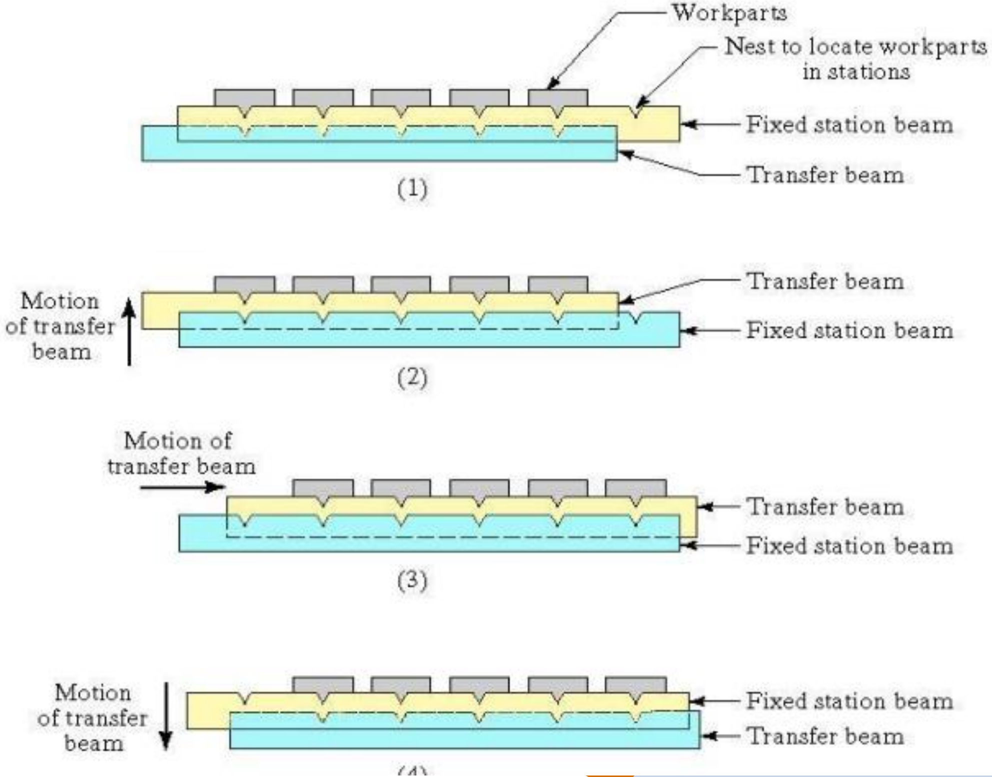
- With the walking beam transfer mechanism, the work-parts are lifted up from their workstation locations by a transfer bar and moved one position ahead, to the next station.
- Transfer bar then lowers the pans into nests which position them more accurately for processing.

6-Station Walking Beam including 2-Vibration stations

Linear Transfer Mechanism

Walking beam transfer bar system

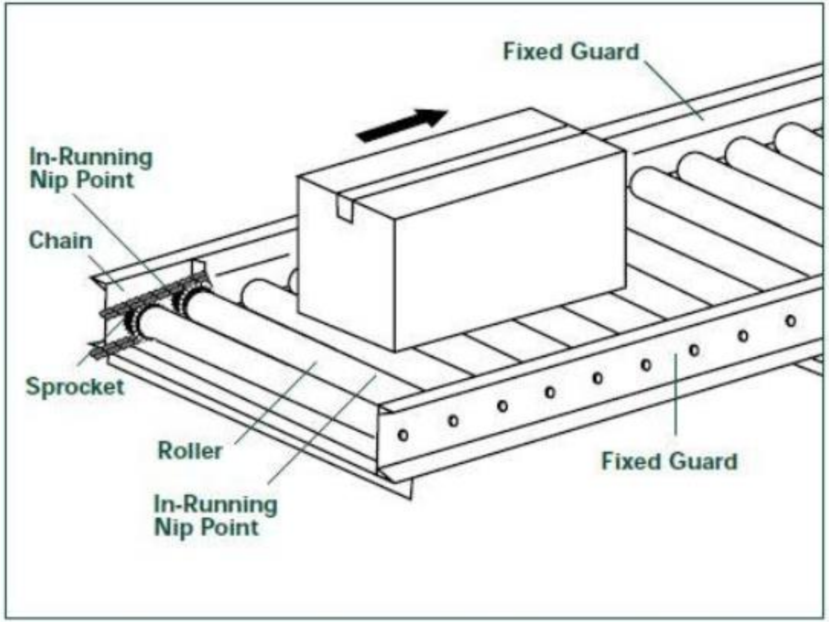
- **For speed and accuracy, the motion of the beam is most often generated by a rotating camshaft powered by an electric motor or a roller movement in a profile powered by hydraulic cylinder. Figure shows the working of the beam**



Linear Transfer Mechanism

Powered Roller Conveyor

- Used in general stock handling systems as well as in automated flow lines.
- Conveyor can be used to move pans or pallets possessing flat riding surfaces.
- Versatile transfer systems because they can be used to divert work pallets into workstations or alternate tracks.



Linear Transfer Mechanism

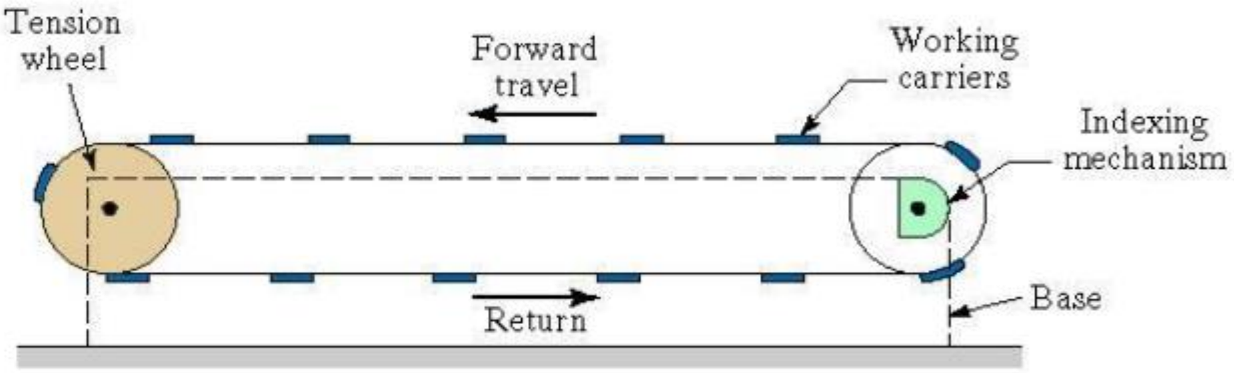
Powered Roller Conveyor

- Rollers can be powered by either of two mechanisms.
  - **First is a belt drive,** in which a flat moving belt beneath the rollers provides the rotation of the rollers by friction.
  - **Chain drive** is the second common mechanism used to power the rollers.

Linear Transfer Mechanism

Chain Drive Conveyor System

- In chain-drive conveyor system either a chain or a flexible steel belt is used to transport the work carriers.
- The chain is driven by pulleys in either an **"over-and under"** configuration, in which the pulleys turn about a horizontal axis, or an **"around-the-corner"** configuration, in which the pulleys rotate about a vertical axis.



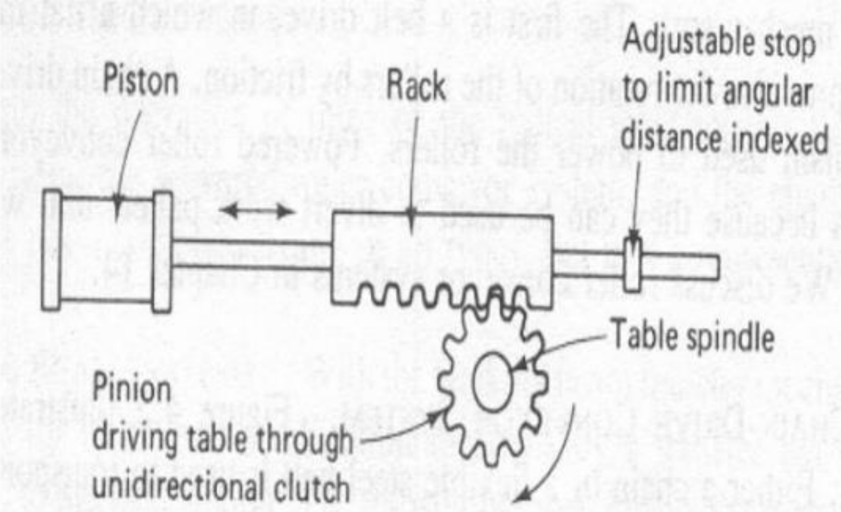
Rotary Transfer Mechanism

There are several methods used to index a circular table or dial at various equal angular positions corresponding to workstation locations.

- **Rack and pinion**
- **Ratchet and pawl**
- **Geneva Mechanism**
- **CAM Mechanism**

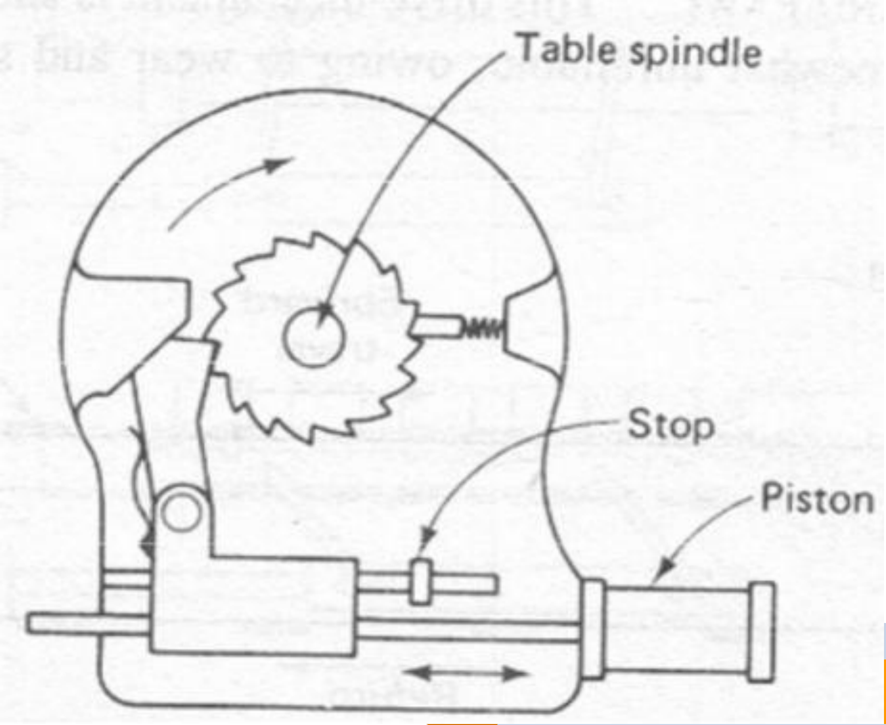
Rotary Transfer Mechanism

- **Rack and pinion**
  - Mechanism is simple but is not considered especially suited to the high-speed operation often associated with indexing machines.
  - Uses a piston to drive the rack, which causes the pinion gear and attached indexing table to rotate, A clutch or other device is used to provide rotation in the desired direction



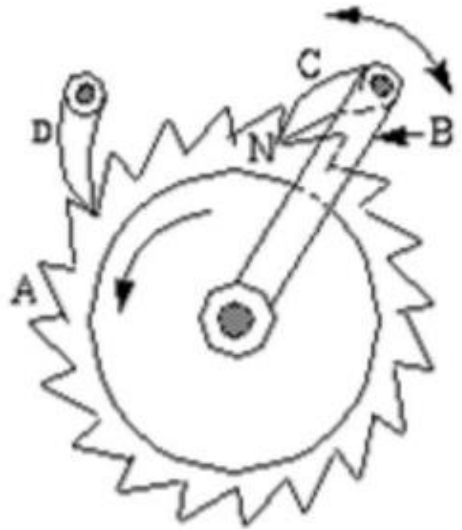
Rotary Transfer Mechanism

- **Ratchet and pawl:**
  - A ratchet is a device that allows linear or rotary motion in only one direction, while preventing motion in the opposite direction.
  - Ratchets consist of a gearwheel and a pivoting spring loaded finger called a pawl that engages the teeth.



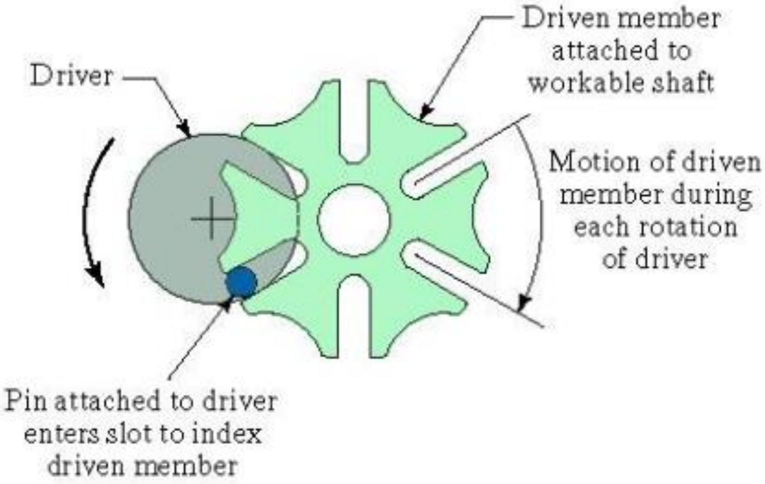
Rotary Transfer Mechanism

- **Ratchet and pawl:**
  - Either the teeth, or the pawl, are slanted at an angle, so that when the teeth are moving in one direction,
  - Pawl slides up and over each tooth in turn, with the spring forcing it back with a 'click' into the depression before the next tooth.
  - When the teeth are moving in the other direction, the angle of the pawl causes it to catch against a tooth and stop further motion in that direction.



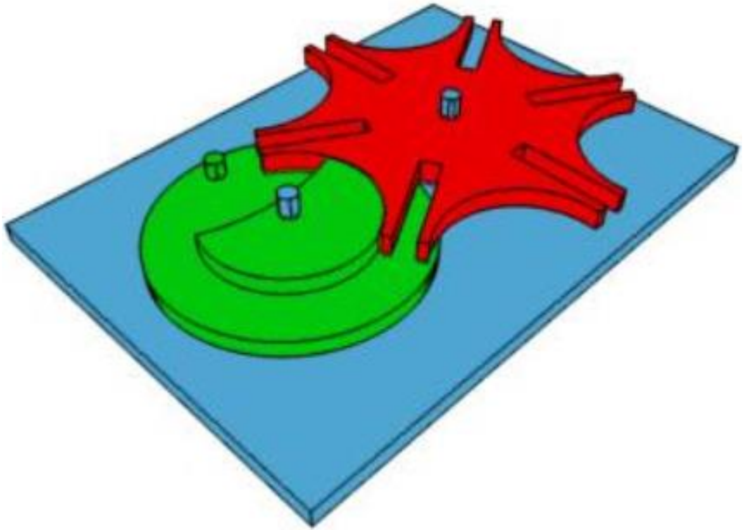
Rotary Transfer Mechanism

- **Geneva Mechanism:**
  - Geneva mechanism uses a continuously rotating driver to index the table, as shown in Figure.
  - If the driven member has six slots for a six-station dial indexing machine, each turn of the driver will cause the table to advance one-sixth of a turn.
  - The driver only causes movement of the table through a portion of its rotation.



Rotary Transfer Mechanism

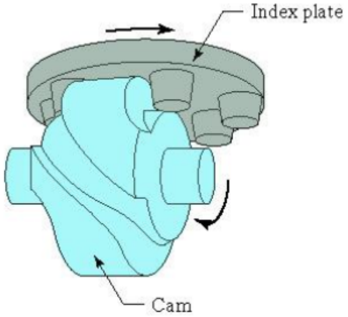
- **Geneva Mechanism:**
  - For a six-slotted driven member, 120° of a complete rotation of the driver is used to index the table.
  - The other 240° is dwell.
  - For a four-slotted driven member, the ratio would be 90° for index and 270° for dwell.
  - The usual number of indexings per revolution of the table is four, five, six, and eight.

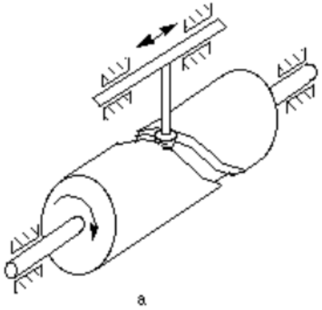


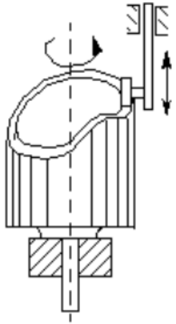
https://www.youtube.com/watch?v=E70bgv_wlTA

Rotary Transfer Mechanism

- **CAM Mechanism:**
  - Various forms of cam mechanisms are illustrated in Figure, provide probably the most accurate and reliable method of indexing the dial.
  - Widespread use in industry despite the fact that the cost is relatively high compared to alternative mechanisms.
  - CAM can be designed to give a variety of velocity and dwell characteristics.







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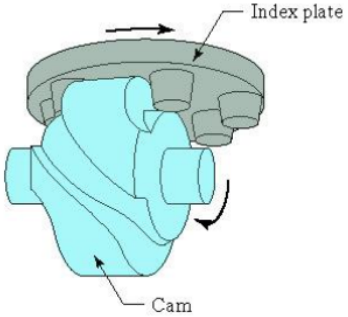
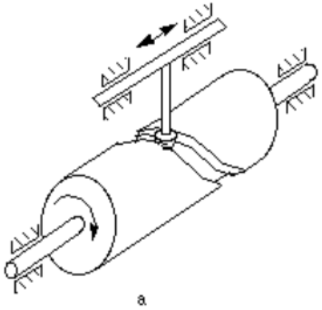
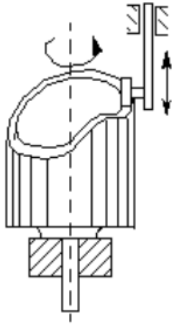






Control Function of Automated Flow Lines

Controlling an automated flow line is a complex problem. There are three main functions that are utilized to control the operation of an automatic transfer system.

- **Sequence control:**
  - Purpose of this function is to coordinate the sequence of actions of the transfer system and its workstations.
  - Various activities of the automated flowline must be carried out with split-second timing and accuracy.
  - Sequence control is basic to the operation of the flow line.

Control Function of Automated Flow Lines

- **Safety Monitoring:**
  - Ensures that the transfer system does not operate in an unsafe or hazardous condition.
  - Sensing devices may be added to make certain that the cutting tool status is satisfactory to continue to process the workpart in the case of a machining-type transfer line.
  - Other checks might include monitoring certain critical steps in the sequence control function to make sure that these steps have all been performed and in the correct order.

Control Function of Automated Flow Lines

- **Quality Monitoring:**
  - Control function is to monitor certain quality attributes of the workpart.
  - Its purpose is to identify and possibly reject defective workparts and assemblies.
  - The inspection devices required to perform quality monitoring are sometimes incorporated into existing processing stations.
  - In other cases, separate stations are included in the line for the sole purpose of inspecting the workpart.

Control Function of Automated Flow Lines

- **Alternative Control Strategies:**
  - Conventional thinking on the control of the line has been to stop operation when amalfunction occurred.
  - Certain malfunctions representing unsafe conditions that demand shutdown of the line, there are other situations where stoppage of the line is not required and perhaps not even desirable. There are alternative control strategies
    - **Instantaneous control**
    - **Memory control**

Control Function of Automated Flow Lines

Instantaneous control:

- control stops the operation of the flow line immediately when a malfunction is detected.
- Relatively simple, inexpensive, and trouble free.
- Stopping the machine results in loss of production from the entire line,

Memory control:

- memory system is designed to keep the machine operating.
- It works to control quality and/or protect the machine by preventing subsequent stations from processing the particular workpart and by segregating the part as defective at the end of the line

Buffer Storage

- Production flow lines to **include storage zones for collecting banks of workparts along the line.**
- There are two principal reasons for the use of buffer storage zones.
  - The first is to **reduce the effect of individual station breakdowns** on the line operation.
  - Continuous or intermittent transfer system acts as a single integrated machine. **When breakdowns occur** at the individual stations or when preventive maintenance is applied to the machine, **production must be halted.**

In many cases, the proportion of time the **line spends out of operation** can be significant, perhaps **reaching 50% or more.**

Buffer Storage

Common reasons for line stoppages are:

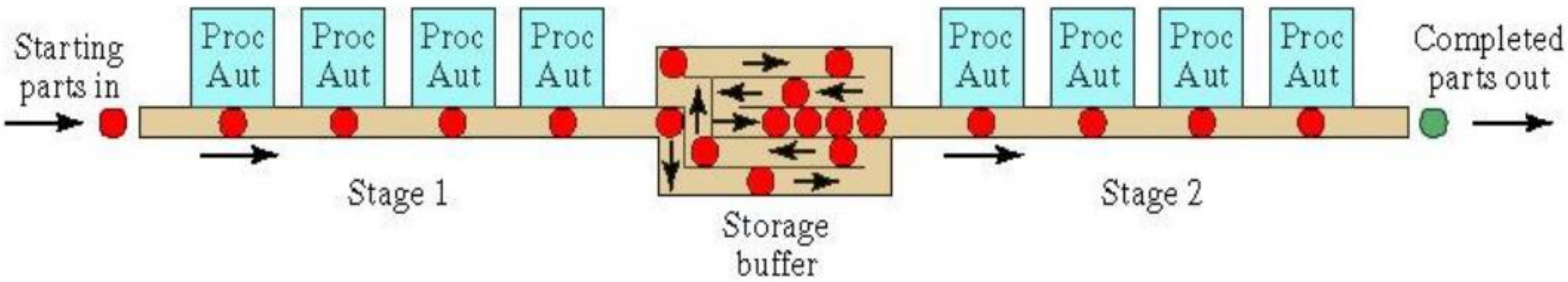
- **Tool failures or tool adjustments** at individual processing stations
- **Scheduled tool changes**
- **Defective workparts** or components at assembly stations, which require that the feed mechanism be cleared
- **Feed hopper needs to be replenished** at an assembly station
- **Limit switch** or other electrical **malfunction**
- **Mechanical failure** of transfer system or workstation.

Buffer Storage

- **When a breakdown occurs** on an automated flow line, the **purpose of the buffer storage zone is to allow a portion of the line to continue operating** while the remaining portion is stopped and under repair.
- Example, assume **20-station line**
  - divided into two sections and
  - connected by a parts storage zone (which collects parts from 1st section)
  - feeds them to the 2nd section.
- **If a station jam** were to **cause the 1st section** of the line **to stop**, the **2nd section could continue to operate** as long as the supply of parts in the.

Buffer Storage

- **If a station jam** were to **cause the 1st section** of the line **to stop**, the **2nd section could continue to operate** as long as the supply of parts in the buffer zone lasts.
- Similarly, **if the 2nd section** were to **shut down**, the **1st section** could **continue to operate** as long as there is room in the buffer zone to store parts.
- Average production rate on the first section would be about equal to that of the second section.



Buffer Storage

Reasons for using storage buffers are:

- To **reduce effect of station breakdowns**
- To provide a **bank of parts to supply** the line
- To **provide a place to put the output** of the line
- To **smooth cycle time** variations
- To **store parts between stages** with different production rates

Disadvantages of buffer storage on flow lines are:

- Increased factory floor space,
- Higher inprocess inventory
- More material handling equipment
- Greater complexity of the overall flow line system.

Design and Fabrication Considerations

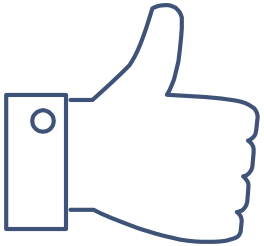
Specifications are required to decide best automated flow line for producing a particular work part or assembly in Manufacturing Unit. In designing and building an automated flow line, some of the details to consider are the following :

- Whether the flow line is to be engineered in-house or by a machine tool builder
- Size, weight, geometry, and material if a processed work part
- Size, weights, and number of components if an assembly
- Tolerance requirements
- Type and sequence of operations
- Production-rate requirements
- Type of transfer system

Design and Fabrication Considerations

In designing and building an automated flow line, some of the details to consider are the following :

- Methods of fixturing and locating work parts
- Methods of orienting and feeding components in the case of assemblies.
- Reliability of individual stations and transfer mechanisms, as well as overall reliability of the line
- Buffer storage capability
- Ease of maintenance
- Floor space available
- Flexibility of line in terms of possible future changes in product design
- Flexibility of line to accommodate more than a single work part
- Initial cost of the line
- Operational and tooling cost for the line



THANKS!