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Automation in Production

Course Code: 23BTMEL402

B. Tech - VII Semester

Prepared by:

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Teaching and Evaluation Scheme

Course Title: **Automation in Production**										
Semester	VII	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	PCC 13	2	-	2	03	10	15	50	25	-
Course Code	23BTMEL402 23BTMEP402									
Teaching Mode	Offline	4 Hrs.			Total	75			25	
Duration of ESE	3 Hrs.					100				

Course Objectives and Outcomes

Course Objectives	1. To introduce concept of fixed automation through design of transfer lines.
	2. . To understand numerical control of machine tools and its component.
	3. To provide exposure to automated material handling and tool handling systems.
Course Outcomes	Upon successful completion of this course, student shall be able to:
	CO 1. Define and select the industrial automation required for a production system.
	CO 2. Demonstrate the CNC machines.
	CO 3. Develop programs for simple robot applications.
	CO 4. Choose the various types of AGV and AS/RS.
	CO 5. Explain GT and FMS concepts in manufacturing

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Mapping of Course Outcomes with Program Outcomes and Program Specific Outcomes:

Following mapping is only for reference

Course Outcomes	Program Outcomes and Program Specific Outcomes														
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO1	3	2	3	-	3	-	-	-	-	-	-	2	3	2	2
CO2	3	1	2	-	3	-	-	-	-	-	-	2	3	2	2
CO3	3	2	1	-	2	-	-	-	-	-	-	2	3	2	2
CO4	3	1	2	-	2	-	-	-	-	-	-	2	3	2	2
CO5	1	3	2	-	3	-	-	-	-	-	-	2	3	2	2

Syllabus

Unit	Contents
Unit 1	**Introduction to Automation:** Definition, Comparison of fixed, programmable and flexible automation, automation strategies, reasons for automation, applications. Automated Flow Line - Methods of work part transport, transfer mechanisms, analysis of transfer lines with and without buffer storage, Assembly line.
Unit 2	**NC and CNC Machines:** Numerical Control – Basic concepts, components of NC, types of NC Systems – point to point, straight cut and continuous path, applications and economics of NC, CNC part programming. Manual part programming
Unit 3	**Industrial Robotics:** Definition, robot anatomy, robot configurations, robot specifications. End effectors, sensors Robot applications – Characteristics of robot applications, work cell layout, robot applications in material handling processing, assembly and inspection

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Syllabus

Unit	Contents
Unit 4	**Automated Material Handling Systems:** Automated Guided Vehicle Systems. Types, Vehicle guidance & Routing, Traffic control & Safety system management, Analysis of AGVS systems, AGVS applications. Automated Storage & Retrieval System. Types, Basic components & special features of AS/RS, Carousel storage systems
Unit 5	**Group Technology and Flexible Manufacturing System:** GT - GT philosophy, part families, parts classification & coding, Optiz classification systems, production flow analysis, Machine cell design – composite part concept, types of cell design, benefits of GT. FMS – Components, Types of systems, FMS layout configuration computer functions, level of flexibility, data files system reports, FMS benefits, **Advanced topic**

Study Material

Text Books	1.	P. Radhakrishnan, S. Subramanyam, V. Raju, “CAD/CAM/CIM”, New Age Publisher, 2004
	2.	Mikell P. Groover, “Automation, Production Systems, and Computer-integrated Manufacturing”, Prentice Hall, 2013
	3.	Industrial Robotics and applications by M P Groover,Tata Mcgrawhill,2016.
E-Books	1.	Frank Lamb, Industrial Automation Hands-On, McGraw Hill Publication, 2013
	2.	Yusuf Altintas, Manufacturing Automation, Cambridge University Press, 2012
Reference Books	1.	Krar, S., and Gill, A., “CNC Technology and Programming”, McGraw Hill Publication Co, 2012.
	2.	Gibbs, D., “An Introduction to CNC Machining”, Casell, 2015.
	3.	Lynch, M., “Computer Numerical Control for Machining”, McGraw Hill, 2002.
	4.	Koren Y, “Computer Control of Manufacturing Systems”, McGraw, 2005.

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Unit 1

Introduction to Automation

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- **Definition of Automation**
- Automation is the use of **control systems, computers, and information technologies** to operate equipment and processes with **minimal human intervention**.
- ☞ In simple terms:
  Automation = *machines doing work automatically with little or no human effort.*

Introduction to Automation

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❑Types of Automation

(a) Fixed Automation (Hard Automation)

- Designed for **high-volume, low-variety production**
- Equipment is **dedicated and rigid**
- High initial investment, low flexibility
- **Examples:**
- Automobile assembly lines
- Continuous chemical processing

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- **(b) Programmable Automation**
- Suitable for **batch production**
- Operations can be changed by modifying the program
- Moderate flexibility
- **Examples:**
- CNC machines
- Industrial robots

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- **(c) Flexible Automation (Soft Automation)**
- Capable of producing **variety of products with little changeover time**
- Controlled by computers and integrated systems
- High flexibility, high cost
- **Examples:**
- Flexible Manufacturing Systems (FMS)
- Automated production cells

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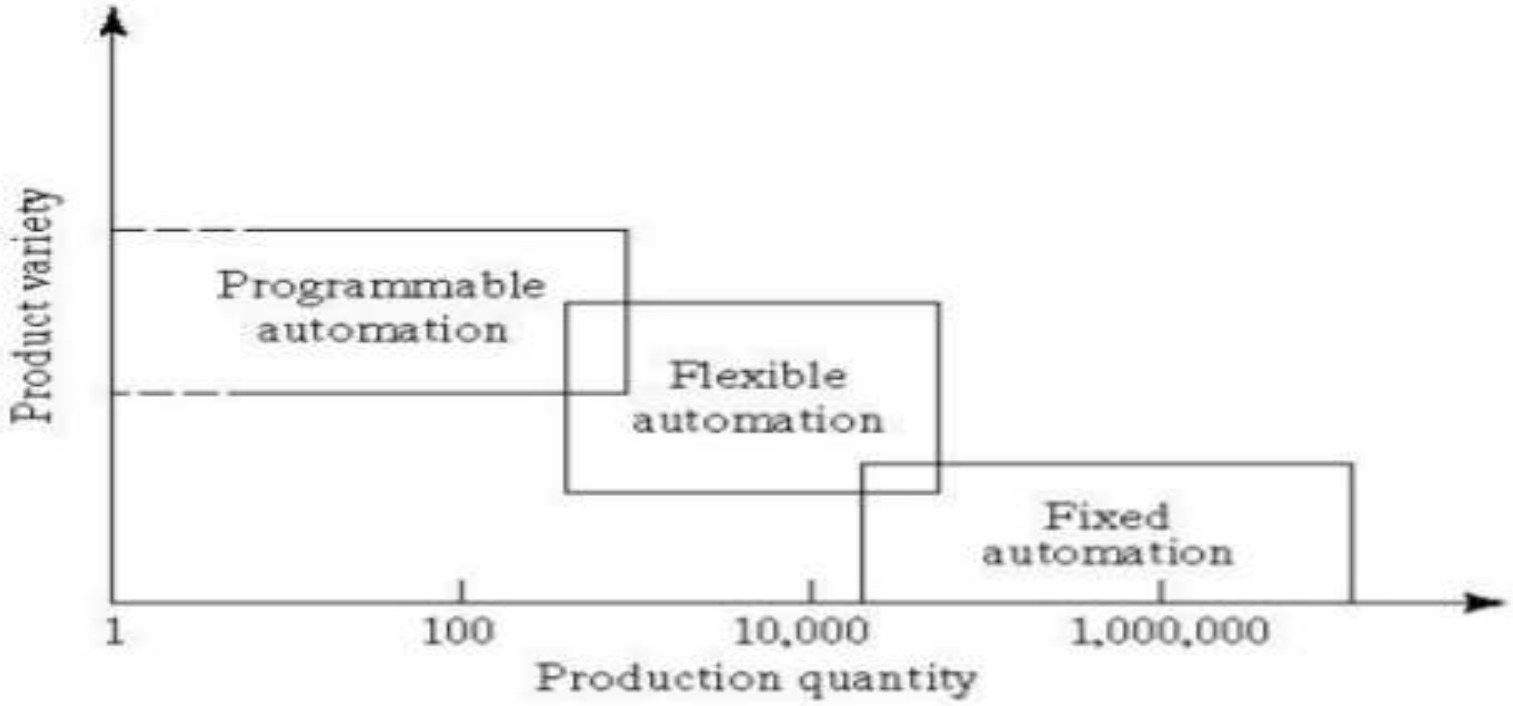
- Comparison Table

Feature	Fixed	Programmable	Flexible
Production Volume	High	Medium	Medium
Product Variety	Low	Medium	High
Flexibility	Very Low	Moderate	High
Setup Time	Very High	High	Low
Cost	High (initial)	Moderate	Very High

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Product Variety and Production Quantity for Three Automation Types



Common Examples of Automation

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Day to Day life

- Automatic washing Machine
- Starting of the vehicle
- Automated Teller Machine
- Electrically driven Pump
- UPS, Canopy (power supply Back up

Common Examples of Automation

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Industry

- CNC Machine
- Painting Welding, Assembly Robots in the automobile mfg industry
- Distributed Control Systems

❑Automation Strategies

Common strategies used in industries:

- **Specialization of operations** – dedicated machines for specific tasks
- **Combined operations** – multiple operations in one workstation
- **Simultaneous operations** – performing tasks at the same time
- **Integration of operations** – linking processes into one system
- **Increased flexibility** – use of programmable machines
- **Improved material handling** – conveyors, AGVs
- **Online inspection** – quality checks during production
- **Process control and optimization** – real-time monitoring

❑Reasons for Automation

Industries adopt automation for:

- Increase productivity
- Improve product quality and consistency
- Reduce labor cost
- Enhance safety (hazardous operations)
- Reduce human error
- Faster production
- Better control and monitoring
- Efficient resource utilization

❑Applications of Automation

Automation is widely used in:

- Manufacturing industries (automobile, electronics)
- Process industries (oil refining, chemical plants)
- Material handling systems (conveyors, AGVs)
- Packaging and assembly
- Robotics applications
- CNC machining
- Warehousing and logistics

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❑Automated Flow Line

- An **automated flow line** is a system of multiple workstations connected by a **material handling system**, where parts move automatically from one station to another.

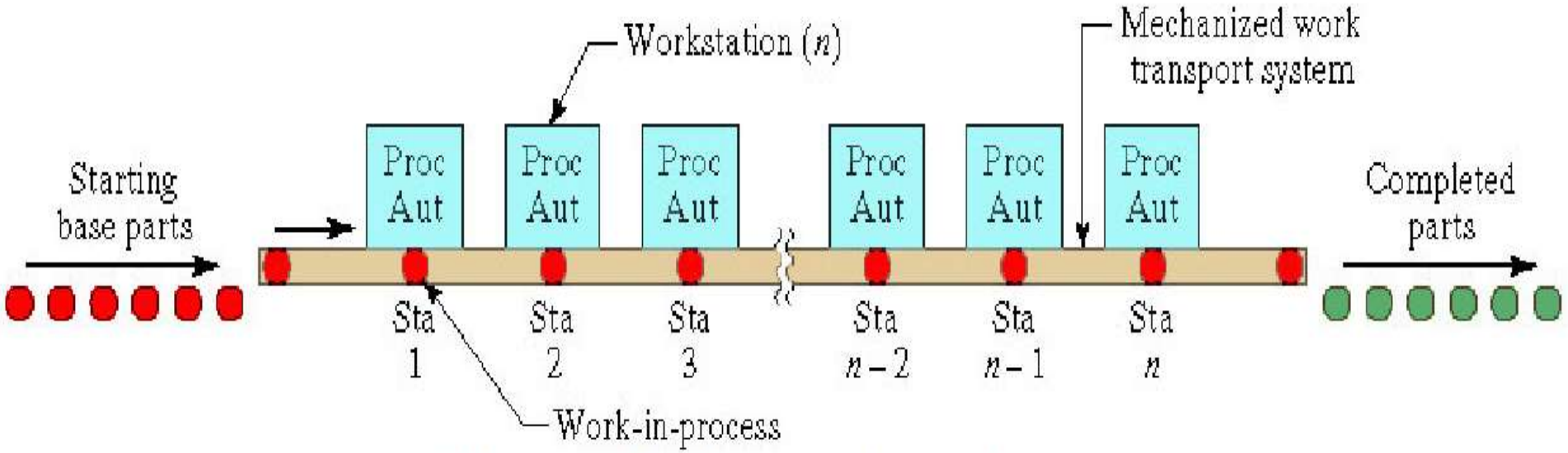


Figure 1 In-line configuration



Figure 27 Example of Transfer line

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❖Methods of Work Part Transport

- **Continuous transfer**
  - Parts move continuously
  - Used in high-speed operations
- **Intermittent (synchronous) transfer**
  - All parts move simultaneously after each cycle
- **Asynchronous transfer**
  - Parts move independently between stations

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❑Transfer Mechanisms

Common mechanisms used:

- Conveyor systems (belt, roller)
- Walking beam transfer
- Chain drives
- Rotary indexing tables
- Pneumatic/hydraulic pushers

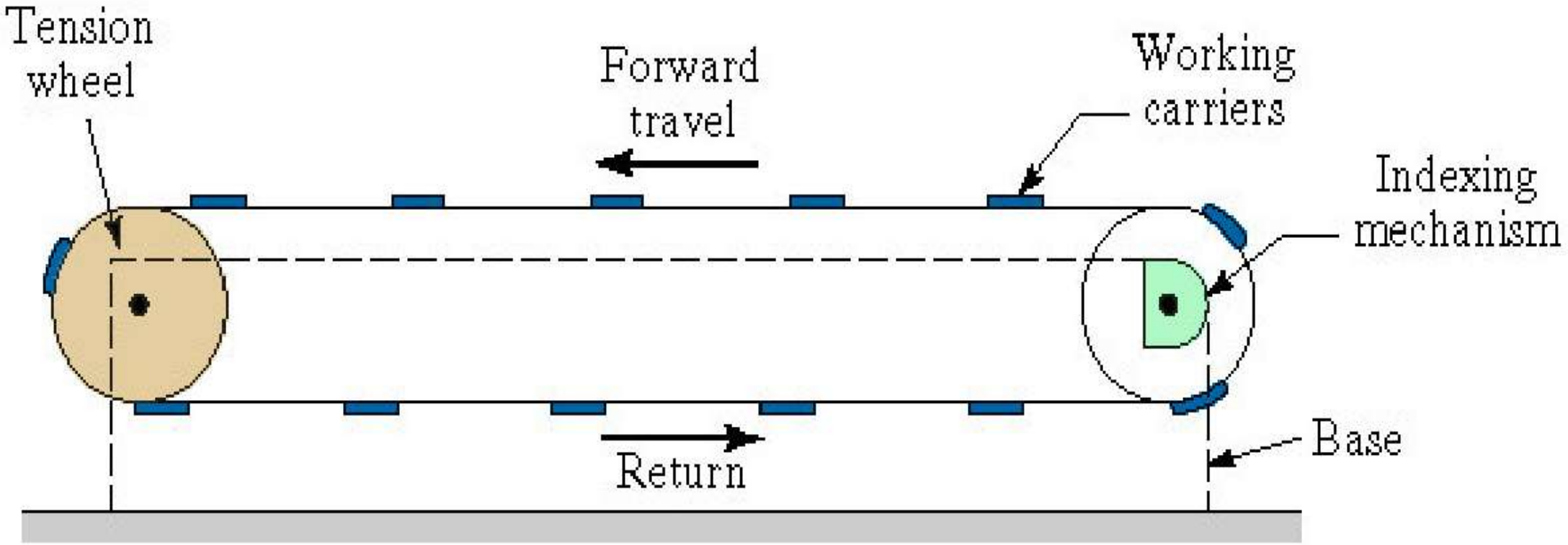


Figure 14 Chain drive conveyor

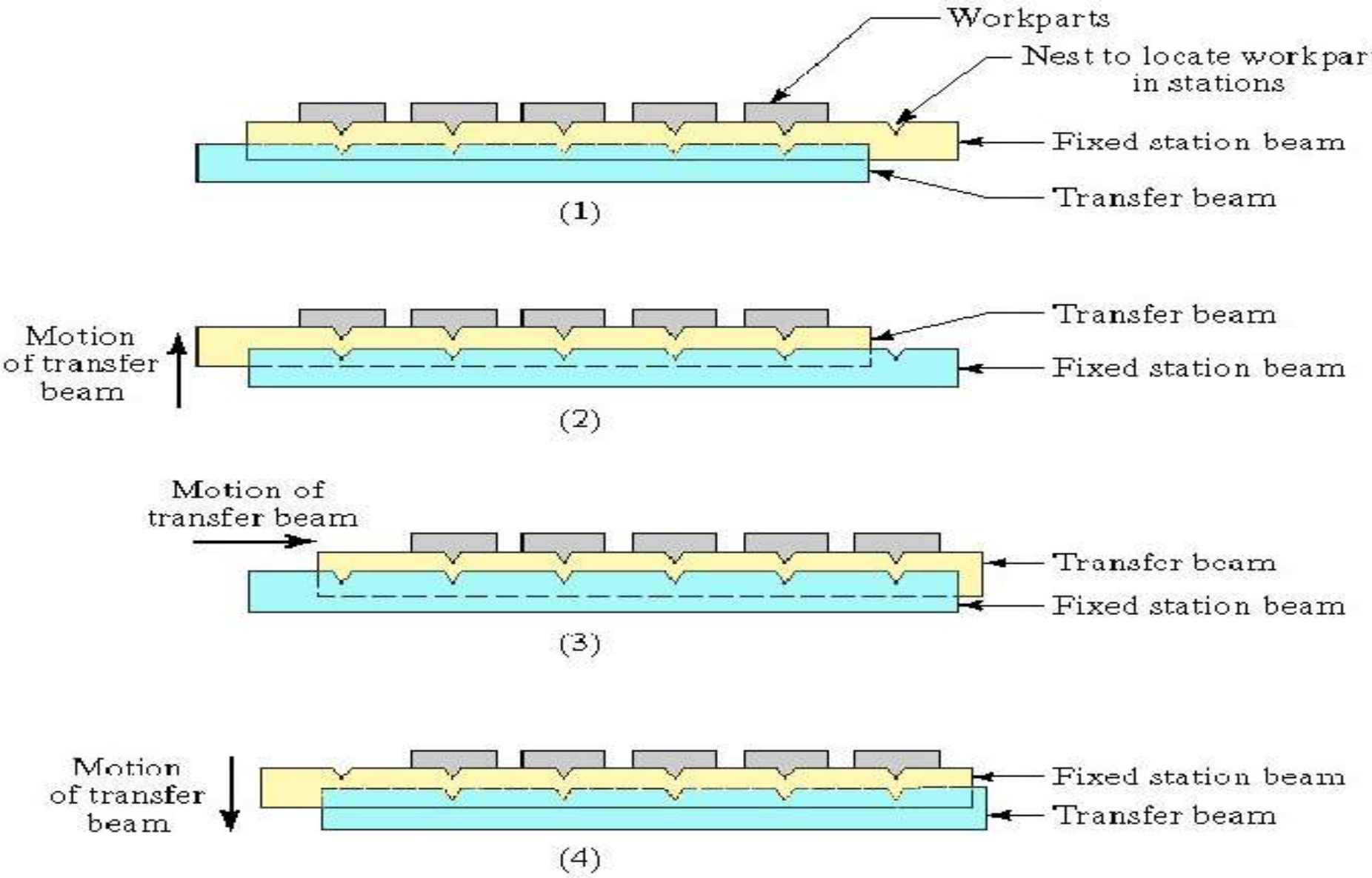


Figure 12 walking beam transfer system, showing various stage during transfer stage

❑Analysis of Transfer Lines

(a) Without Buffer Storage

- No intermediate storage between stations
- Entire line stops if one station fails

Advantages:

- Simple design
- Low cost

Disadvantages:

- Low reliability
- High downtime

(b) With Buffer Storage

- Buffers store parts between stations
- Allows independent operation of stations

Advantages:

- Increased efficiency
- Reduced downtime
- Better line balancing
- **Disadvantages:**
- Higher cost
- More space required

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❑Assembly Line

- An **assembly line** is a production system where:
- Products move sequentially through stations
- Each station performs a specific task

Key Concepts:

- Workstations
- Cycle time
- Line balancing
- Throughput

Types of Assembly Lines:

- Manual assembly line
- Automated assembly line
- **Advantages:**
- High production rate
- Reduced labor cost
- Consistent quality

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Storage Buffer :- A storage buffer in a production line is a location where parts can be collected and temporarily stored before proceeding to subsequent (downstream) workstation

Why Buffer Storage are used on automated production line

1. To reduce the effect of station breakdown

2. To provide a bank of parts to supply the line

3. To provide a place to put the output of the line

4. To allow for curing time or other required delay

5. To smooth cycle time variation

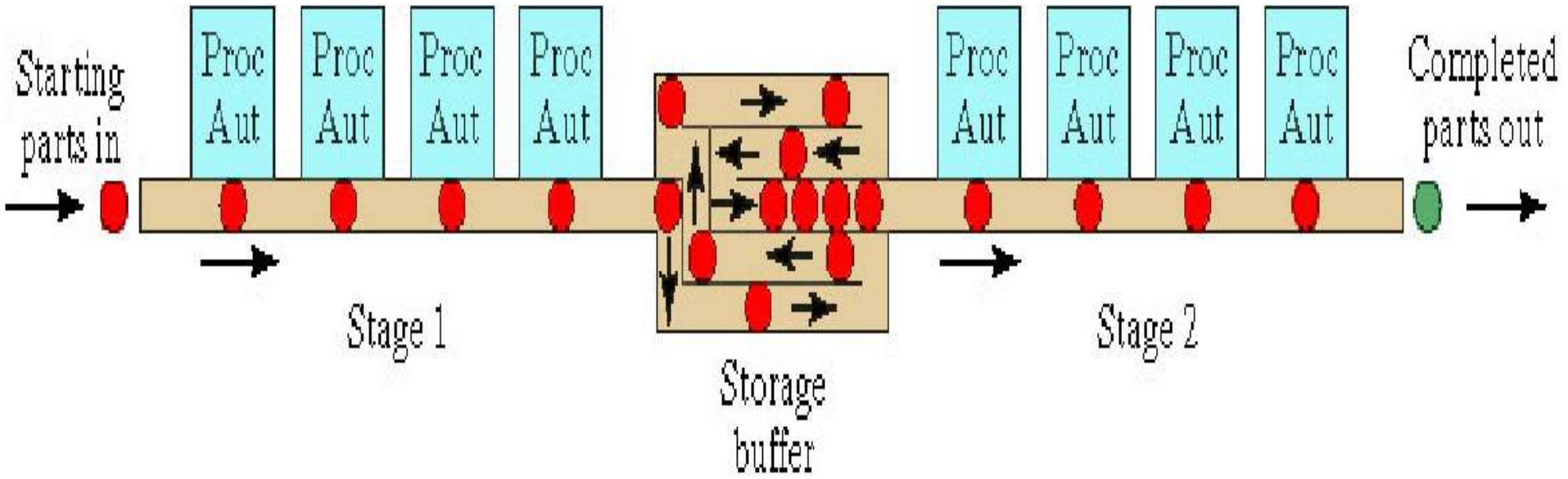


Figure 20 Storage buffer between two stages of a production

Why Buffer Storage are used on automated production line

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1. To reduce the effect of station breakdown

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Control of the Production Line

1. Control Function – i)Sequence Control

ii)Safety Monitoring

iii)Quality Control

Alternative control - iv)Instantaneous Control

- v)Memory Control

2. Line Control

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Unit 2

NC and CNC Machines

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❑Numerical Control (NC) – Basic Concept

- **Numerical Control (NC)** is a method of controlling machine tools using **coded numerical data** (numbers, letters, symbols).
- Instructions are given in the form of a **part program**
- The machine follows these instructions automatically
- Reduces human intervention and improves accuracy
- ☞ Example: Drilling holes at specific coordinates using coded instructions

NC and CNC Machines

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❑Components of NC System

An NC system consists of three main components:

1. Program of Instructions

- Set of coded instructions (G-codes, M-codes)
- Specifies tool movement, speed, feed, etc.

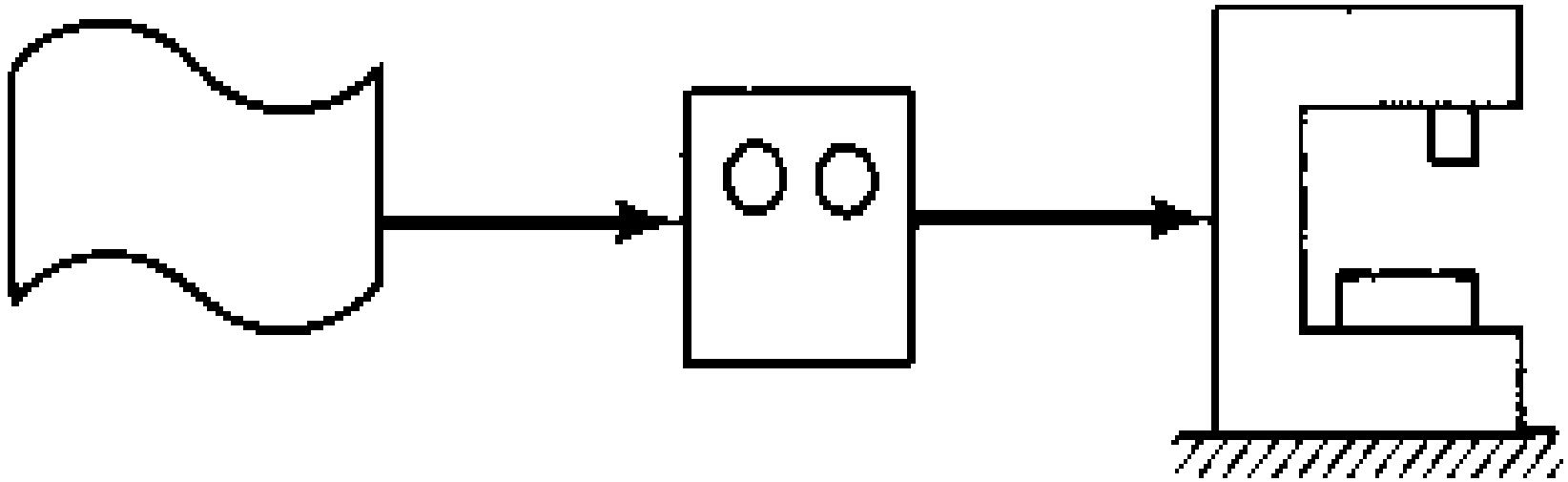
2. Machine Control Unit (MCU)

- The “brain” of the NC machine
- Reads and interprets the program
- Converts instructions into electrical signals

3. Machine Tool

- The actual equipment (lathe, milling, drilling machine)
- Performs machining operations based on commands

NC and CNC Machines



7.1 Three basic components of a numerical control system.

NC and CNC Machines

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- Program of Instructions :- The input medium for program instruction are

i) Punched Card

ii) Magnetic Tapes and Floppy Disks

iii) Paper Tape

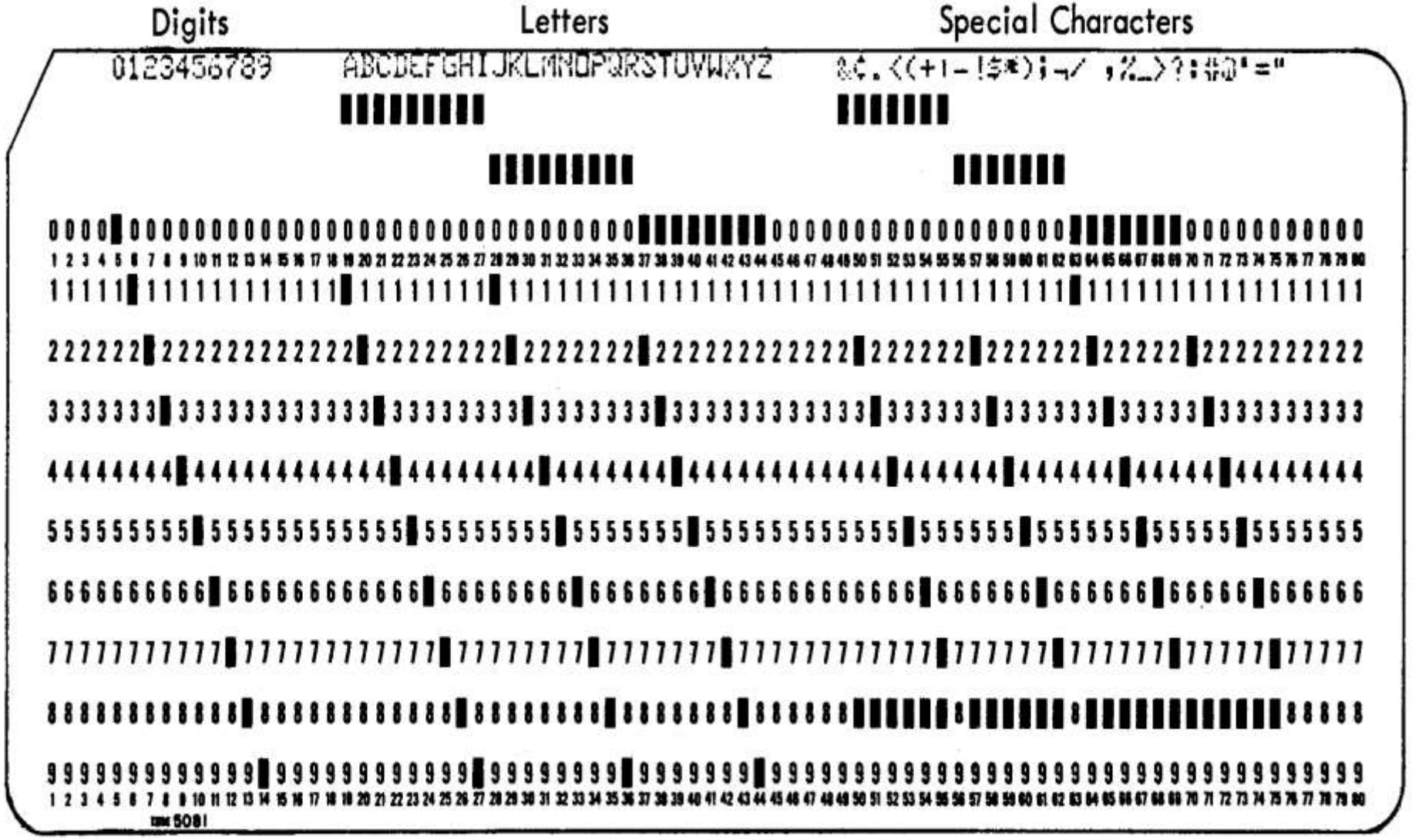


Figure 4. Card Codes and Graphics for 64-Character Set

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Machine Control Unit (MCU) :- The element used in machine control unit are

Programme reader :-

i) Card reader

ii) Punched Tape Reader

a)Mechanical Tape Reader

b)Optical or Photo Electrical Tape Reader

c)Pneumatic

iii) Magnetic Tape Reader

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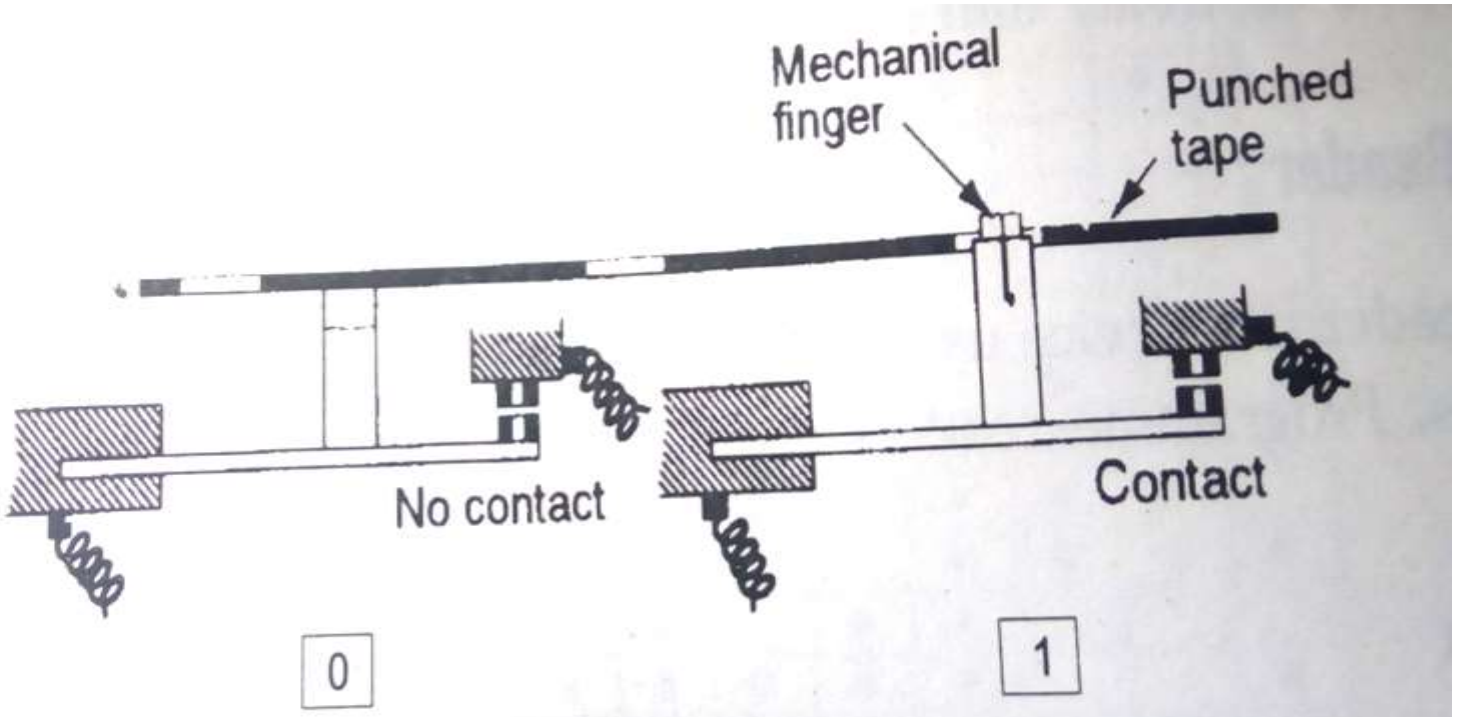


Fig. 2.5 Principle of the mechanical tape reader

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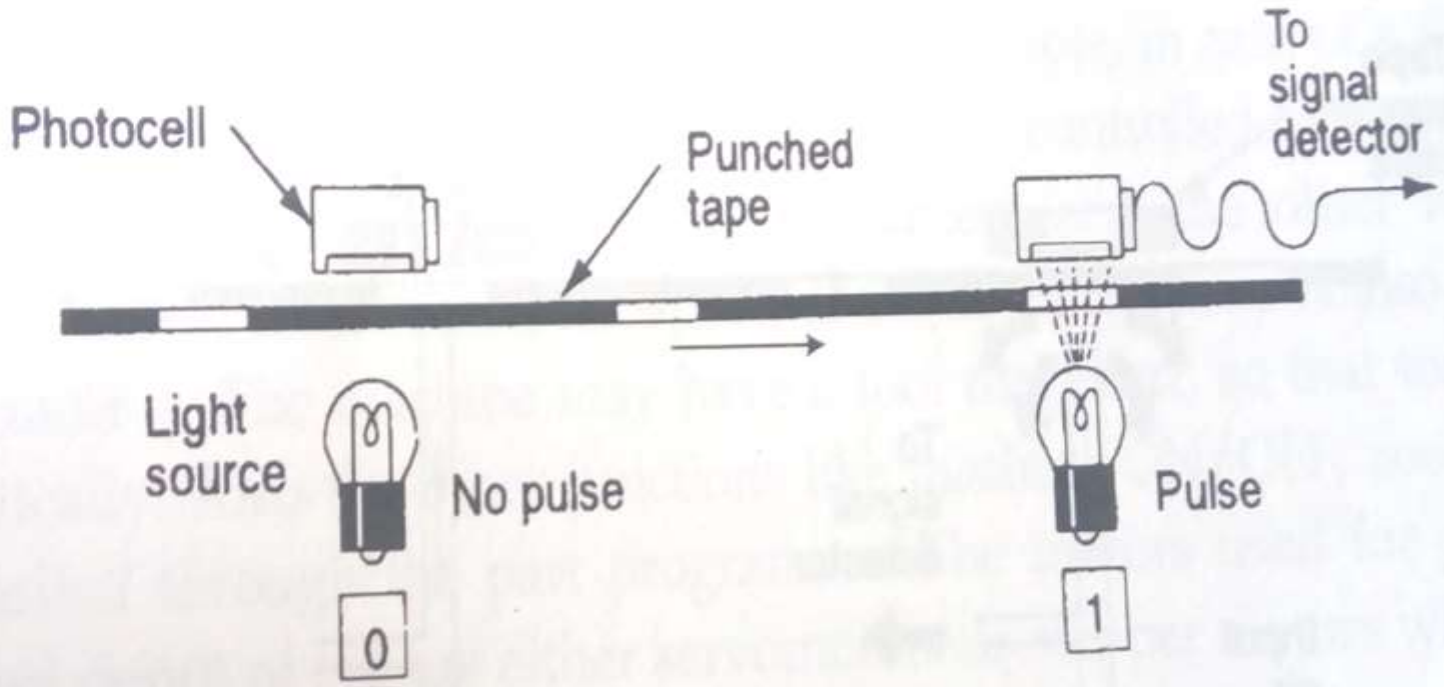


Fig. 2.6 Principle of the optical tape reader

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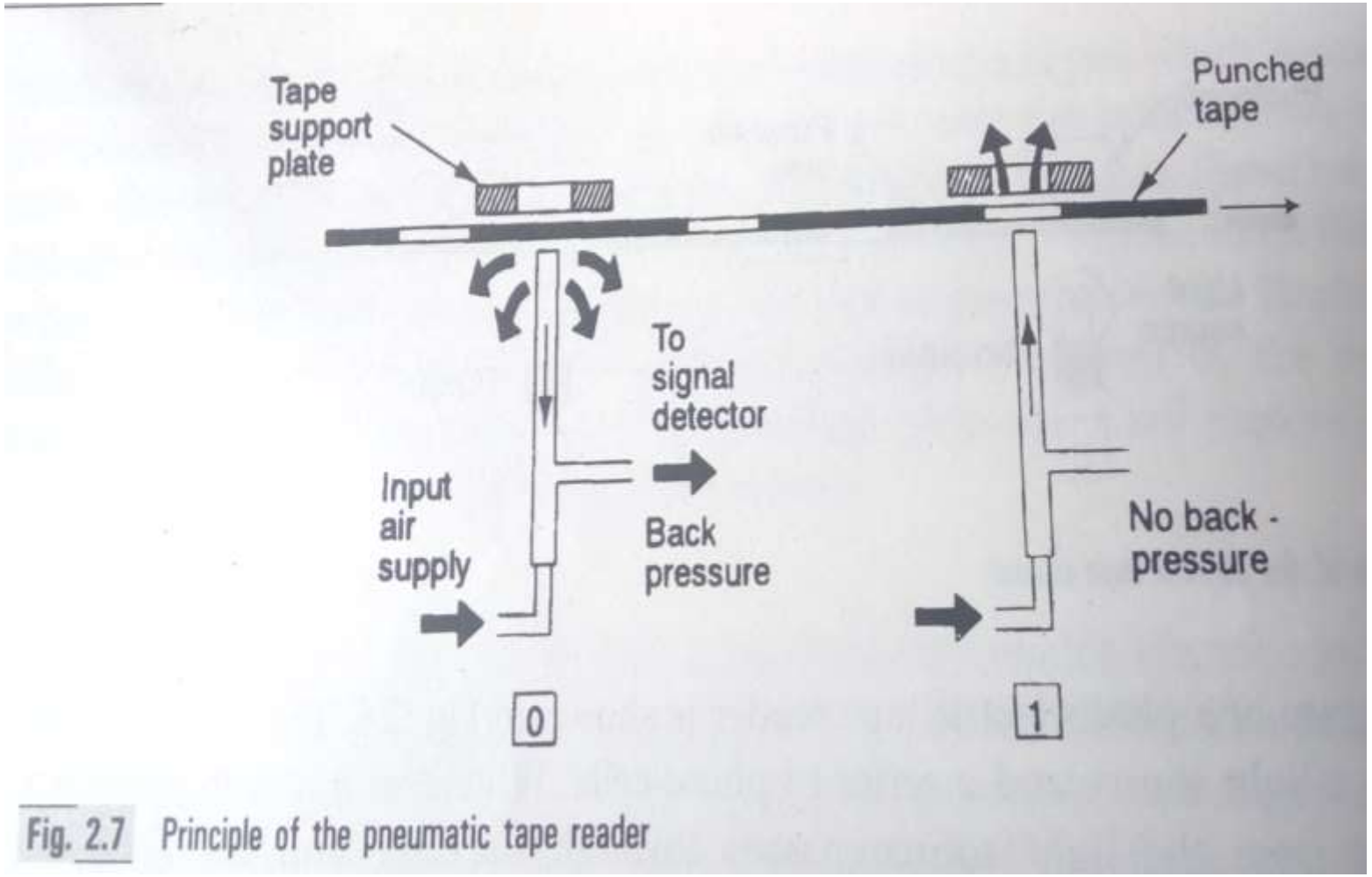


Fig. 2.7 Principle of the pneumatic tape reader

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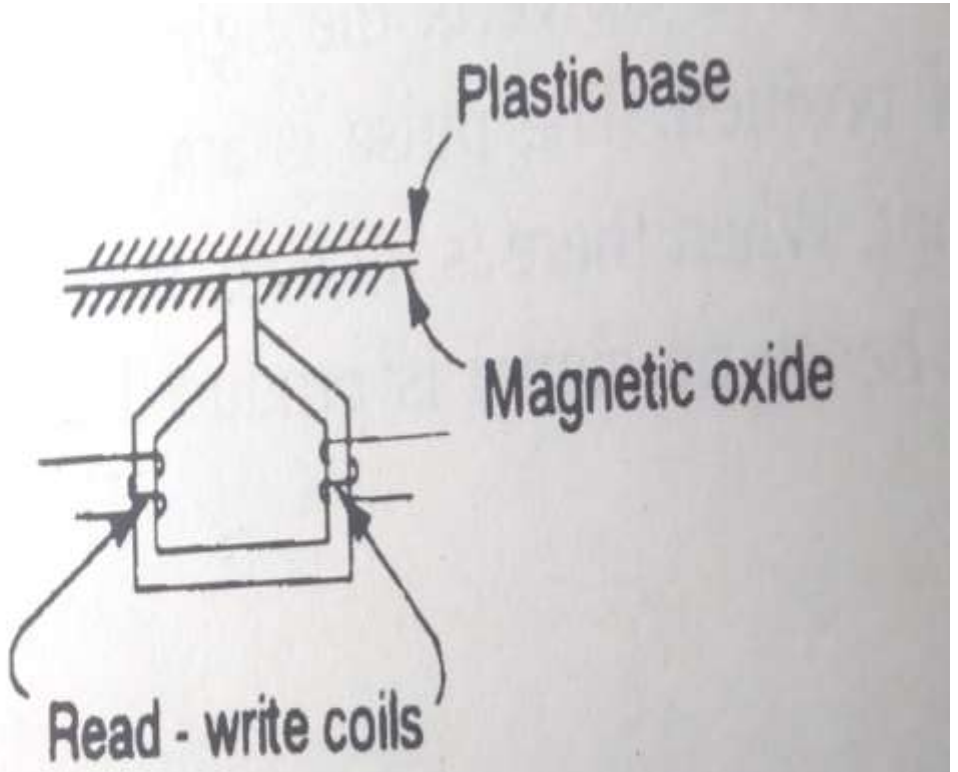
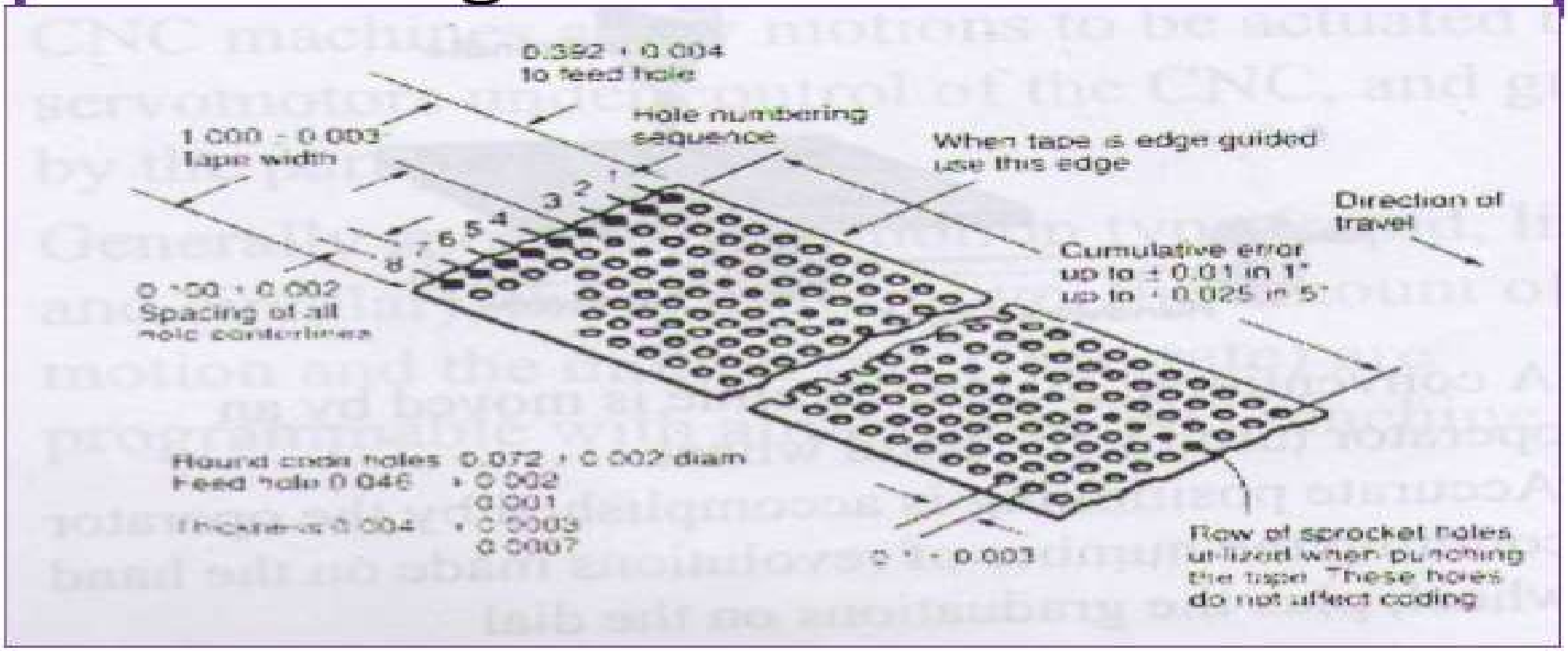


Fig. 2.8 Read-write head for magnetic tape

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Punched tape used for Transfer of Part Program to NC Machine



NC and CNC Machines

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➢ **Types of NC Systems**

1. Point-to-Point (PTP) System

- Tool moves from one point to another
- Path is not important, only position matters

➢ **Applications:**

- Drilling
- Punching
- Spot welding

NC and CNC Machines

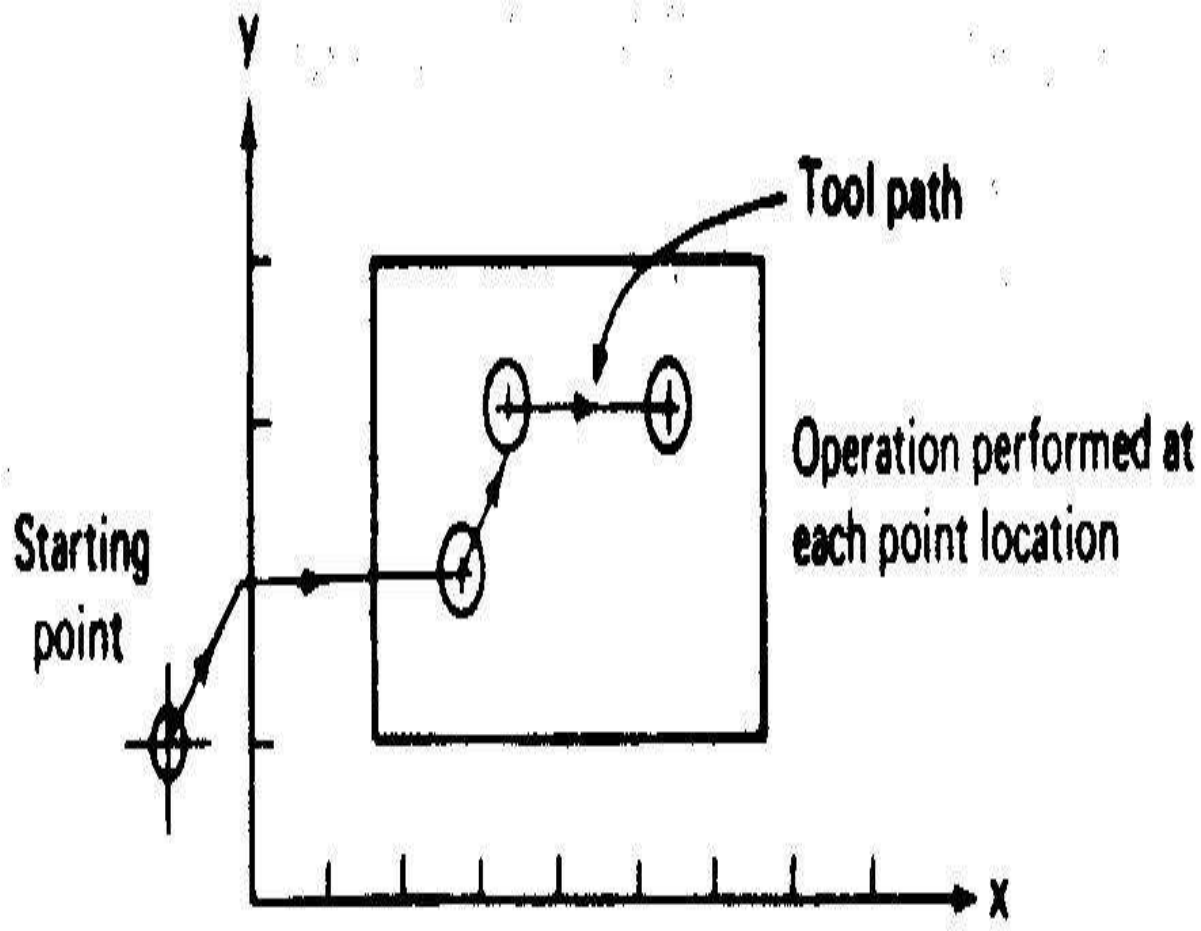
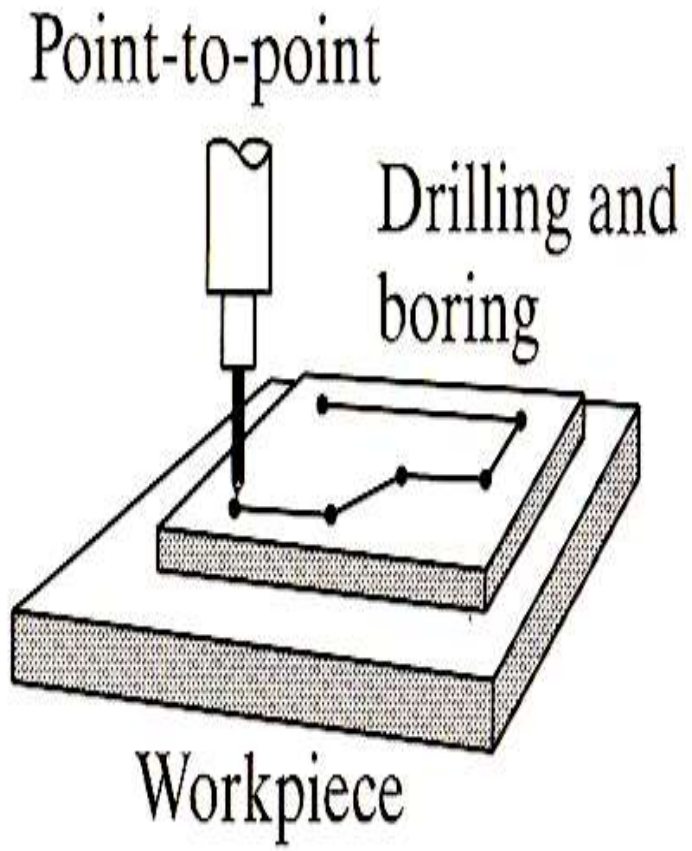


FIGURE 8.5 Point-to-point (positioning) control in NC.



NC and CNC Machines

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➢Straight Cut System

- Tool moves in a straight line (one axis at a time)
- Controls movement along a single axis

➢Applications:

- Simple milling operations
- Straight turning

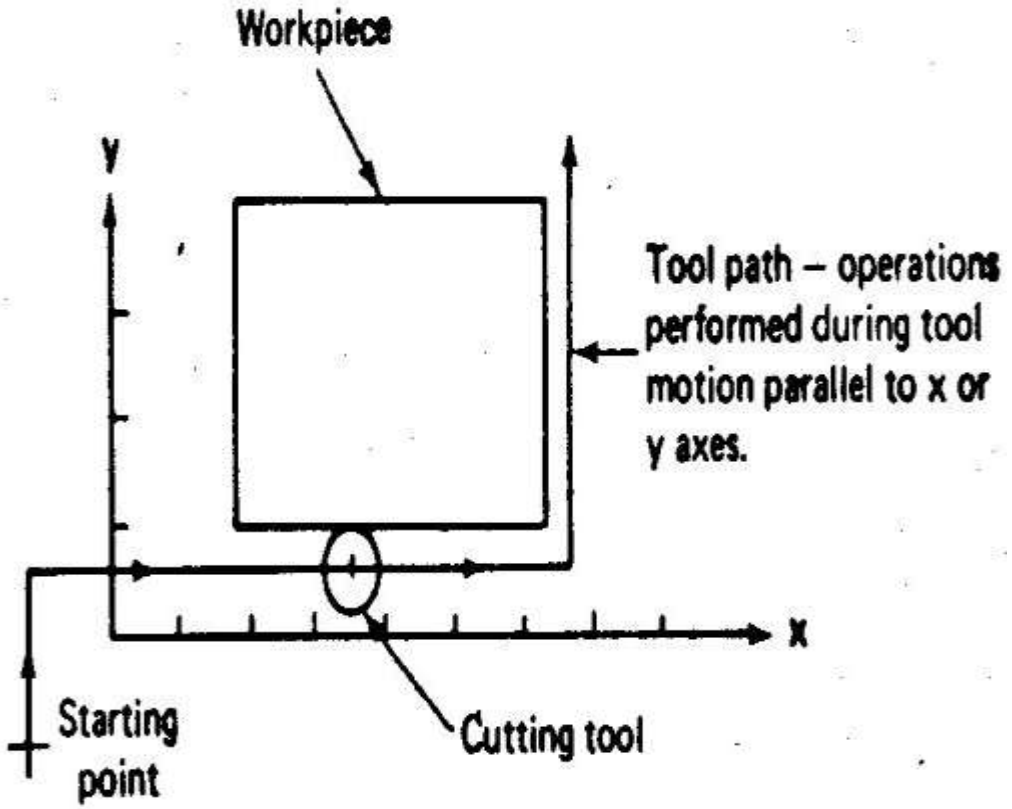


FIGURE 8.6 Straight-cut control in NC.

NC and CNC Machines

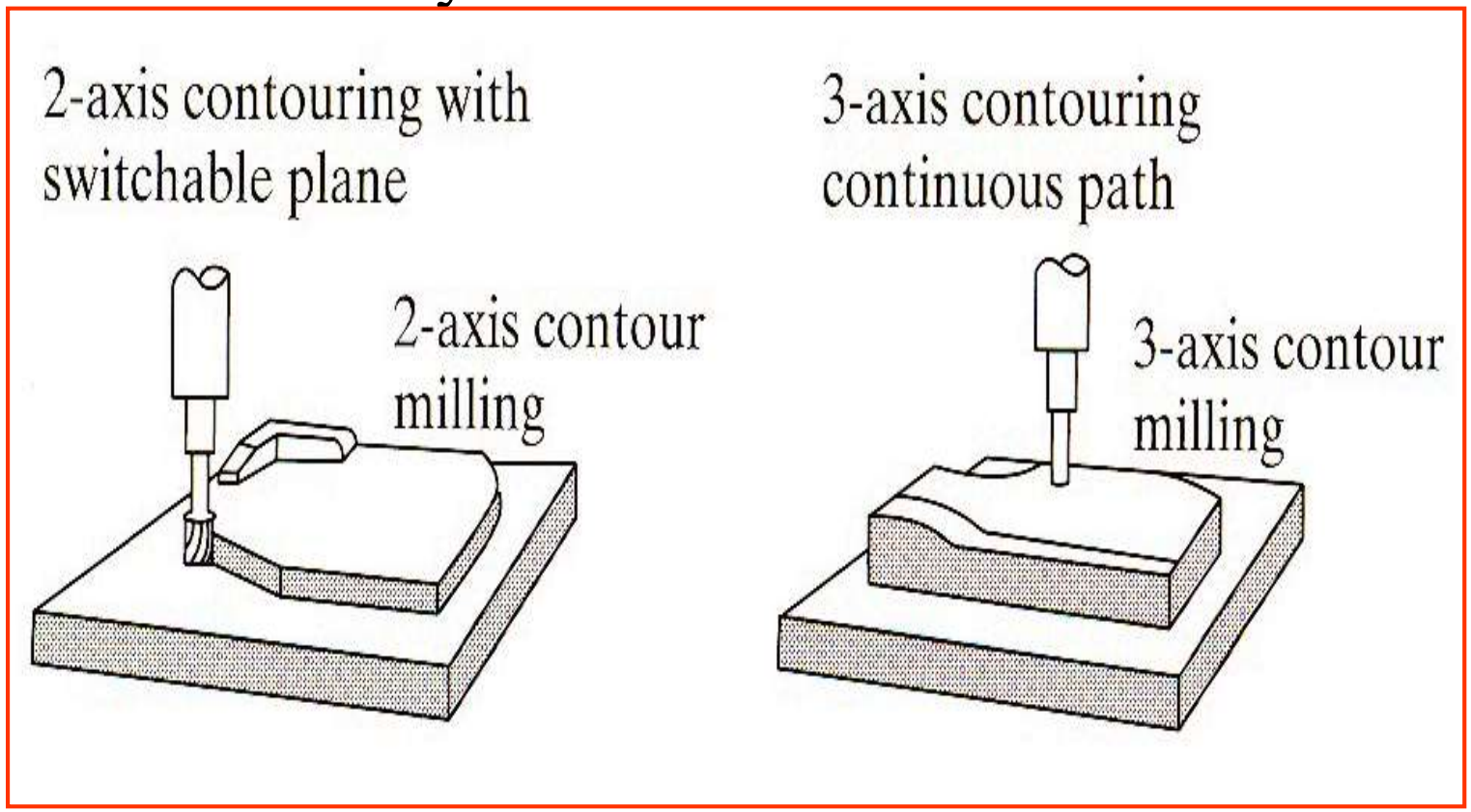
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➢**Continuous Path System (Contouring)**

- Tool moves continuously along a defined path
- Multiple axes controlled simultaneously

➢**Applications:**

- Complex shapes
- CNC milling
- Aerospace components



NC and CNC Machines

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❑Applications of NC Machines

- Automotive industries
- Aerospace manufacturing
- Tool and die making
- Mass production of precision parts
- PCB drilling and fabrication

NC and CNC Machines

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❑Economics of NC

Advantages:

- High accuracy and repeatability
- Reduced human error
- Increased productivity
- Complex shapes can be machined easily
- Reduced inspection requirements

Disadvantages:

- High initial cost
- Skilled programmers required
- Maintenance cost is higher

NC and CNC Machines

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❑CNC (Computer Numerical Control)

CNC is an advanced form of NC where a **computer is used to control the machine tool**.

➢Features of CNC:

- Stores multiple programs
- Easy editing and modification
- High flexibility
- Automatic tool changing
- Integration with CAD/CAM systems

NC and CNC Machines

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❑CNC Part Programming

- **Definition:** Writing a sequence of instructions (program) to control CNC machine operations.

Types of Programming:

- Manual part programming
- Computer-assisted programming

NC and CNC Machines

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- **Manual Part Programming**
- **Steps:**
- Study the component drawing
- Select coordinate system
- Decide tool path
- Write program using G-codes and M-codes

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- **Common Codes:**
- **G-Codes (Preparatory Functions)**
- G00 – Rapid movement
- G01 – Linear interpolation
- G02 – Circular interpolation (clockwise)
- G03 – Circular interpolation (anticlockwise)
- **M-Codes (Miscellaneous Functions)**
- M03 – Spindle ON (clockwise)
- M05 – Spindle OFF
- M06 – Tool change
- M30 – End of program

NC and CNC Machines

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Example of Manual CNC Program (Simple Turning)

N10 G21 (Metric units)

N20 G90 (Absolute programming)

N30 G00 X50 Z5 (Rapid move)

N40 G01 X30 Z0 F100 (Cutting)

N50 M30 (End program)

Other Examples of Manual CNC Program

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Unit 3

Industrial Robotics

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Definition

- An **industrial robot** is a **reprogrammable, multifunctional manipulator** designed to move materials, parts, tools, or specialized devices through programmed motions to perform various tasks.
- ☞ According to International Federation of Robotics: An industrial robot is *"an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes."*
- An industrial robot is a general purpose, programmable machine possessing certain anthropomorphic characteristics.
- The most typical anthropomorphic or human like, characteristics of a robot is its arm. This arm, together with the robots capacity to be programmed, make it ideally suited to a variety of production tasks.

Industrial Robotics

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Robot Anatomy (Basic Structure)

A robot consists of the following main parts:

a) Manipulator (Arm & Body)

- Mechanical structure (links and joints)
- Provides movement and reach

b) End Effector

- Attached to the wrist
- Interacts with the workpiece (gripper, tool, etc.)

c) Actuators (Drives)

- Provide motion (electric, hydraulic, pneumatic)

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Robot Anatomy (Basic Structure) Cont…

d) Sensors

- Provide feedback (position, force, vision)

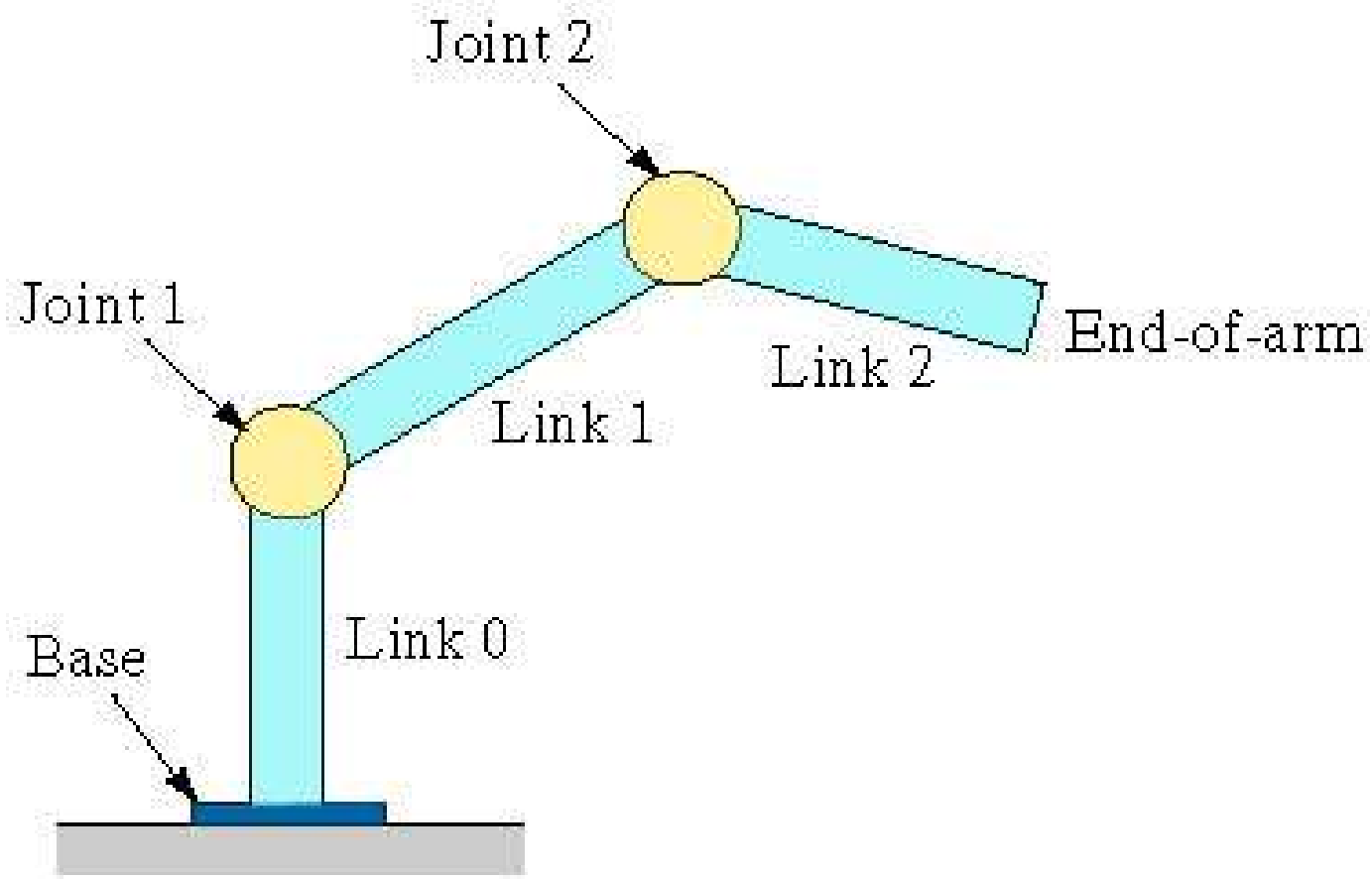
e) Controller

- "Brain" of the robot
- Executes programmed instructions

f) Power Supply

- Supplies energy to actuators and control system

Industrial Robotics



Anatomy Robot manipulator -a series of joint-link combinations

Industrial Robotics

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Industrial Robotics

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❑Robot Configurations (Types)

Different robots are classified based on geometry and movement:

1. Cartesian Robot

- Linear movement (X, Y, Z axes)
- High accuracy
- Used in CNC, 3D printing

Industrial Robotics

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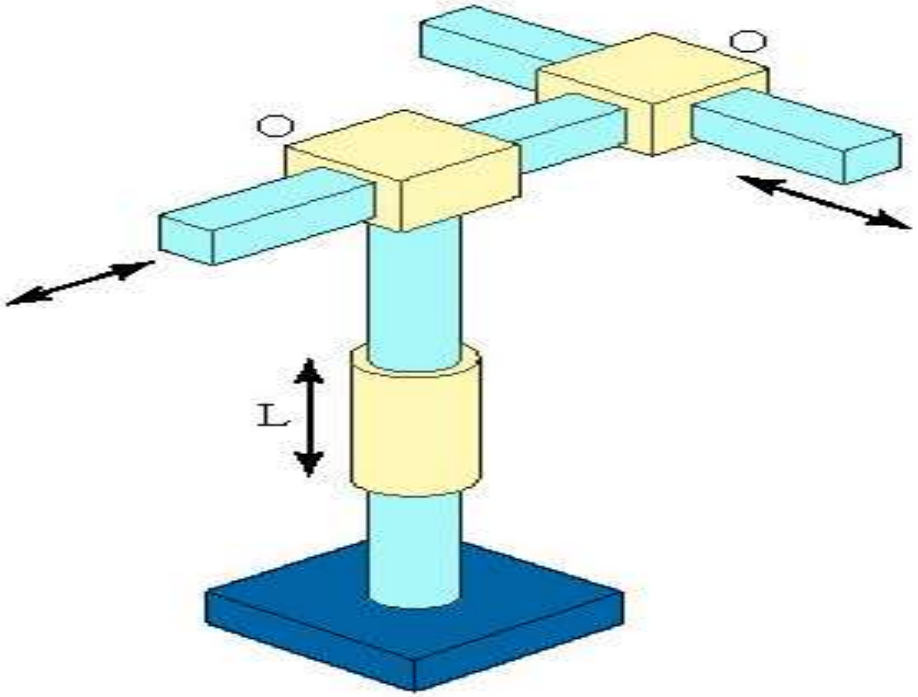




Fig:- Cartesian configuration

Industrial Robotics

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2. Cylindrical Robot

- Rotary + linear motion
- Used in handling and assembly

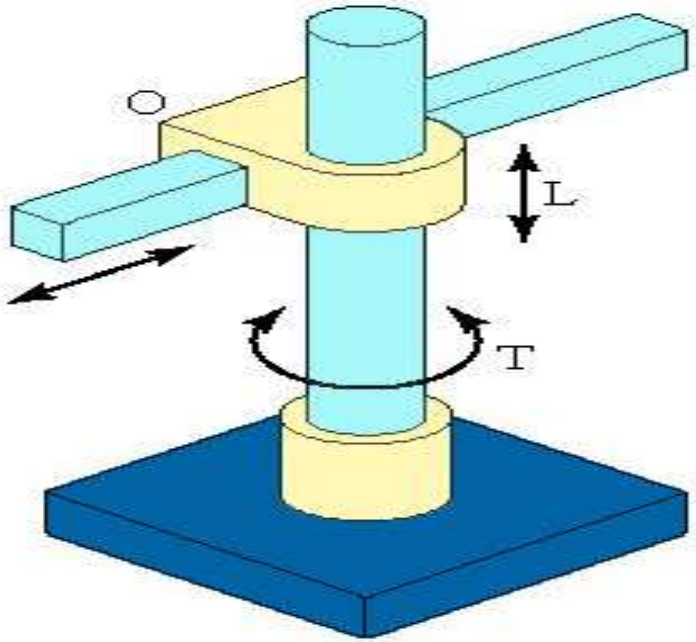
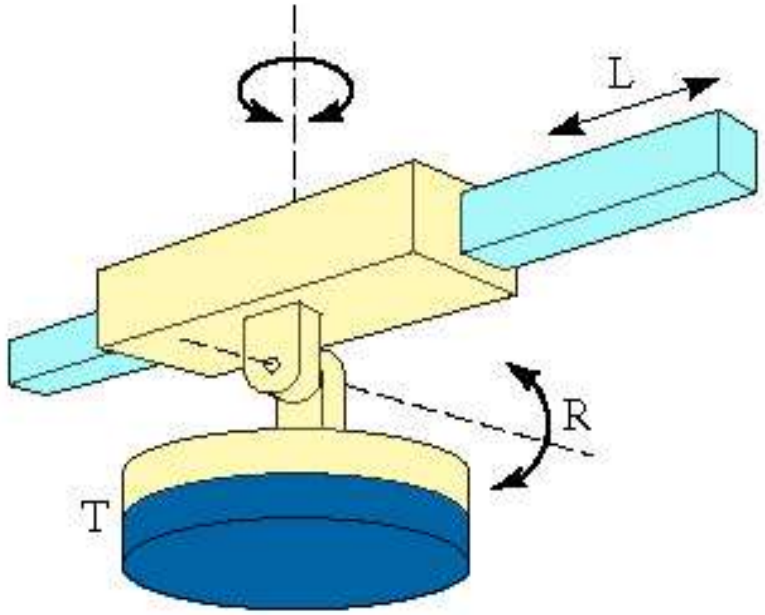




Fig:- Cylindrical configuration

Industrial Robotics



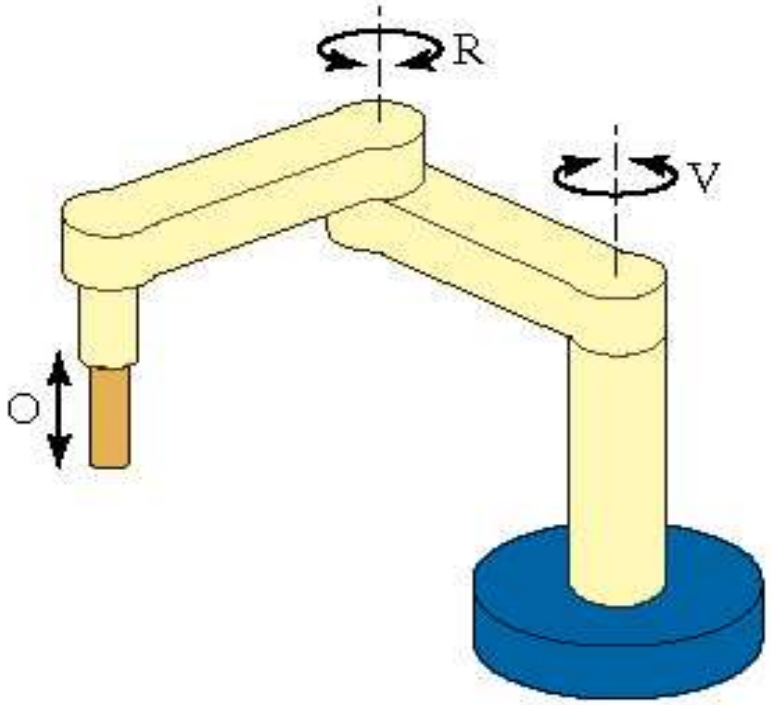


3. Spherical (Polar) Robot

- Rotational + telescopic arm
- Good for wide workspace

Fig:- Polar configuration

Industrial Robotics





4. SCARA Robot

- Selective Compliance Assembly Robot Arm
- Fast and precise
- Used in electronics assembly

SCARA(Selectively Compliant Assembly Robot Arm)

Industrial Robotics

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Configurations	Advantages	Disadvantages
Cartesian coordinates	3 linear axes, easy to visualize,rigid structure ,easy programming	Can only reach front of itself, requirse long room space.
Cylindrical coordinates	2 linear axes +1 rotating can reach all around itself ,reach and height axes rigid ,rotational axis easy to seal	Can't reach above itself, base rotation axis as less rigid, linear axis is hard to seal.
SCARA coordinates	1 linear + 2 rotational axes is rigid, large work space area for floor space	2 ways to reach point ,difficult to program offline, highly complex arm
Spherical coordinates	1 linear + 2 rotational axes , long horizontal reach	Can't reach around obstacles .short vertical length
Revolve coordinates	3 rotational axes can reach above or below obstacles.	Difficult to program off-line , most complex manipulator

Industrial Robotics

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❑Robot Specifications

Important parameters used to describe robot performance:

- **Degrees of Freedom (DOF)** → Number of independent movements
- **Payload Capacity** → Maximum load robot can carry
- **Reach** → Maximum working distance
- **Accuracy** → Closeness to desired position
- **Repeatability** → Ability to return to same position
- **Speed** → Movement rate
- **Resolution** → Smallest movement increment

Typical Specification of Robot

Model Puma - 550

Payload - **3**Kg

Reach - 750 mm

Configuration – Revolute

Degree of Freedom - 6(3linear, 3rotational)

Accuracy - +/- 0.1mm

Precision(Repeatability) - +/- 0.1mm

Actuator – Electric

End Effector - Linkage actuated mechanical gripper

Controller – Electronic Sequencer

Sensor – Force Sensor

Programming – Leadthrough

Application – Pick and place

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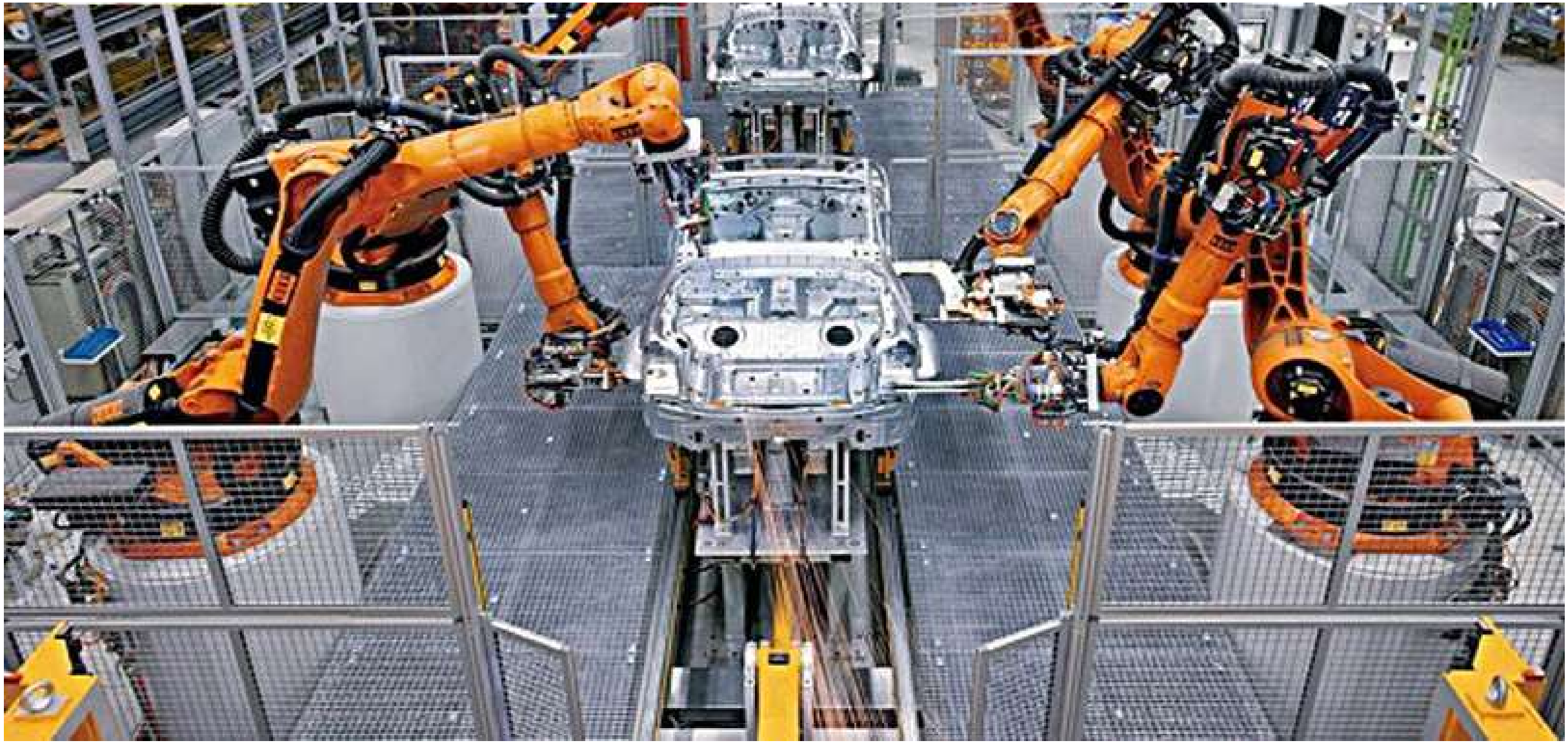
Industrial Robotics

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Industrial Robotics

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Industrial Robotics

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Industrial Robotics

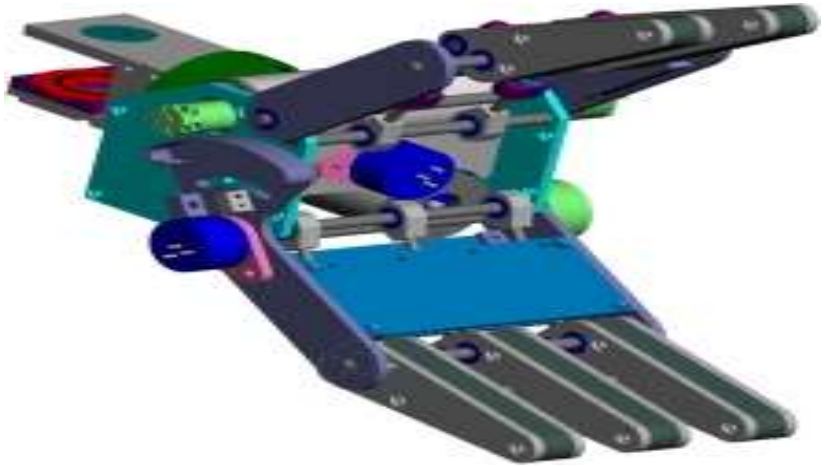
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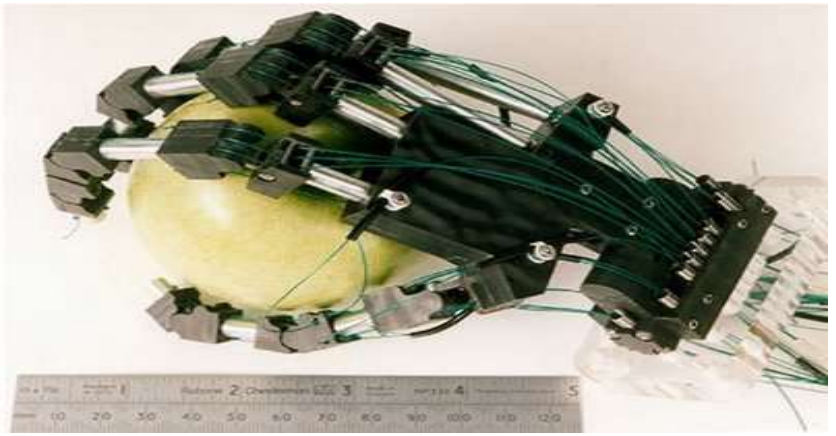
- **Grippers-** It is define as a device which is attached to robot wrist to perform specific task.
  - Mechanical (finger type)
  - Vacuum grippers
  - Magnetic grippers
- **Tools (Process End Effectors)**
  - Welding torch
  - Spray gun
  - Cutting tool
- ☞ Selection depends on:
- Shape of object
- Weight
- Material
- Task requirement

Industrial Robotics

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- **Grippers-**









Industrial Robotics

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❑Sensors in Robotics

Sensors provide feedback and intelligence.

Types:

a) Internal Sensors

- Position sensors (encoders)
- Velocity sensors

b) External Sensors

- Proximity sensors
- Vision systems
- Force/Torque sensors
- Tactile sensors

Industrial Robotics

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❑Work Cell Layout

A **robot work cell** includes:

- Robot
- Workstations
- Material handling system
- Safety systems (fencing, sensors)

Types of Layouts:

- **In-line layout** (flow production)
- **Circular layout** (continuous operation)
- **Cellular layout** (flexible manufacturing)

Industrial Robotics

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❑Robot Applications

a) Material Handling

- Pick and place
- Palletizing
- Machine loading/unloading

b) Processing Operations

- Welding (arc, spot)
- Painting
- Cutting, grinding

Industrial Robotics

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❑Robot Applications Cont…

c) Assembly

- Electronic component assembly
- Mechanical assembly
- Fastening operations

d) Inspection

- Vision-based quality control
- Surface defect detection
- Dimensional inspection

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Unit 4

Automated Material Handling Systems

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❑Automated Material Handling Systems (AMHS)

- AMHS are systems that **automatically move, store, control, and protect materials** throughout manufacturing and warehousing processes with minimal human intervention.

❖Objectives

- Reduce labor cost
- Improve efficiency & productivity
- Ensure safety
- Minimize material damage
- Enable continuous production flow

❑Automated Guided Vehicle Systems (AGVS)

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Definition

AGVS consists of **driverless vehicles** used to transport materials along predefined paths using guidance systems.

❖Types of AGVs

Tow Vehicles (Tuggers)

- Pull multiple trailers
- Used in bulk transport

Unit Load Carriers

- Carry individual loads (pallets, containers)

Pallet Trucks

- Handle palletized loads at floor level

Forklift AGVs

- Automated forklifts for stacking and retrieval

Assembly Line Vehicles

- Move products along assembly lines

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❑Analysis of AGVS Systems

Key factors:

- **Vehicle requirement calculation**
- **Flow analysis** (material movement frequency)
- **Travel time estimation**
- **System utilization**
- **Queueing analysis**

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❑Applications of AGVS

- Manufacturing industries
- Warehouses & distribution centers
- Hospitals (medicine delivery)
- Airports (baggage handling)
- Automotive assembly

Conventional Storage Methods

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- **Bulk storage**
- **Rack systems**
- **Shelving and bins**
- **Drawer storage**

Storage Systems

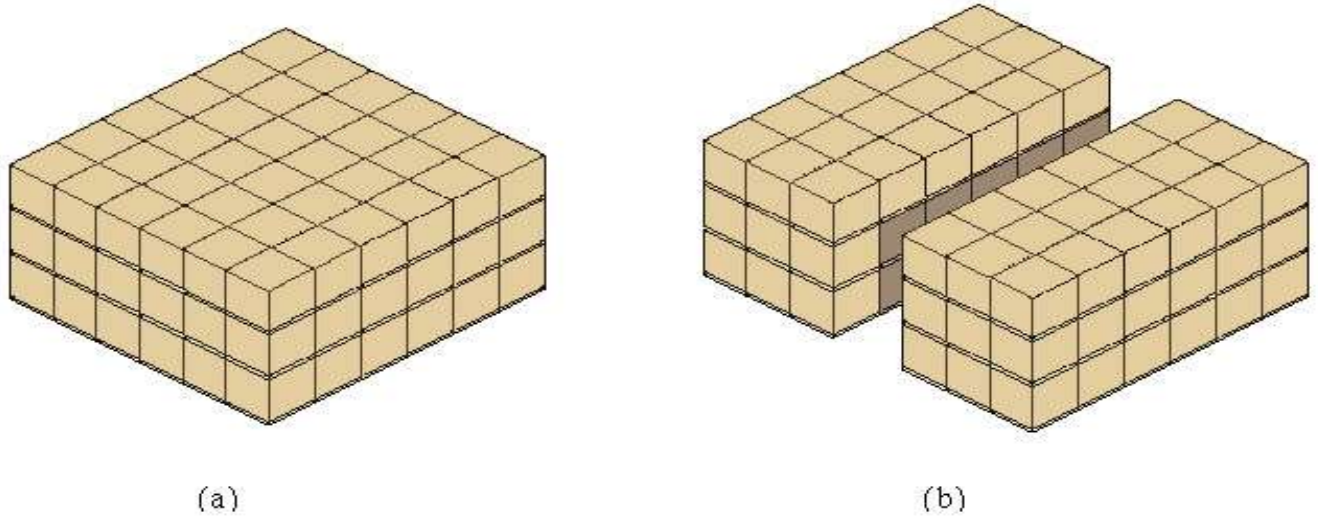
Function – to store materials (e.g., parts, work-in-process, finished goods) for a period of time and permit retrieval when required

- Used in factories, warehouses, distribution centers, wholesale dealerships, and retail stores
- Important supply chain component
- Automation available to improve efficiency

Conventional Storage Methods

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- **Bulk storage** – storage in an open floor area
  - Problem: achieving proper balance between storage density and accessibility



(a) (b)

- Bulk storage arrangements:

(a) high-density bulk storage provides low accessibility,

(b) bulk storage with loads forming rows and blocks for improved accessibility

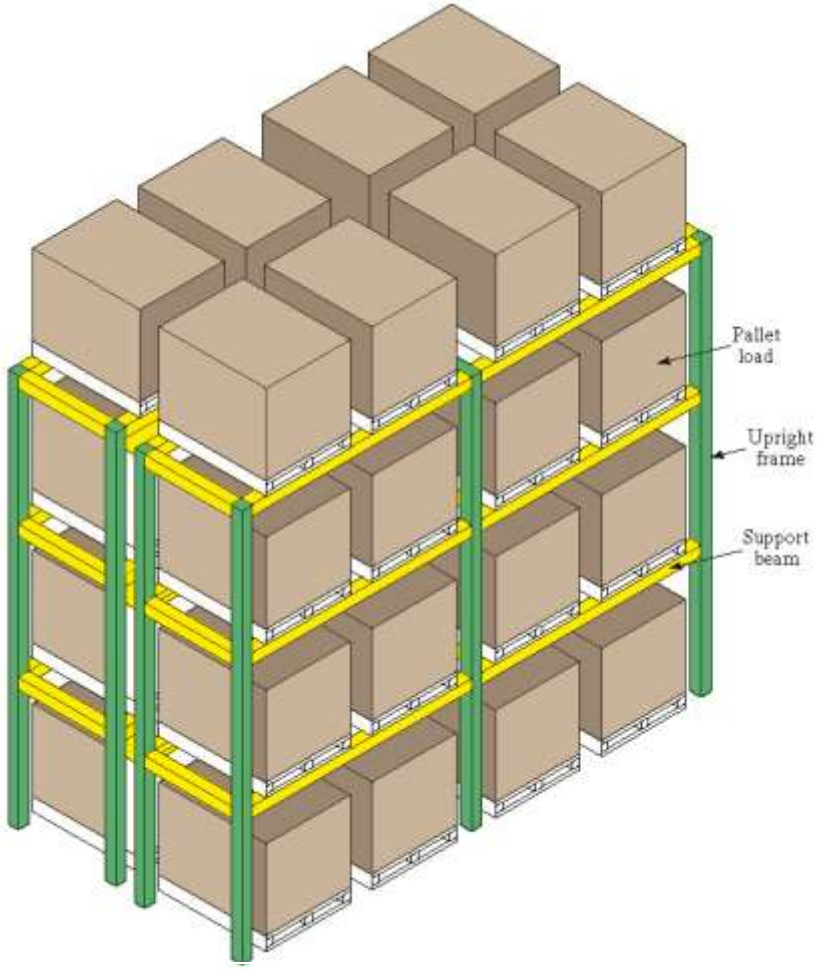
(c) Low cost per sq meter

•

Conventional Storage Methods

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- **Rack systems** –
- structure with racks for pallet loads
  - Permits vertical stacking of materials



Pallet loads placed on racks in multi-rack structure

(a) Low cost

(b) Good stroge density

(c) Good accessibility

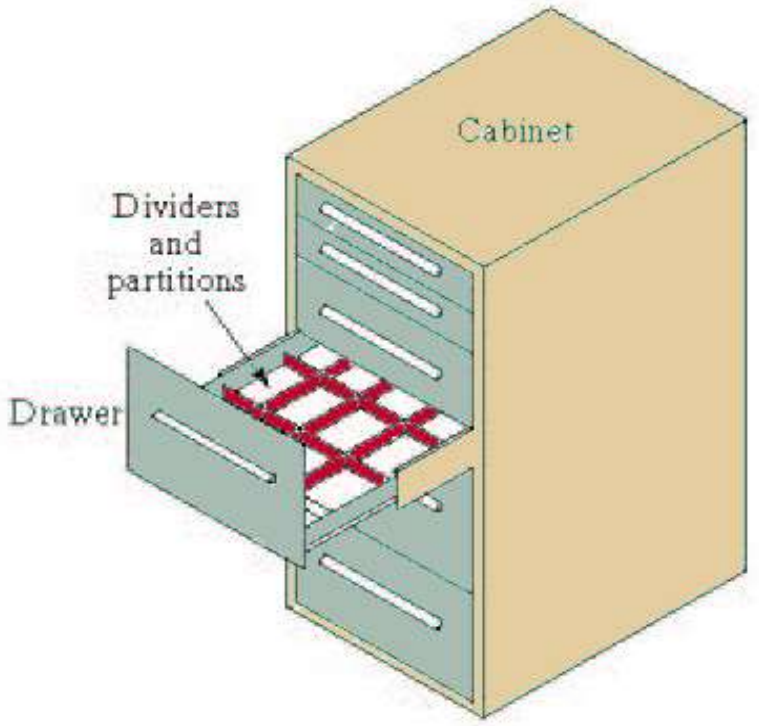
Conventional Storage Methods

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- **Drawer storage** –
- Entire contents of each drawer can be viewed

  - Contents easily visible
  - Good accessibility
  - Relatively high cost

  Small items (tools, repair parts, etc.)



Automated Storage Systems

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Mechanized and automated storage equipment to reduce the human resources required to operate a storage facility

- Significant investment
- Level of automation varies
  - In mechanized systems, an operator participates in each storage/retrieval transaction
  - In highly automated systems, loads are entered or retrieved under computer control

Objectives and Reasons for Automating Storage Operations

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- To increase storage capacity
- To increase storage density
- To recover factory floor space currently used for WIP
- To improve security and reduce pilferage
- To reduce labor cost and/or increase productivity
- To improve safety
- To improve inventory control
- To improve stock rotation
- To improve customer service

Types of Automated Storage System

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1. Automated Storage/Retrieval System (AS/RS)

- Rack system with mechanized or automated crane to store/retrieve loads

2. Carousel Storage System

- Oval conveyor system with bins to contain individual items

AS/RS COMPONENTS AND TERMINOLOGY

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- An AS/RS consists of one or more storage aisles that are serviced a storage/retrieval (S/R) machine.
- The stored materials are held by storage racks of aisles.
- The S/R machines are used to deliver and retrieve materials in and out of inventory.
- There are one or more input/output stations in each AS/RS aisle for delivering the material into the storage system or moving it out of the system.
- In AS/RS terminology, the input/output stations are called pickup-and-deposit (P&D) stations.

AS/RS COMPONENTS AND TERMINOLOGY

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- **Storage Space**
- It is the three-dimensional space in the storage racks used to store a single load unit of material.
- **Storage Racks**
- This structural entity comprises storage locations, bays and rows.
- **Bay/Rack Height**
- It is the height of the storage rack from floor to the ceiling.
- **Row**
- It is a series of bays placed side by side.
- **Aisle**
- It is the spacing between two rows for the machine operations of AS/RS.
- **Aisle Unit**
- It encompasses aisle space and racks adjacent to an aisle.

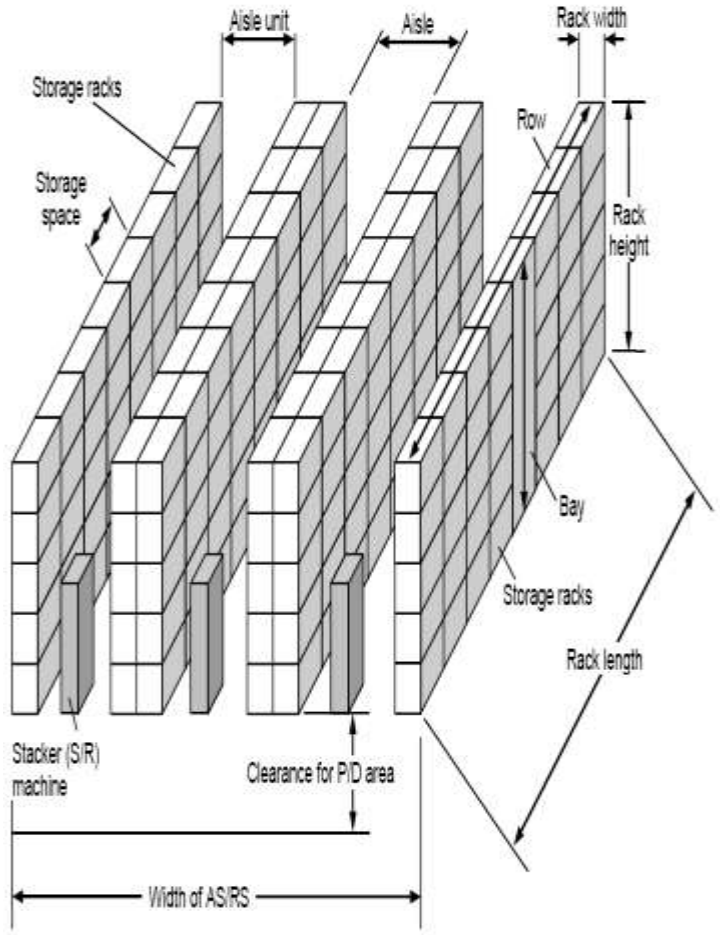


Figure 4.1 : Generic Structure of as AS/RS

AS/RS COMPONENTS AND TERMINOLOGY

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- **Storage Structure**
- It is the rack framework, made of fabricated steel that supports the loads contained in the AS/RS and is used to store inventory items.
- **Storage/Retrieval Machine**
- It is used to move items in and out of inventory. An S/R machine is capable of both horizontal and vertical movement. A rail system along the floor guides the machine and a parallel rail at the top of the storage structure is used to maintain its alignment.
- **Storage Modules**
- These are the unit load containers used to hold the inventory items. These include pallets, steel wire baskets and containers, pans and special drawers. These modules are generally made to a standard base size capable of being stored in the structure and moved by the S/R machines.
- **Pickup and Deposit (P/D) Stations**
- P/D stations are where inventory are transferred into and out of the AS/RS.

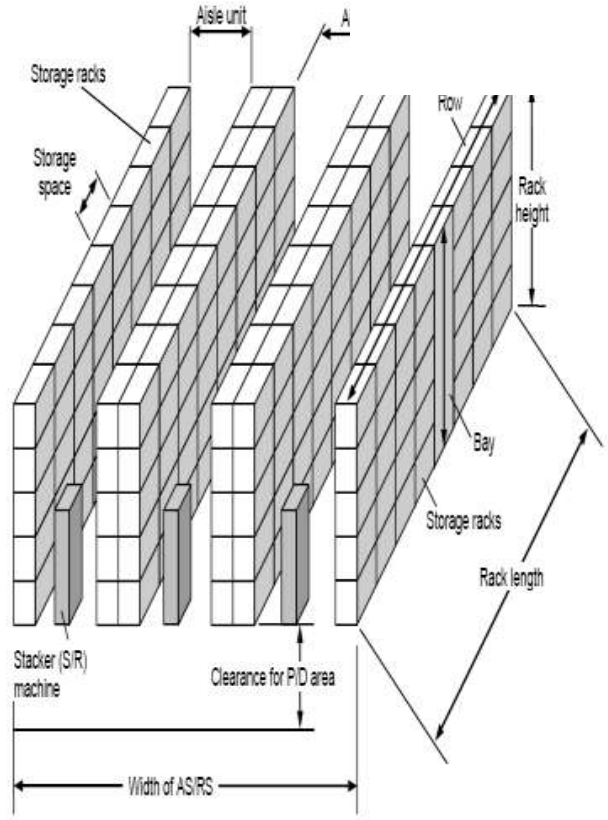


Figure 4.1 : Generic Structure of as AS/RS

AS/RS Types

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- **Unit load AS/RS** - large automated system for pallet loads
- **Deep-lane AS/RS** - uses flow-through racks and fewer access aisles
- **Miniload AS/RS** - handles small loads contained in bins or drawers to perform order picking
- **Man-on-board AS/RS** - human operator rides on the carriage to pick individual items from storage
- **Automated item retrieval system** - picks individual items
- **Vertical lift storage modules (VLSM)** - uses a vertical aisle rather than a horizontal aisle as in other AS/RS types

AS/RS Applications

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1. Unit load storage and retrieval
   - Warehousing and distribution operations
   - AS/RS types: unit load, deep lane (food industry)
2. Order picking
   - AS/RS types: miniload, man-on-board, item retrieval
3. Work-in-process storage
   - Helps to manage WIP in factory operations
   - Buffer storage between operations with different production rates
   - Supports JIT manufacturing strategy
   - Kitting of parts for assembly

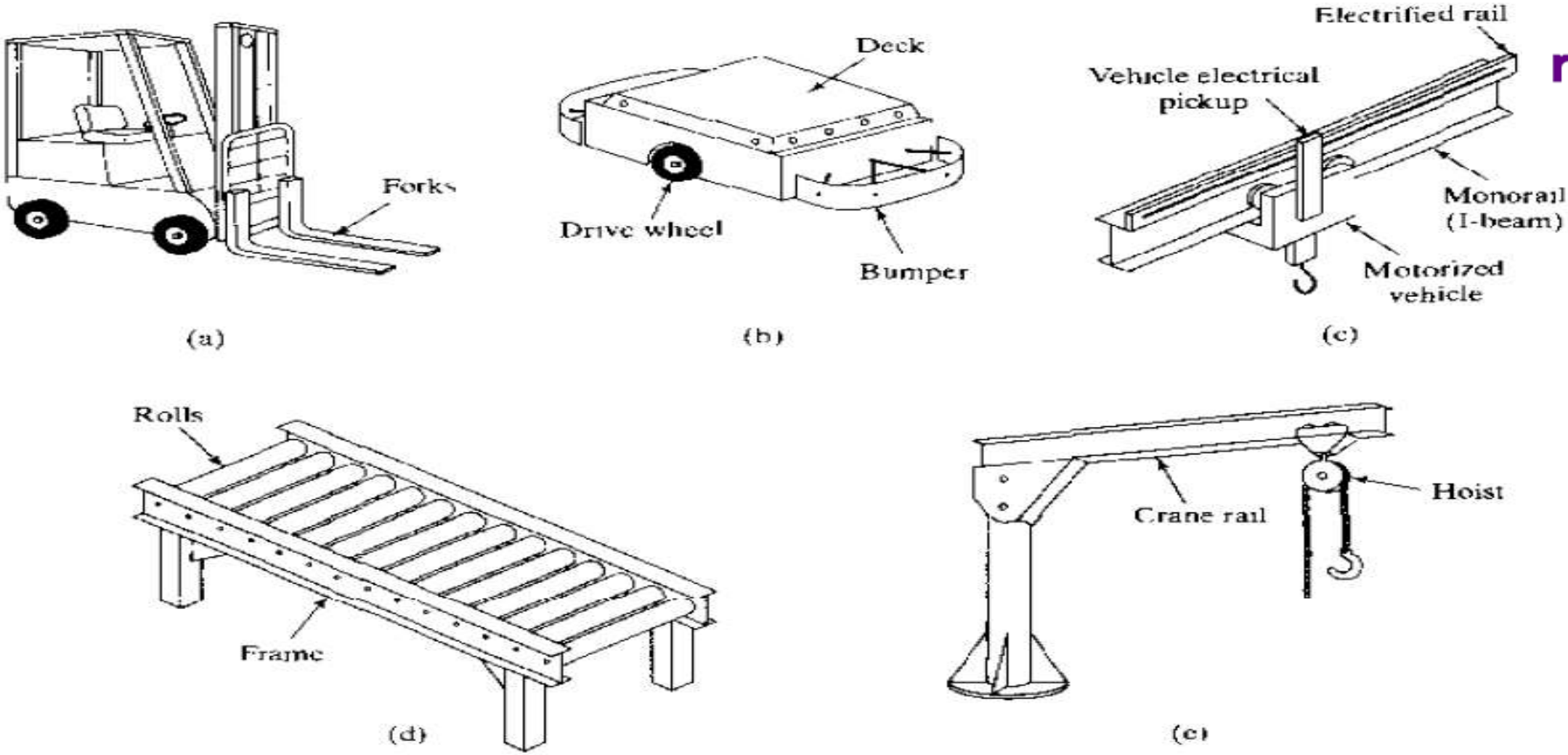


Figure 9.2 Examples of the five basic types of material handling equipment: (a) fork lift truck, industrial truck, (b) unit load automated guided vehicle, (c) monorail, (d) roller conveyor, and (e) jib crane with hoist.

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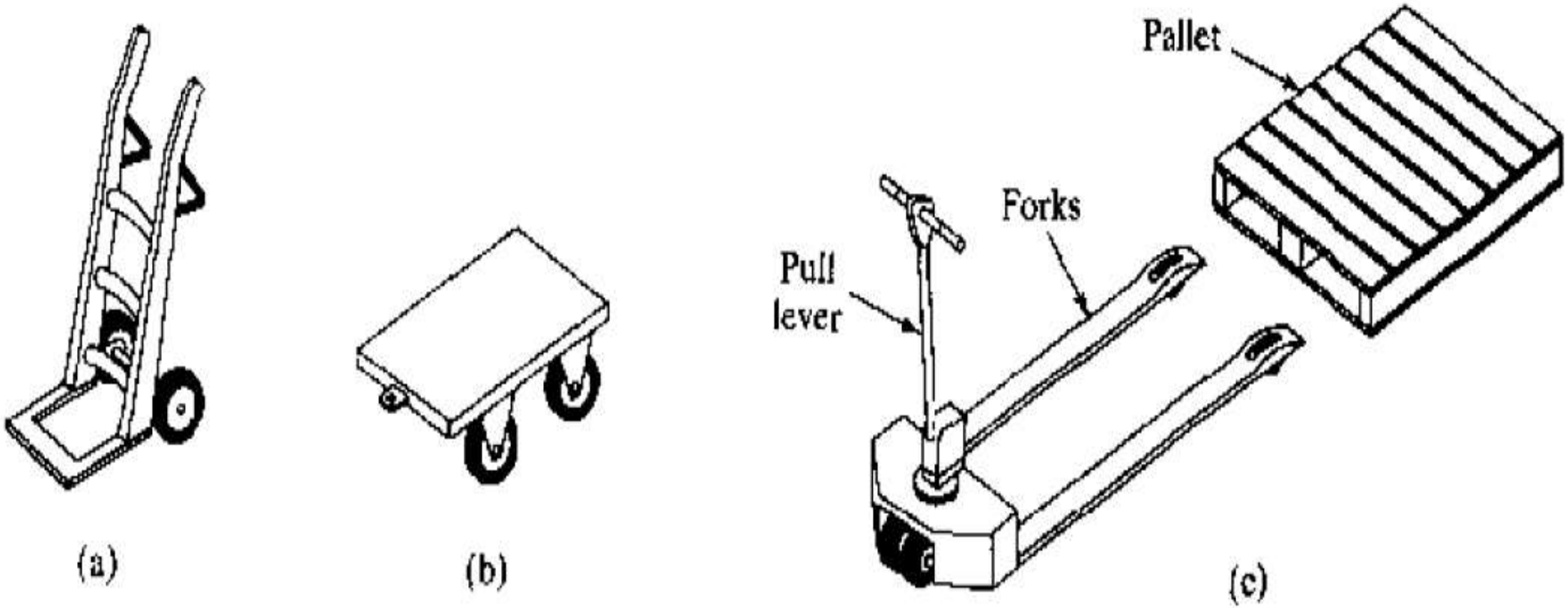


Figure 10.1 Examples of non-powered industrial trucks (hand trucks): (a) two-wheel hand truck, (b) four-wheel dolly, and (c) hand-operated low-lift pallet truck.

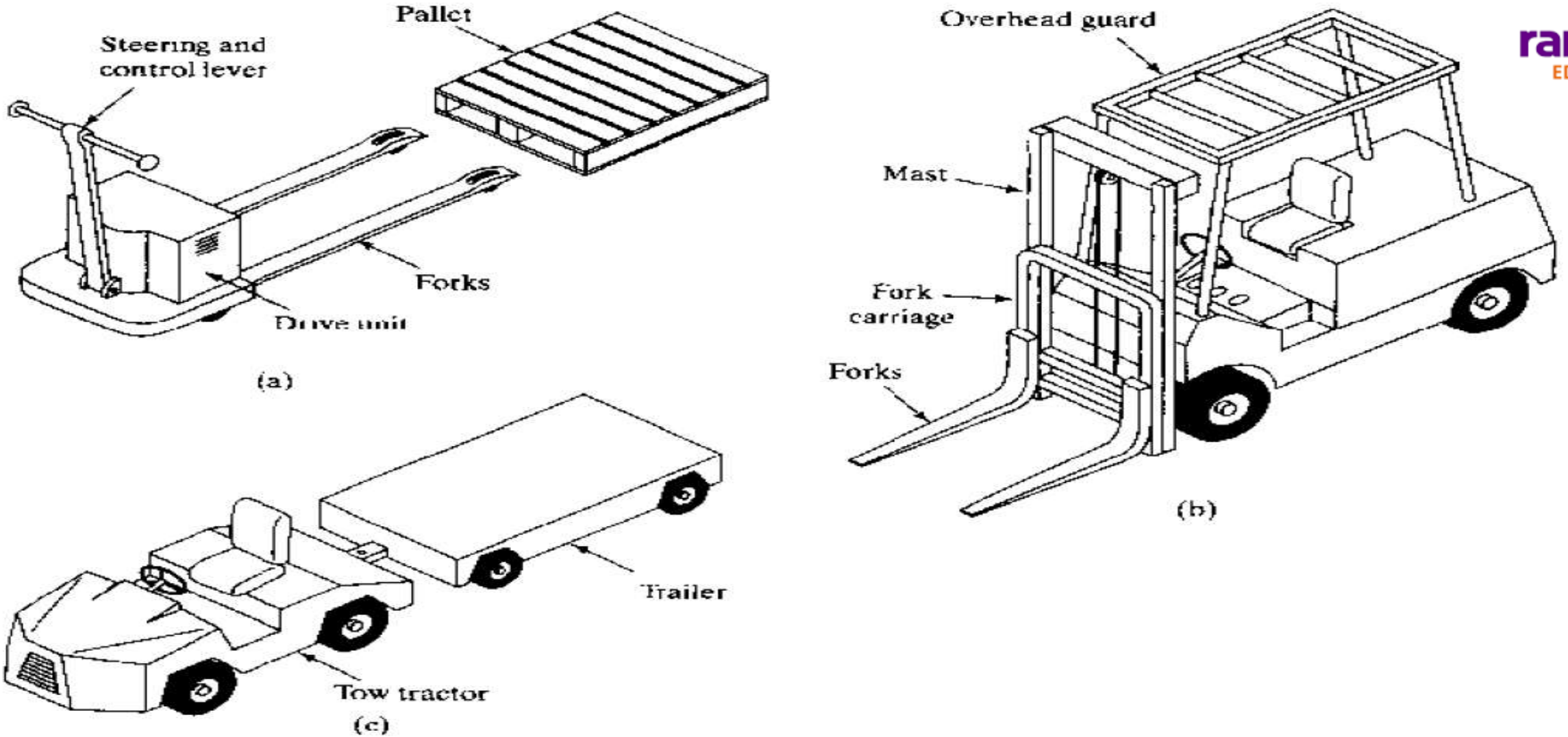


Figure 10.2 Three principal types of powered trucks: (a) walkie truck, (b) fork lift truck, and (c) towing tractor.

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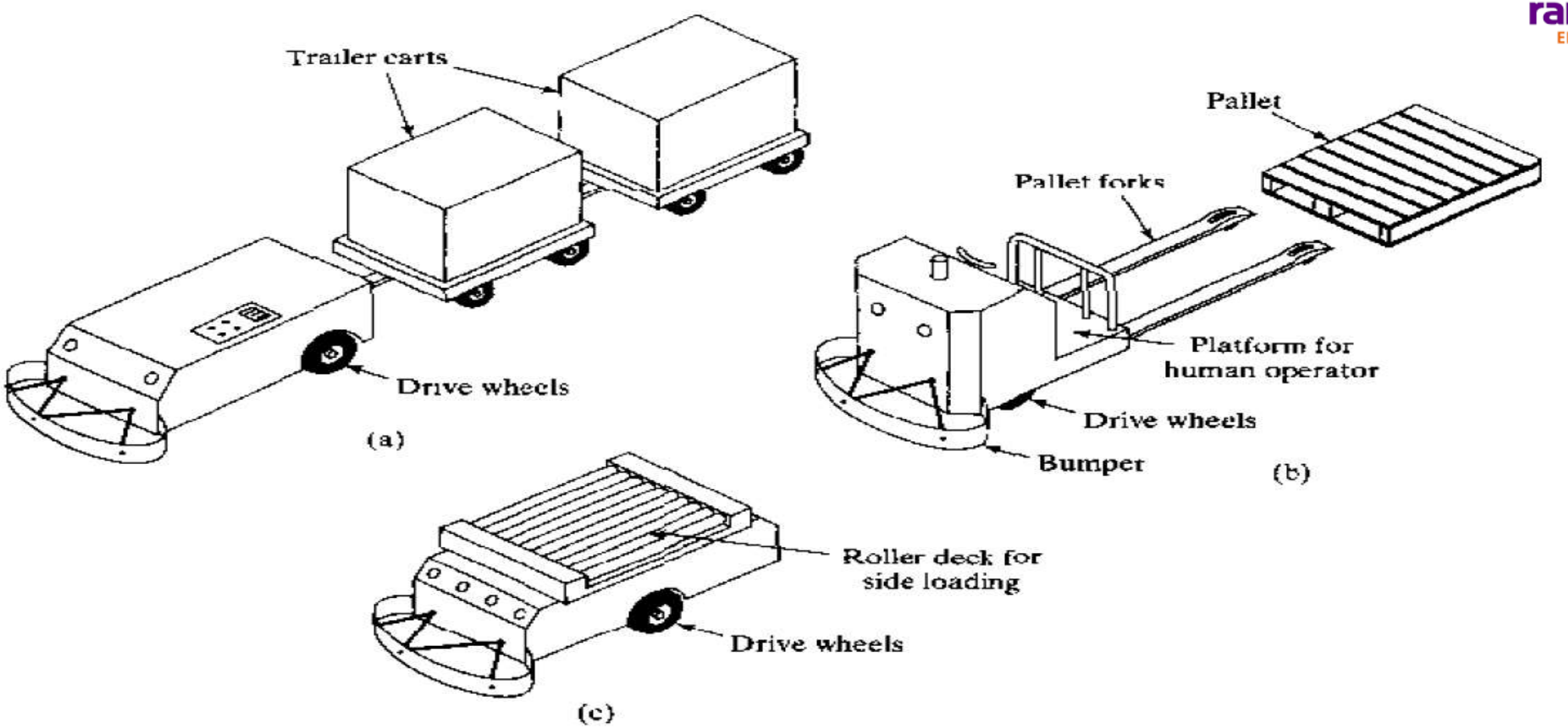


Figure 10.3 Three types of automated guided vehicles: (a) driverless automated guided train, (b) AGV pallet truck, and (c) unit load carrier.

L-25



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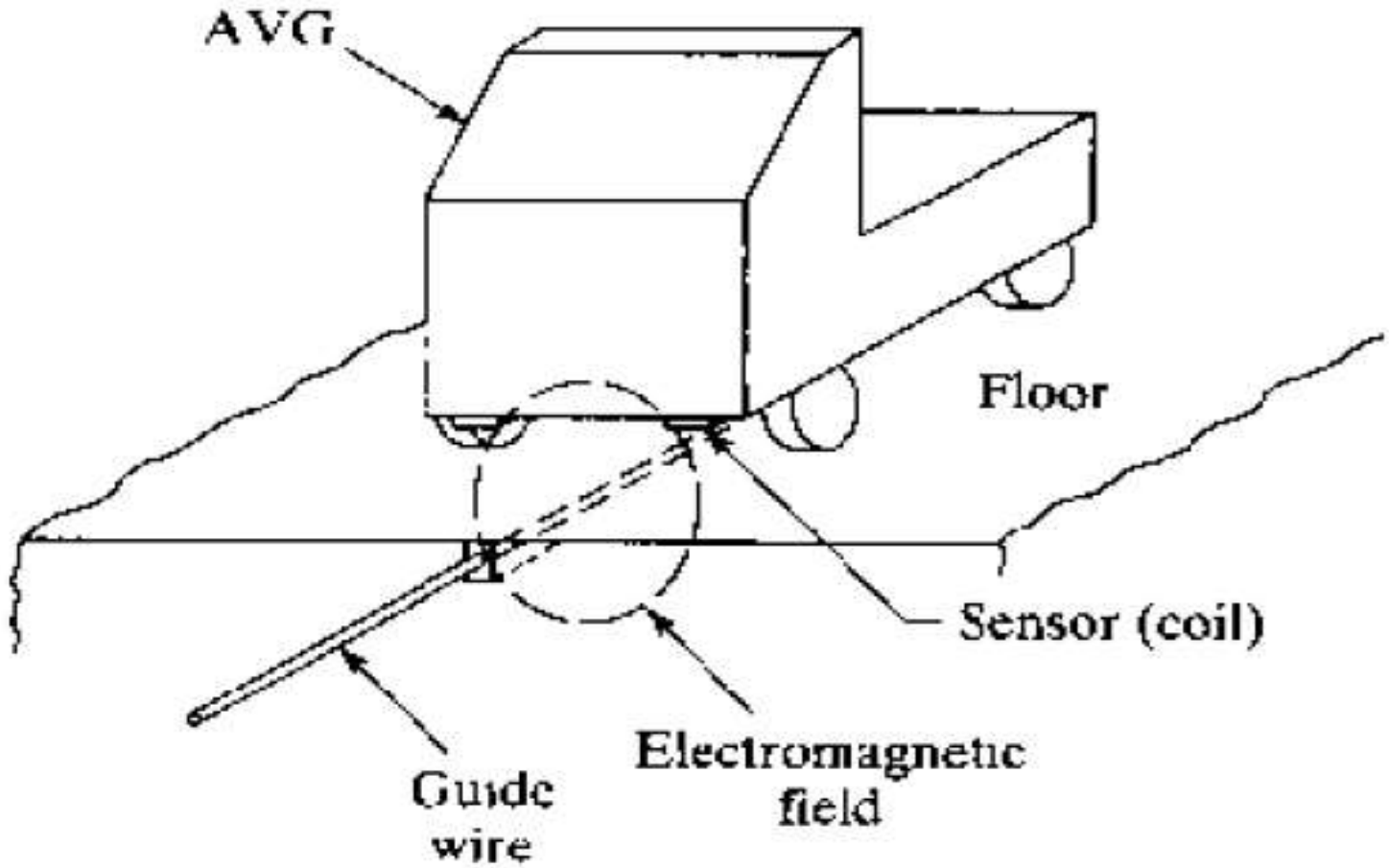


Figure 10.4 Operation of the on-board sensor system that uses two coils to track the magnetic field in the guide wire.

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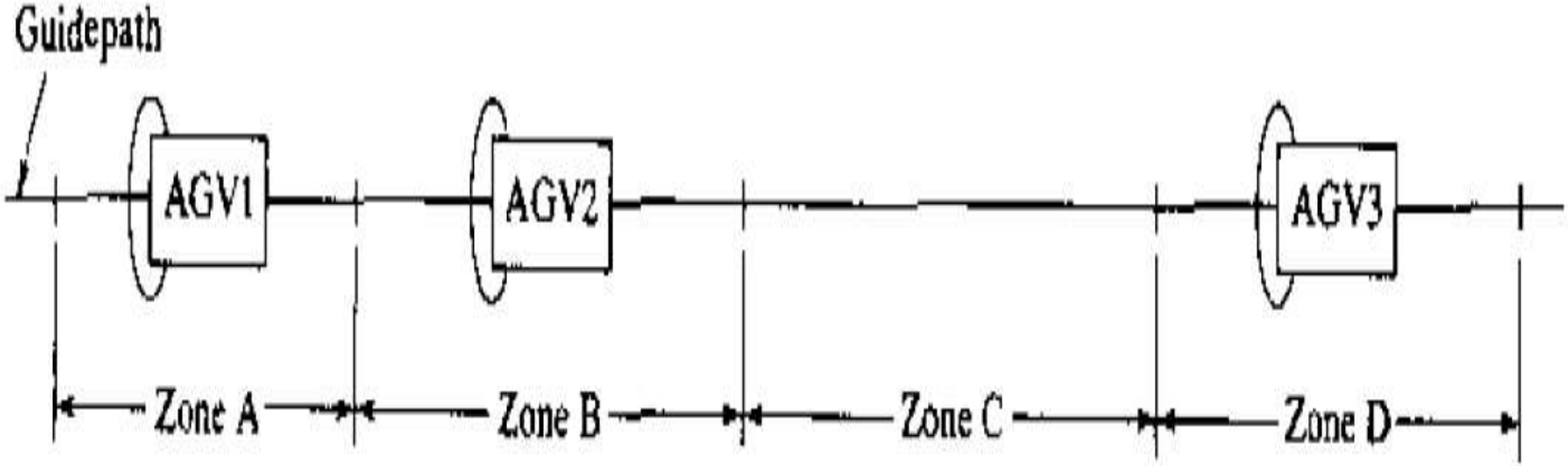


Figure 10.5 Zone control to implement blocking system. Zones A, B, and D are blocked. Zone C is free. Vehicle 2 is blocked from entering Zone A by Vehicle 1. Vehicle 3 is free to enter Zone C.

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Unit 5

Group Technology (GT) & Flexible Manufacturing System (FMS)

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❑GT Philosophy

Definition: Group Technology is a manufacturing philosophy in which **similar parts are identified and grouped into families** to take advantage of their similarities in design and production.

Core idea: *"Similar things should be done similarly."*

Focus: Reduce duplication, improve efficiency, and standardize processes.

GT is most appropriately applied under the following conditions:

- 1)The plant currently uses traditional batch production and a process type layout
- 2)The parts can be grouped into part families.

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❑Benefits of Group technology are

1) GT promotes standardization of tooling, fixturing. and setups.

2) Material handling is reduced because parts are moved within a machine cell rather than within the entire factory.

3) Process planning and production scheduling are simplified

4)Setup times are reduced, resulting in lower manufacturing lead times.

5)Work-in-process is reduced.

6)Worker satisfaction usually improves when workers collaborate in a GT cell.

7)Higher quality work is accomplished using group technology.

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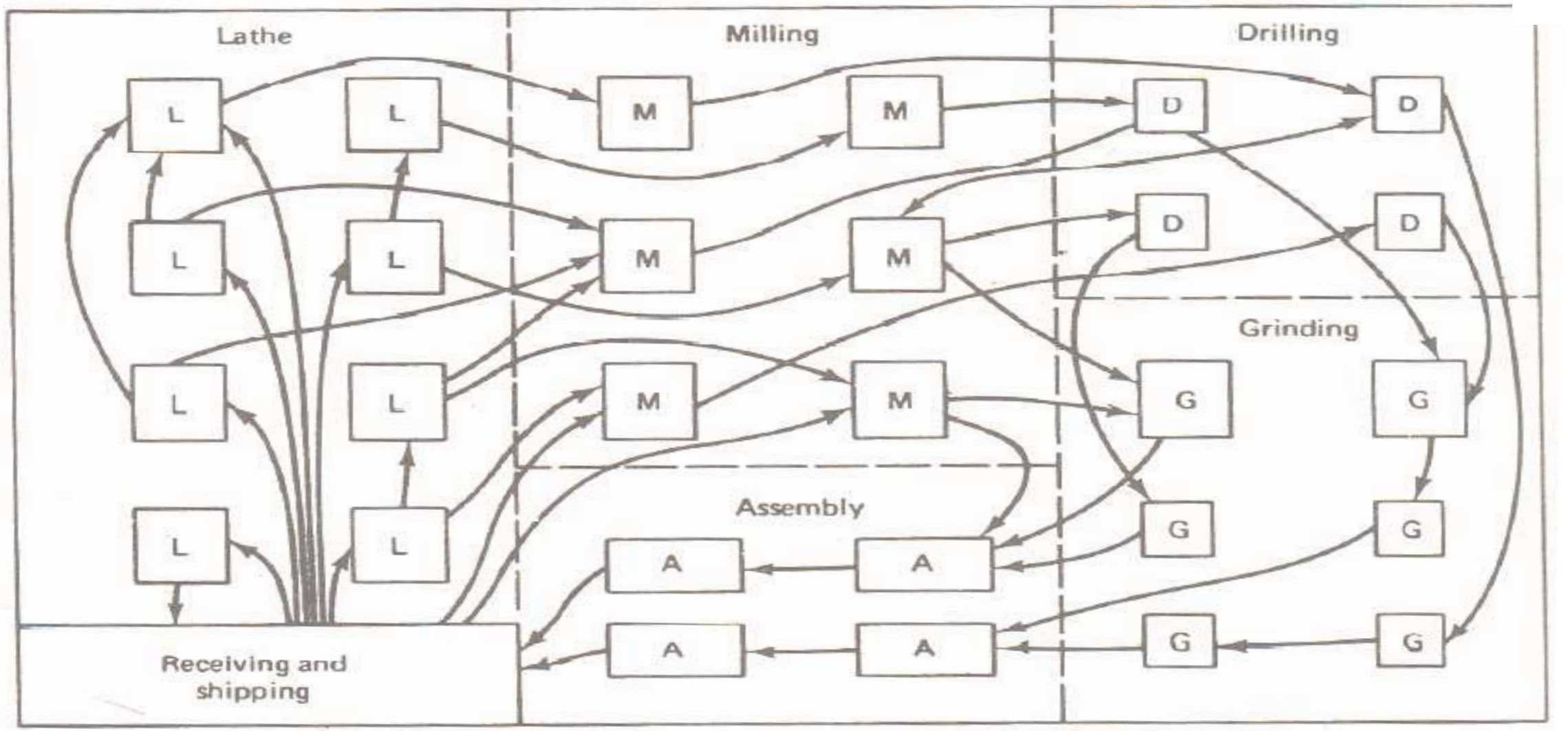


FIGURE 12.3 Process-type layout.

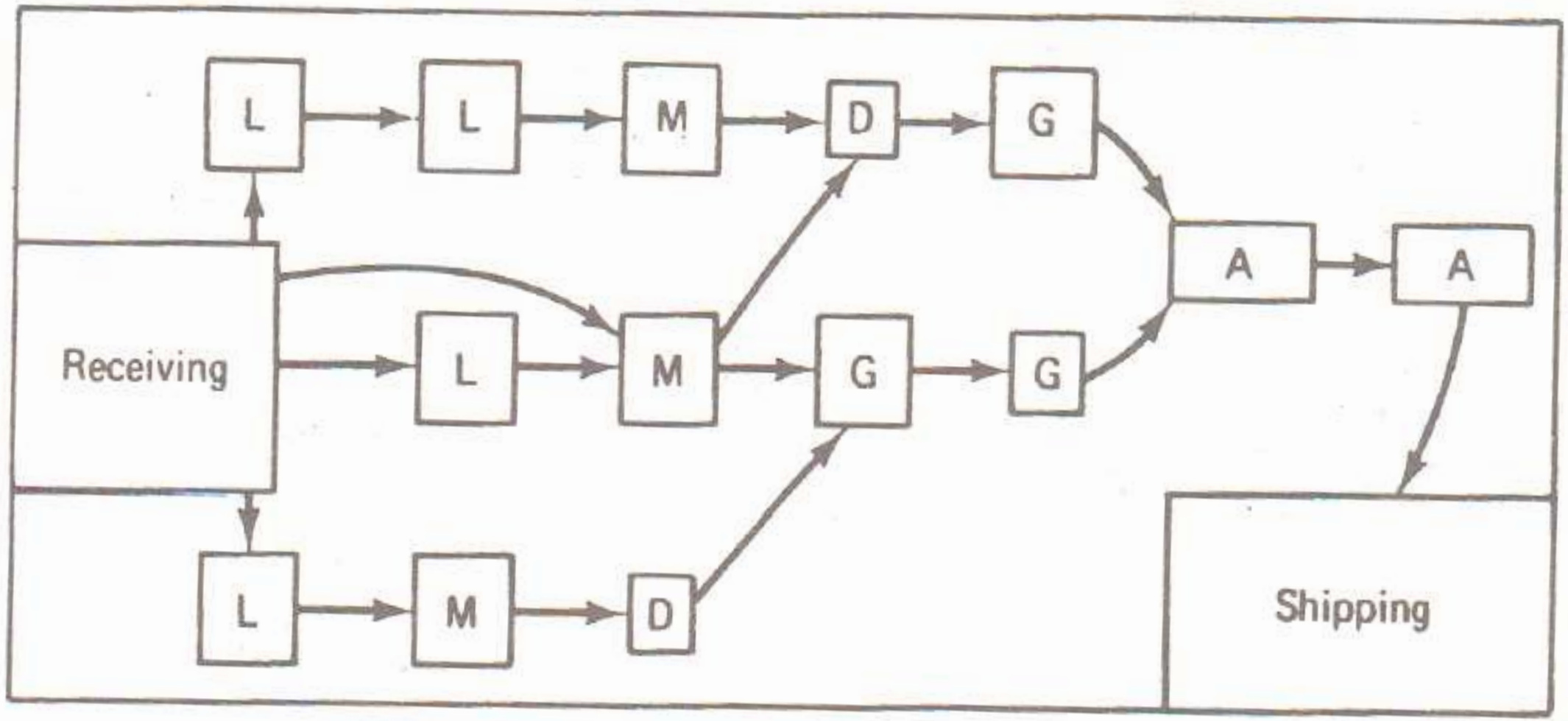


FIGURE 12.4 Group technology layout.

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❑Part Families

A part family is a collection of parts that are similar either because of geometric shape and size or because similar processing steps are required in their manufacture.

A **part family** is a collection of parts having:

- Similar **design features** (shape, size)
- Similar **manufacturing processes**

- Example:
  - Shafts of different lengths but similar operations → same family

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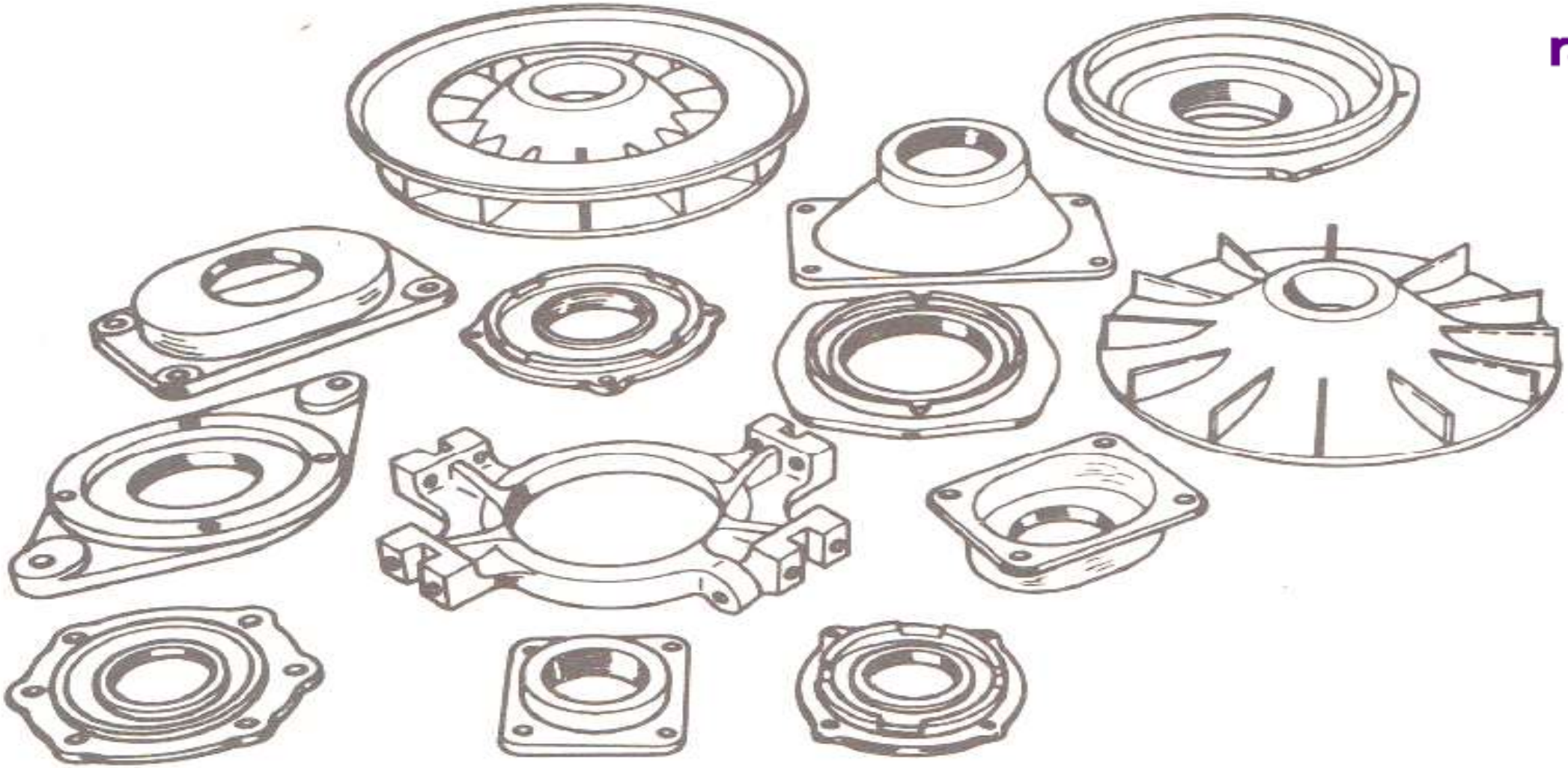
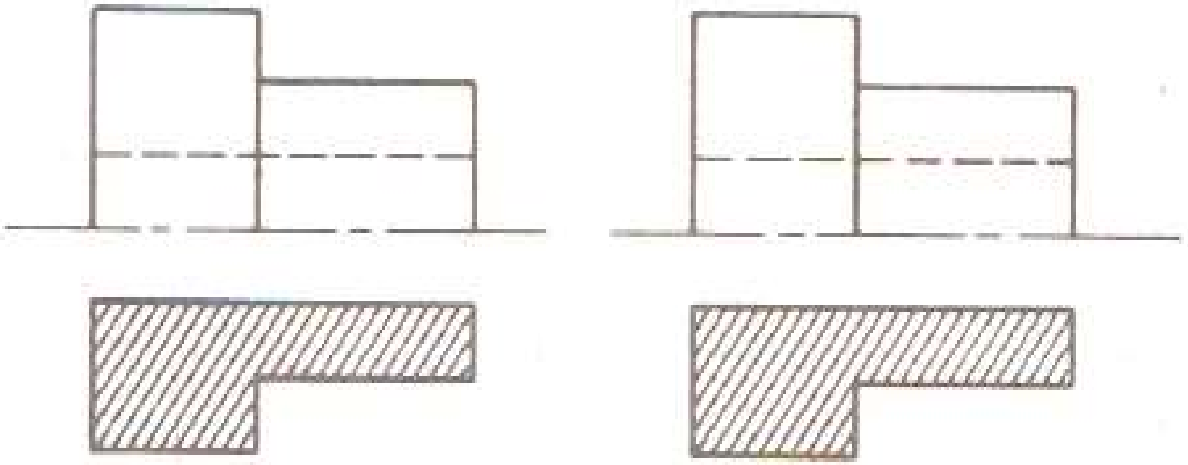


FIGURE 12.2 Thirteen parts with similar manufacturing process requirements but different design attributes.

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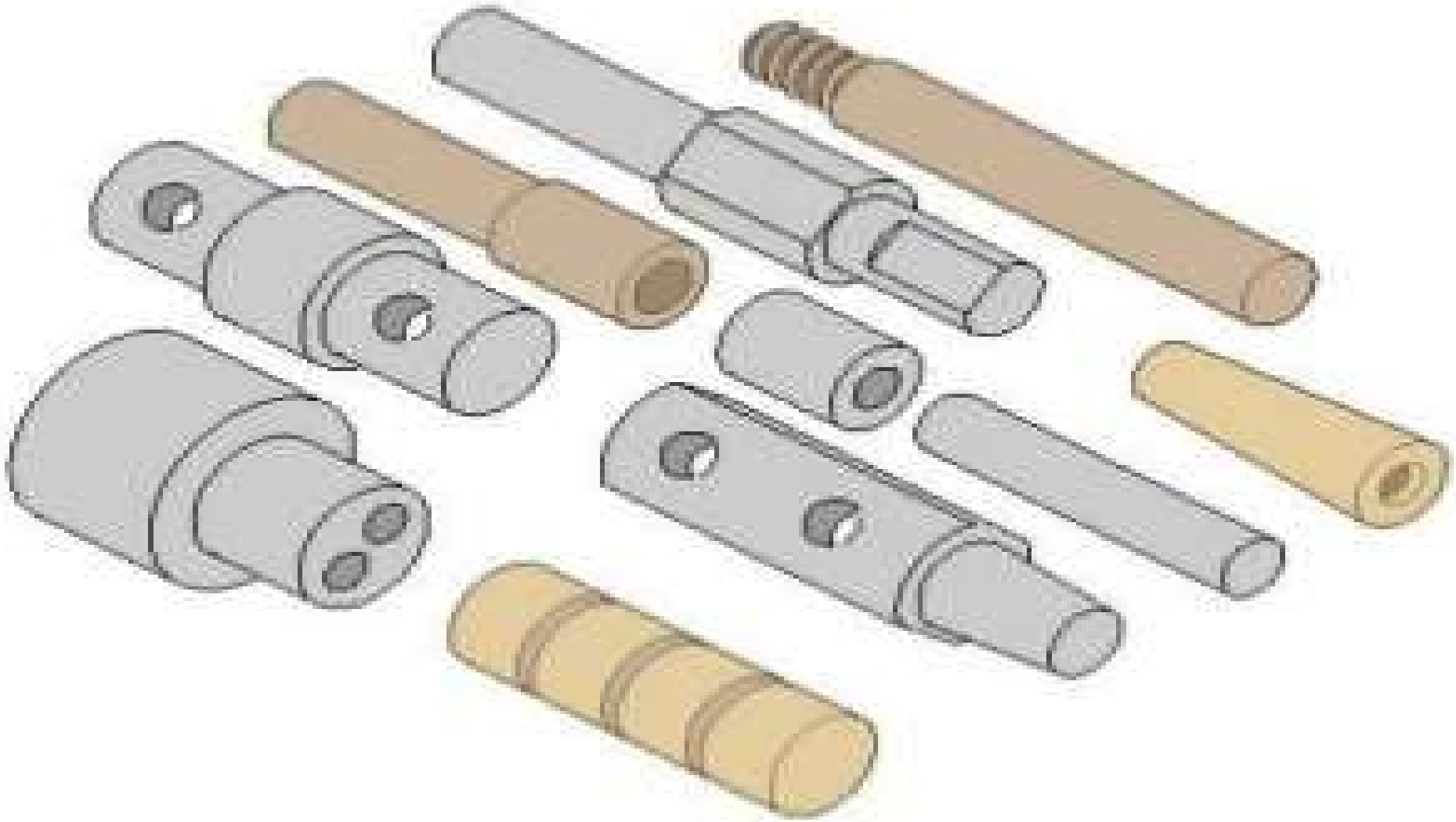


Part 1
100,000/yr
Tolerance ± 0.015
1020 CRS
nickel plate

Part 2
100/yr
Tolerance ± 0.001
18-8 stainless

FIGURE 12.1 Two parts of identical shape and size but different manufacturing requirements.

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FROM TRADITIONAL PRODUCTION SHOP TO GROUP TECHNOLOGY IS USE THREE METHOD

1) Visual Inspection

2) Production Flow Analysis

3) Parts Classification and Coding System

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PARTS CLASSIFICATION AND CODING

In parts classification and coding, system two categories of part similarities can be distinguished

1) Design attributes,

2) Manufacturing attributes

- Used to identify and group similar parts systematically
- Each part is assigned a code representing:
  - Geometry
  - Dimensions
  - Material
  - Manufacturing process

TABLE 15.1 Design and Manufacturing Attributes Typically Included in a Group Technology Classification and Coding System

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Part Design Attributes	*Part Manufacturing Attributes*
Basic external shape	Major processes
Basic internal shape	Minor operations
Rotational or rectangular shape	Operation sequence
Length-to-diameter ratio (rotational parts)	Major dimension
Aspect ratio (rectangular parts)	Surface finish
Material type	Machine tool
Part function	Production cycle time
Major dimensions	Batch size
Minor dimensions	Annual production
Tolerances	Fixtures required
Surface finish	Cutting tools

Parts Classification systems are in three categories

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1)systems based on part design attributes

2)systems based on part manufacturing attributes

3)systems based on both design and manufacturing attributes

There are three structures used in coding system structure

1. Hierarchical structure

2. Chain type structure

3. Mixed-mode structure.

Hierarchical structure:- It is also know as **Monocode**. Successive symbol de on the value of the preceding symbols.

Chain type structure:- It is also know as **Polyocode**. Successive symbol not depends on the value of the preceding symbols

Mixed-mode structure:-It is mixture of Hierarchical structure and Chain type structure.

Part Classification and Coding are two types

1. OPITZ CLASSIFICATION SYSTEM
2. MULTICLASS SYSTEM

1. OPITZ CLASSIFICATION SYSTEM

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12345 6789 ABCD

12345 - Form code - design attribute, machine feature

6789 - Supplementary code - dimension, material, accuracy

ABCD - Secondary code - production operation type, sequence

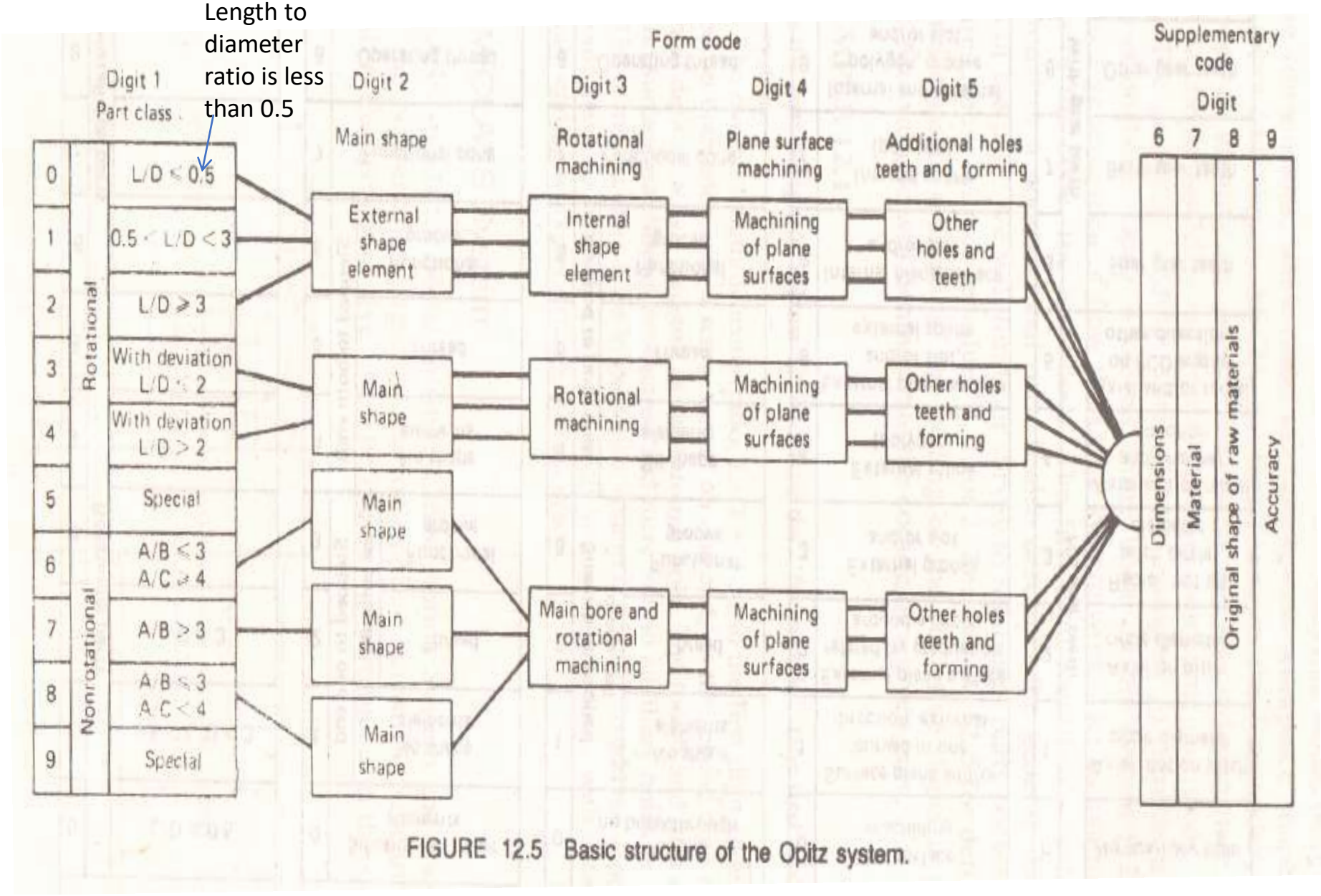


FIGURE 12.5 Basic structure of the Opitz system.

Form code (digits 1-5) for rotational parts in the Opitz coding system

Length-to-diameter ratio is less than 0.5

Digit 1		Part class
0	Rotational parts	L/D ≤ 0.5
1		0.5 < L/D < 3
2		L/D ≥ 3
3		
4		
5		
6	Nonrotational parts	
7		
8		
9		

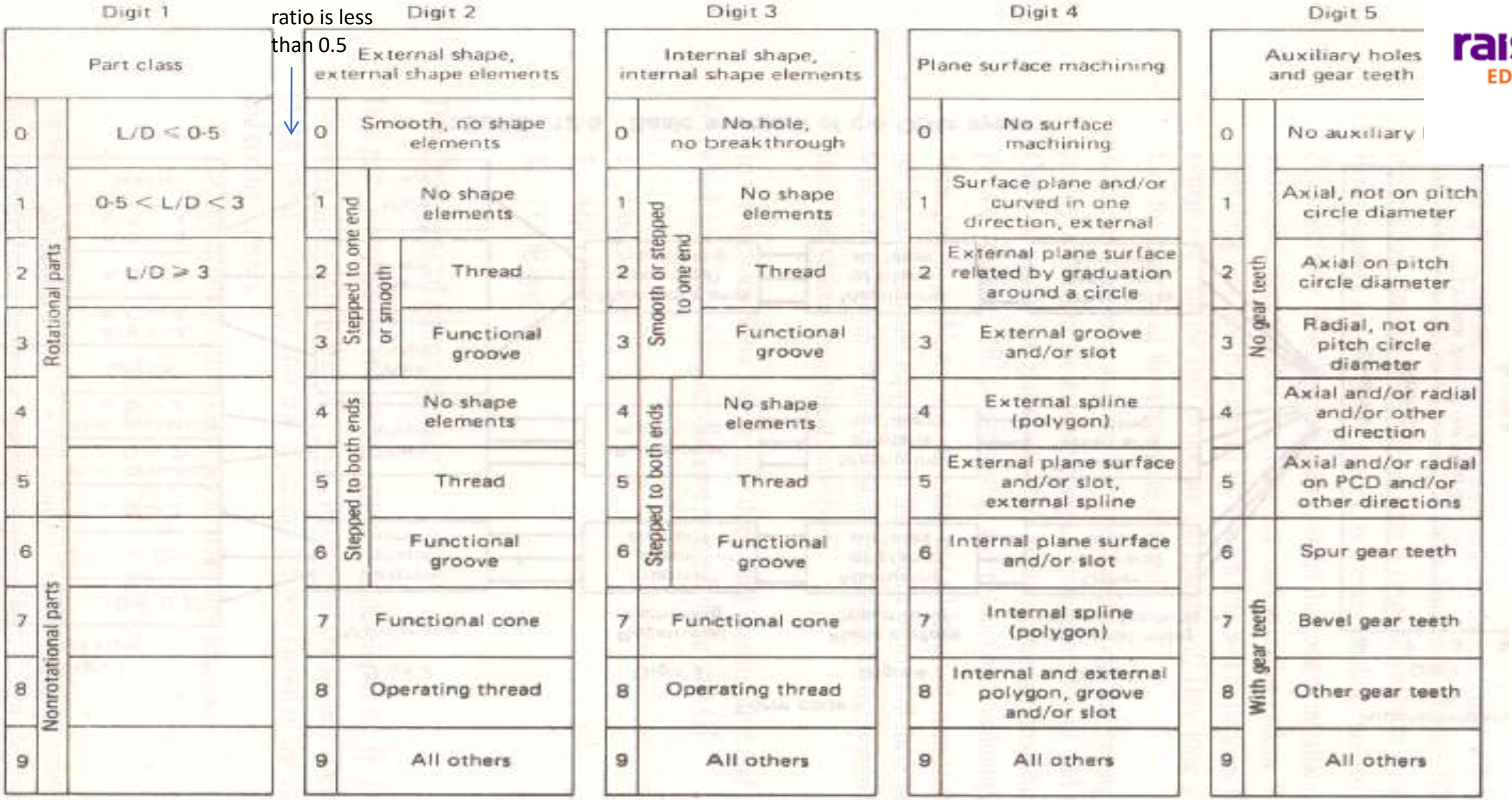
Digit 2		External shape, external shape elements
0		Smooth, no shape elements
1	Stepped to one end or smooth	No shape elements
2		Thread
3		Functional groove
4	Stepped to both ends	No shape elements
5		Thread
6		Functional groove
7		Functional cone
8		Operating thread
9		All others

Digit 3		Internal shape, internal shape elements
0		No hole, no breakthrough
1	Smooth or stepped to one end	No shape elements
2		Thread
3		Functional groove
4	Stepped to both ends	No shape elements
5		Thread
6		Functional groove
7		Functional cone
8		Operating thread
9		All others

Digit 4	Plane surface machining
0	No surface machining
1	Surface plane and/or curved in one direction, external
2	External plane surface related by graduation around the circle
3	External groove and/or slot
4	External spline (polygon)
5	External plane surface and/or slot, external spline
6	Internal plane surface and/or slot
7	Internal spline (polygon)
8	Internal and external polygon, groove and/or slot
9	All others

Digit 5		Auxiliary hole and gear teeth
0	No gear teeth	No auxiliary hole
1		Axial, not on pitch circle diameter
2		Axial on pitch circle diameter
3		Radial, not on pitch circle diameter
4		Axial and/or radial and/or other direction
5		Axial and/or radial on PCD and/or other directions
6	With gear teeth	Spur gear teeth
7		Bevel gear teeth
8		Other gear teeth
9		All others

Length to diameter ratio is less than 0.5



Digit 1		Part class
0	Rotational parts	L/D < 0·5
1		0·5 < L/D < 3
2		L/D ≥ 3
3		
4		
5		
6	Nonrotational parts	
7		
8		
9		

Digit 2			External shape, external shape elements
0			Smooth, no shape elements
1	Stepped to one end or smooth		No shape elements
2			Thread
3			Functional groove
4	Stepped to both ends		No shape elements
5			Thread
6			Functional groove
7			Functional cone
8			Operating thread
9			All others

Digit 3			Internal shape, internal shape elements
0			No hole, no breakthrough
1	Smooth or stepped to one end		No shape elements
2			Thread
3			Functional groove
4	Stepped to both ends		No shape elements
5			Thread
6			Functional groove
7			Functional cone
8			Operating thread
9			All others

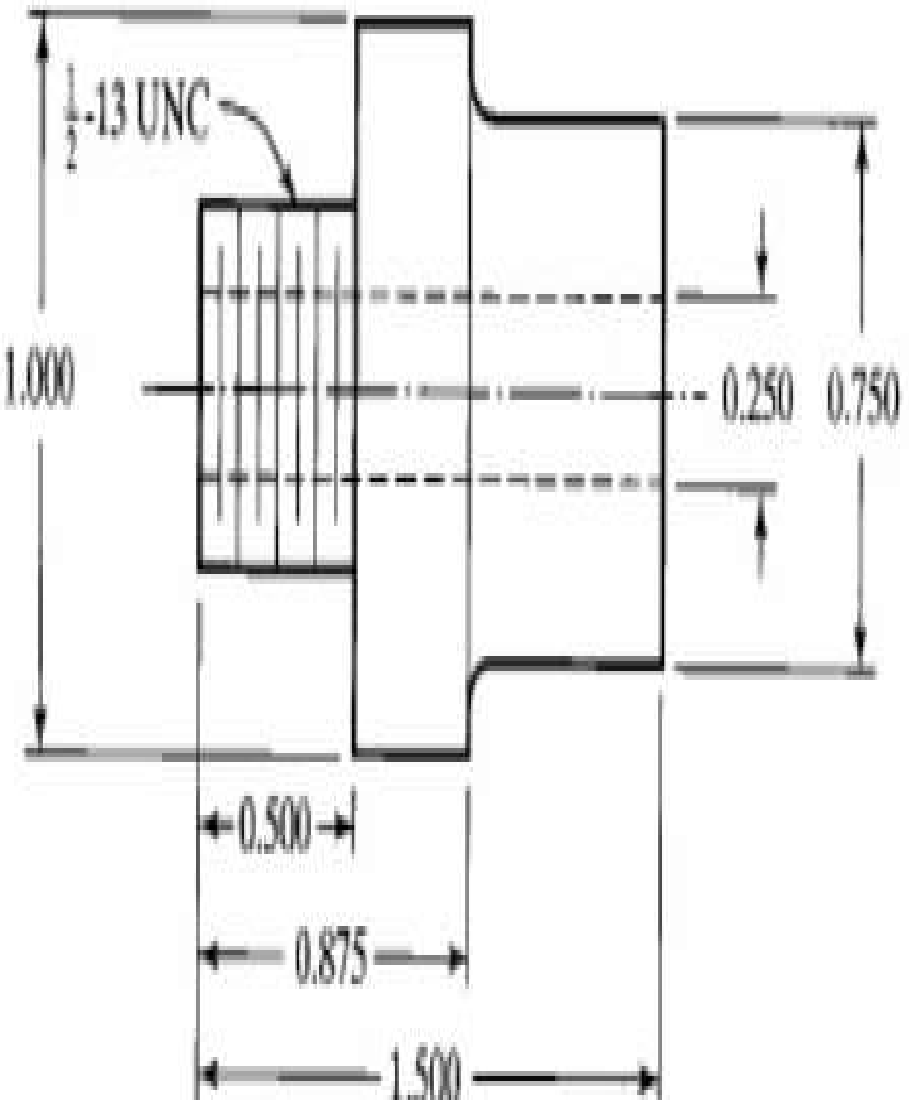
Digit 4		Plane surface machining
0		No surface machining
1		Surface plane and/or curved in one direction, external
2		External plane surface related by graduation around a circle
3		External groove and/or slot
4		External spline (polygon)
5		External plane surface and/or slot, external spline
6		Internal plane surface and/or slot
7		Internal spline (polygon)
8		Internal and external polygon, groove and/or slot
9		All others

Digit 5			Auxiliary holes and gear teeth
0	No gear teeth		No auxiliary
1			Axial, not on pitch circle diameter
2			Axial on pitch circle diameter
3			Radial, not on pitch circle diameter
4			Axial and/or radial and/or other direction
5			Axial and/or radial on PCD and/or other directions
6	With gear teeth		Spur gear teeth
7			Bevel gear teeth
8			Other gear teeth
9			All others

FIGURE 12.6 Form code (digits 1 through 5) for rotational parts in the Opitz system.

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L-27 OPITZ CLASSIFICATION SYSTEM



Length to diameter ratio, L/D=1.5/1 =1.5
Digit 1 = 1

External shape –stepped on both ends with screw thread on one end, thread
Digit 2 = 5

Internal shape – part contains a through Hole
Digit 3 = 1

Plane surface machining - none **Digit 4 = 0**

Auxiliary holes, gear teeth - none **Digit 5 = 0**

The Form Code in the Opitz system is **15100**

MULTI CLASS SYSTEM

Multiclass is a classification & coding system developed by the Organizatıon for Industrial Research

It is relatively flexible

It is used for different variety manufactured items including machined and sheet metal parts, tooling, electronics, purchased parts, assemblies and subassemblies, machine tools, and other elements.

2. MULTI CLASS SYSTEM

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TABLE 15.2 First 18 digits of the Multiclass Classification and Coding System

Digit	*Function*
0	Code system prefix
1	Main shape category
2, 3	External and internal configuration
4	Machined secondary elements
5, 6	Functional descriptors
7–12	Dimensional data (length, diameter, etc.)
13	Toferances
14, 15	Material chemistry
16	Raw material shape
17	Production quantity
18	Machined element orientation

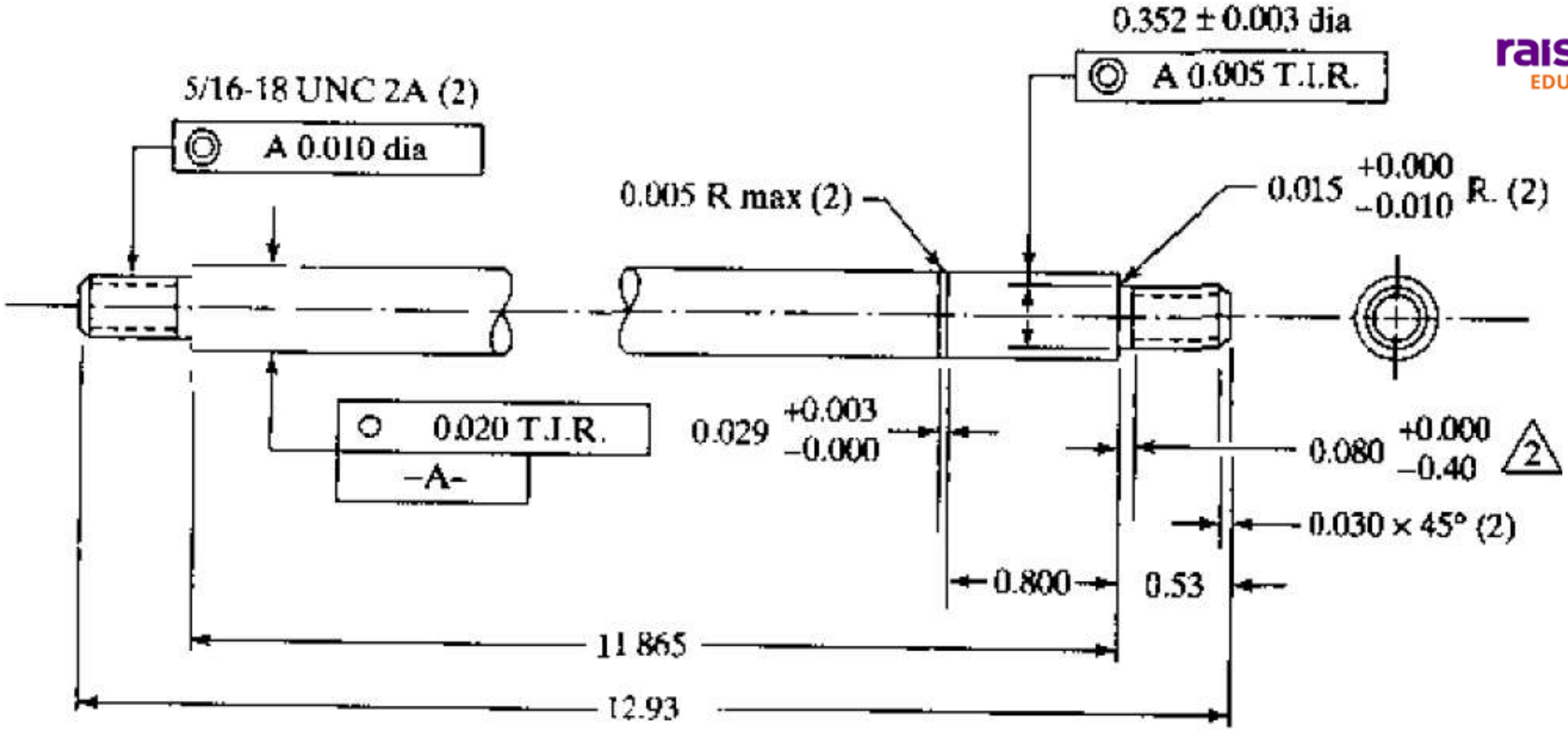


Figure 15.8 Workpart of Example 15.2. (Courtesy of OIR, Organization for Industrial Research.)

MultiClass System

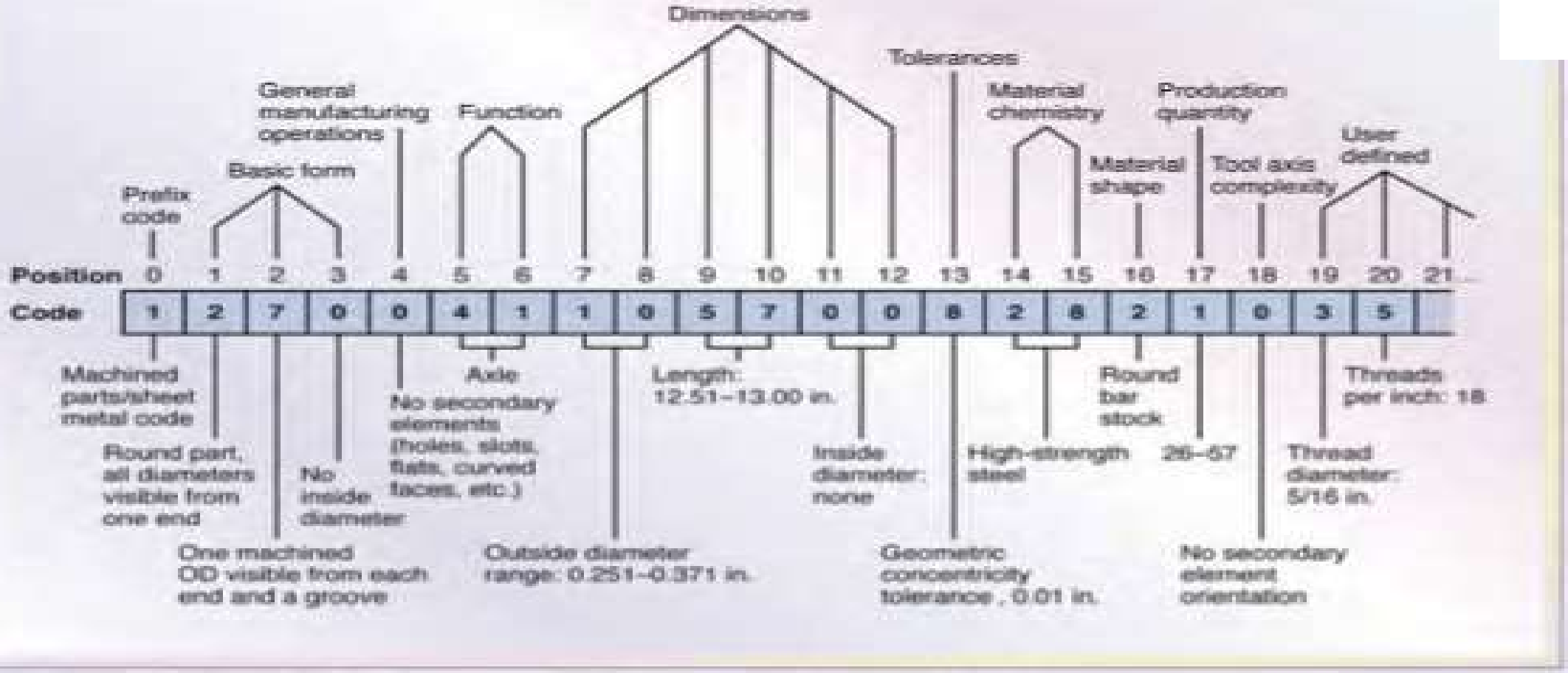


Figure 38.16 Typical multiClass code for a machined part.
Source: Courtesy of Organization for Industrial Research.

PRODUCTION FLOW ANALYSIS

Following are the steps in Production Flow Analysis

1. Data collection

2. Sortation of Process Routing

3. PFA chart

4. Cluster Analysis

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TABLE 15.3 Possible Code Numbers Indicating Operations and/or Machines for Sortation in Production Flow Analysis (Highly Simplified)

Operation or Machine	*Code*
Cutoff	01
Lathe	02
Turret lathe	03
Mill	04
Drill: manual	05
NC drill	06
Grind	07

TABLE 15.4 PFA Chart, Also Known as a Part-Machine Incidence Matrix

Machines	Parts A	B	C	D	E	F	G	H	I
1	1			1				1	
2					1				1
3			1		1				1
4		1				1			
5	1							1	
6			1						1
7		1				1	1		

TABLE 15.5 Rearranged PFA Chart, Indicating Possible Machine Groupi

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Machines	Parts C	E	I	A	D	H	F	G	B
3	1	1	1						
2		1	1						
6	1		1						
1				1	1	1			
5				1		1			
7							1	1	1
4							1		1

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CELLULAR MANUFACTURING

Application of group technology in which dissimilar machines or processes are aggregated into cells, each of which is dedicated to the production of a part family or limited group of families

Typical objectives of cellular manufacturing:-

1)To shorten manufacturing lead times and material handling
2)To reduce WIP
3)To improve quality
4)To simplify production scheduling and process planning
5)To reduce setup times

COMPOSITE PART CONCEPT

A composite part for a given family is a hypothetical part that includes all of design and manufacturing attributes of the family.

In general, an individual part in the family will have some of the features of the family, but not all of them

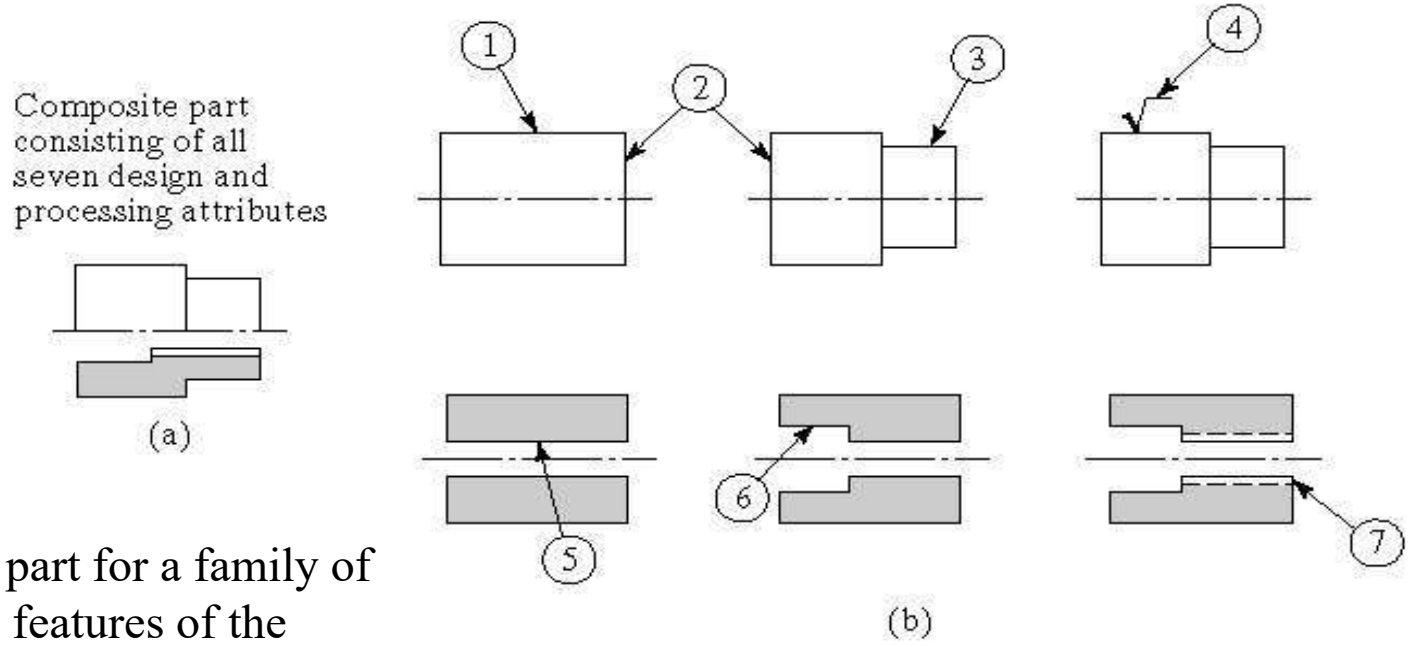


Fig:- Composite part concept: (a) the composite part for a family of machined rotational parts, and (b) the individual features of the composite part

PART FEATURES AND CORRESPONDING MANUFACTURING OPERATIONS

	Design feature	Corresponding operation
1.	External cylinder	Turning
2.	Face of cylinder	Facing
3.	Cylindrical step	Turning
4.	Smooth surface	Grinding
	External cylindrical	
5.	Axial hole	Drilling
6.	Counter bore	Counterboring
7.	Internal threads	Tapping

MACHINE CELL DESIGN

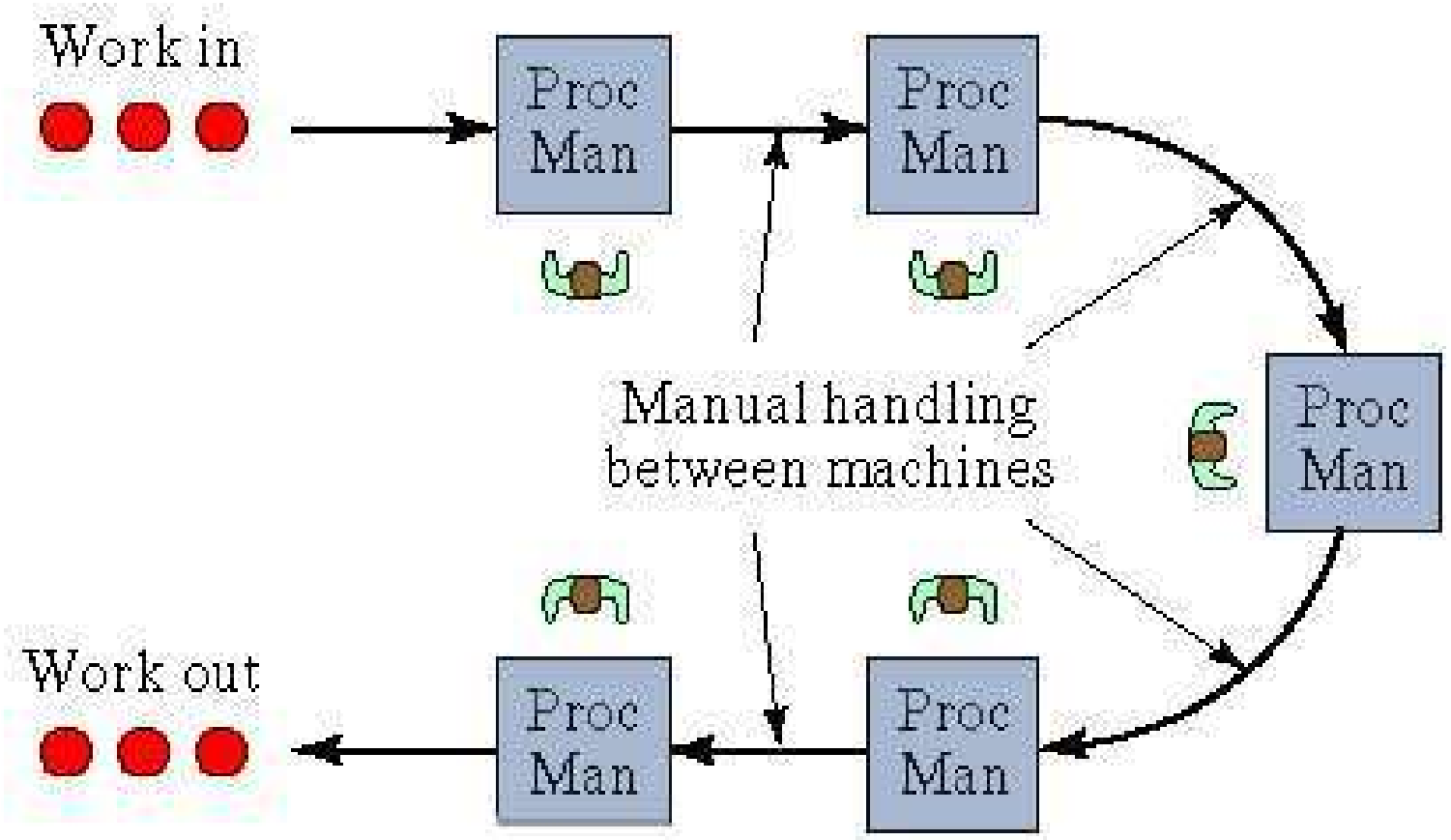
1. Single Machine Cell

2. Group Machine Cell with Manual Handling

3. Group Machine Cell with Semi Integrated Handling

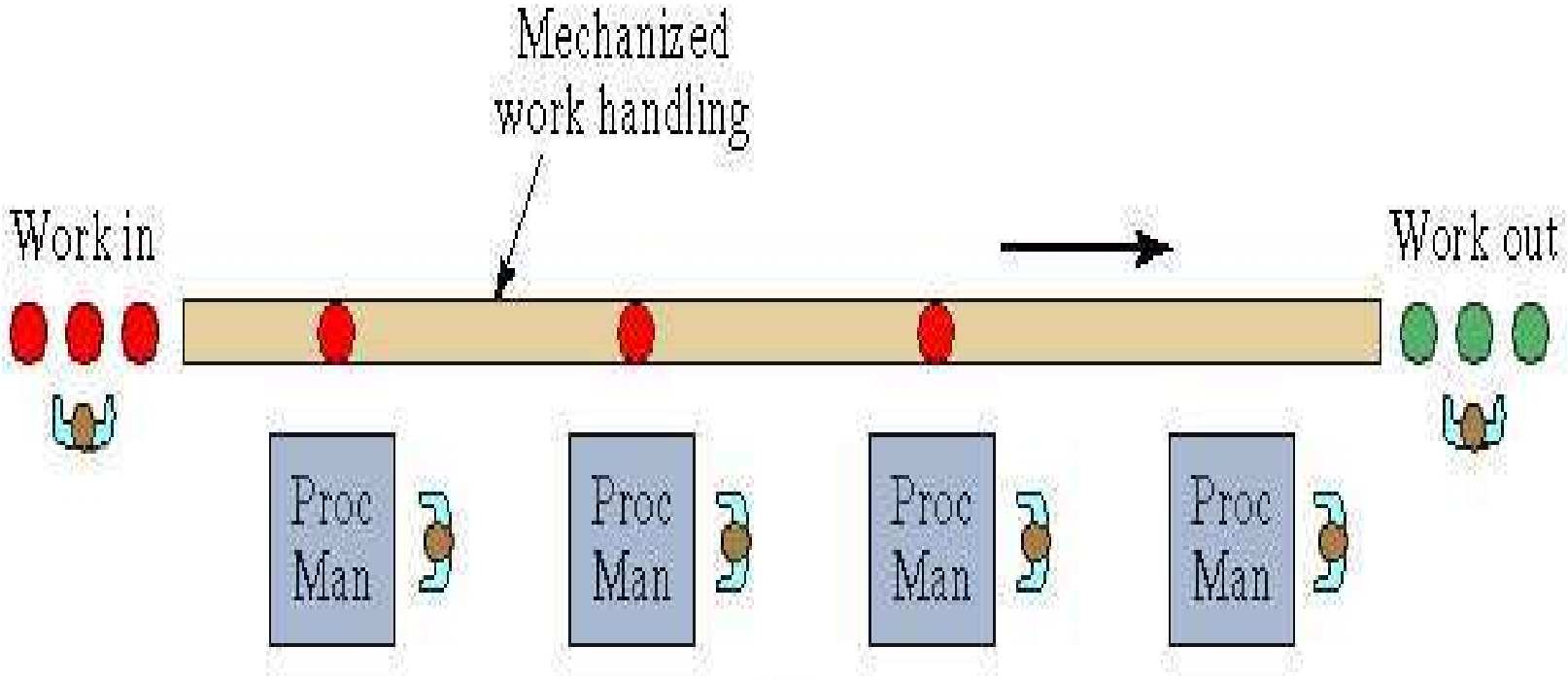
4. Flexible Manufacturing Cell

Machine Cell with Manual Handling

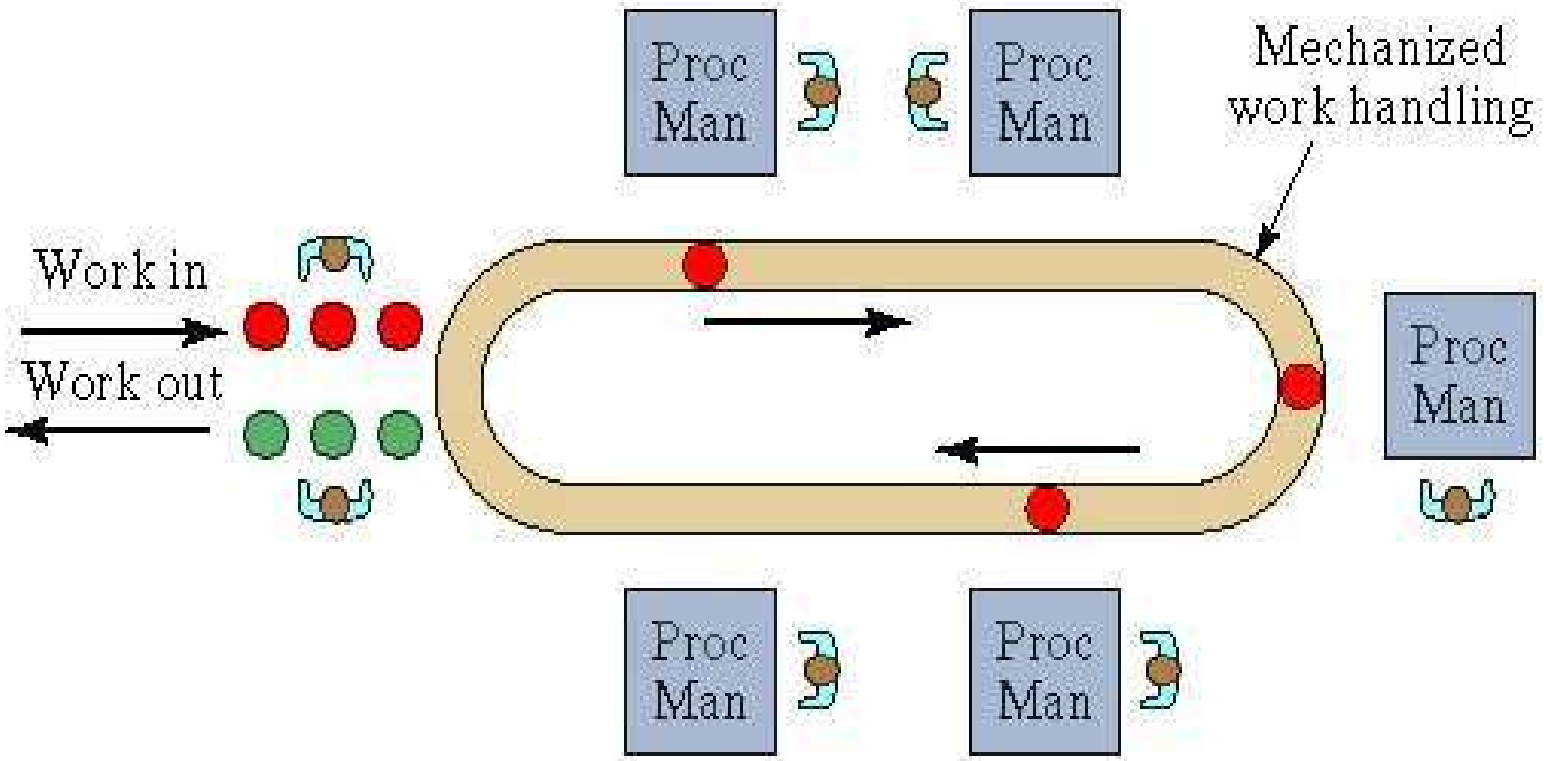


U-shaped machine cell with manual part handling between machines

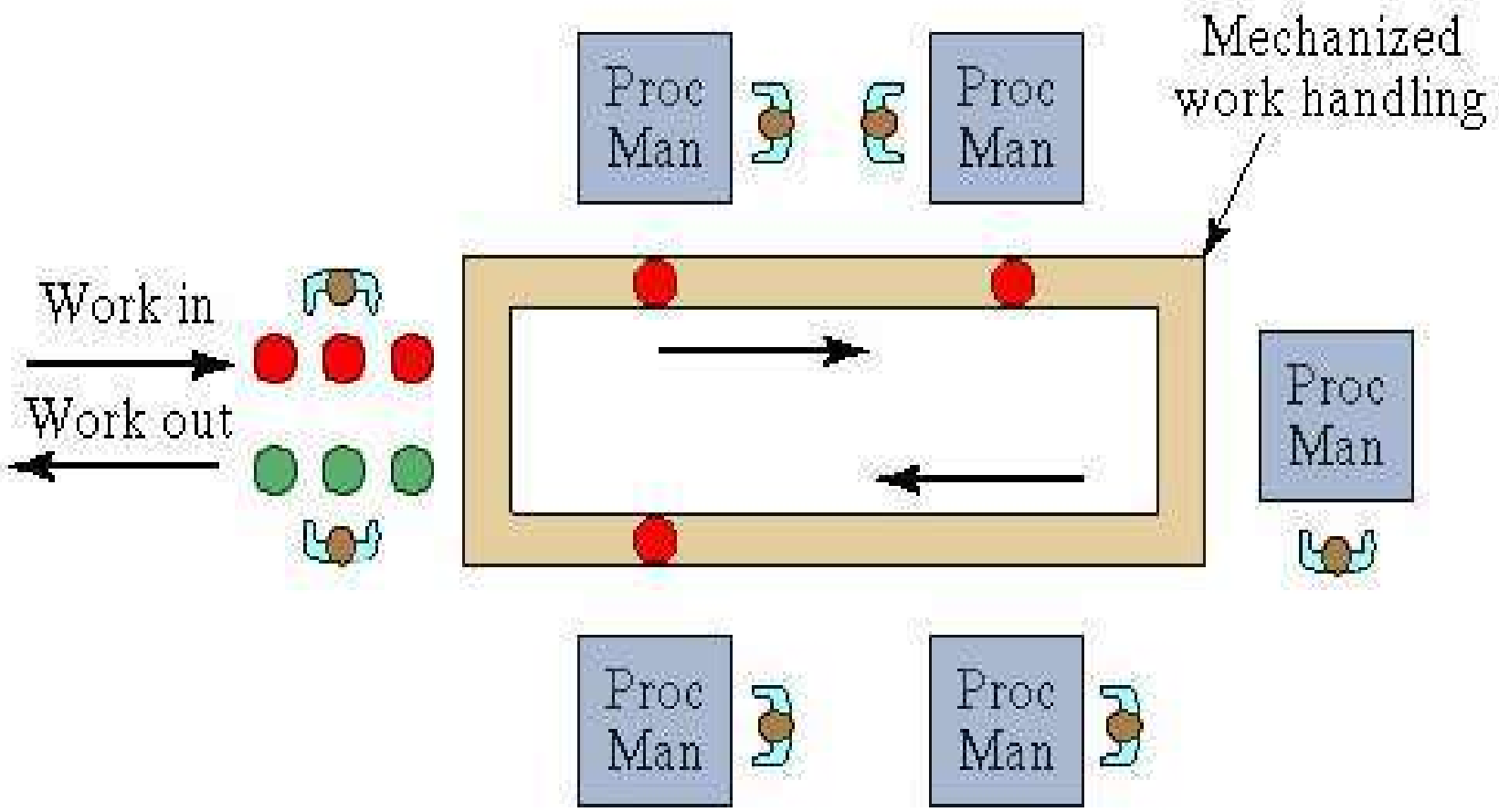
Cell with Semi-Integrated Handling



In-line layout using mechanized work handling between machines



Loop layout allows variations in part routing between machines



Rectangular layout also allows variations in part routing and allows for return of work carriers if they are used.

Group Technology (GT) & Flexible Manufacturing System (FMS)

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❑GT Philosophy

Definition: Group Technology is a manufacturing philosophy in which **similar parts are identified and grouped into families** to take advantage of their similarities in design and production.

Core idea: *"Similar things should be done similarly."*

Focus: Reduce duplication, improve efficiency, and standardize processes.

GT is most appropriately applied under the following conditions:

- 1)The plant currently uses traditional batch production and a process type layout
- 2)The parts can be grouped into part families.

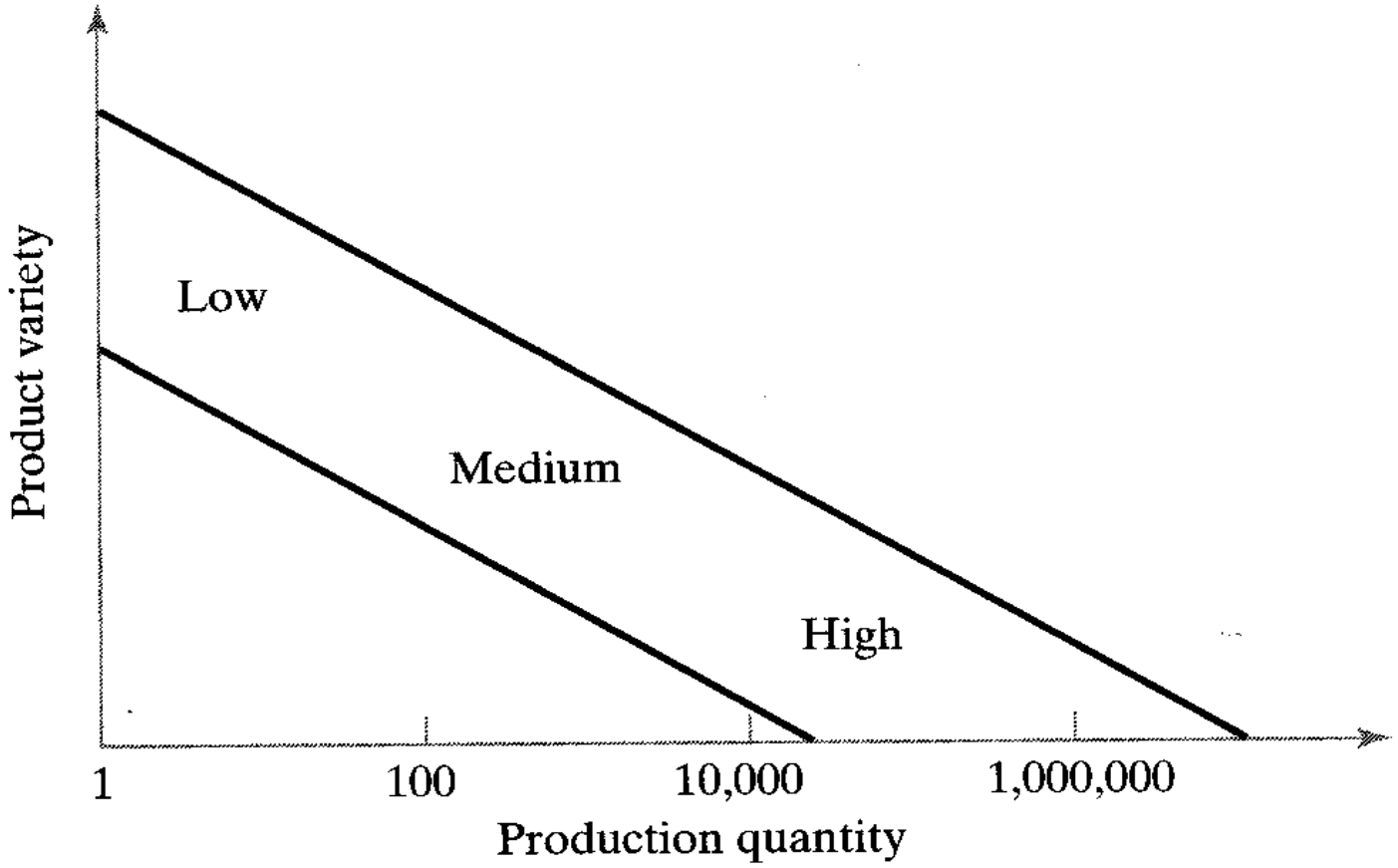
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FELXIBLE MANUFACURING SYSTEM

- A **flexible manufacturing system(FMS)** is a highly automated GT mac cell, consisting of a group or processing workstations (usually CNC mac tools), interconnected by an automated material handling and storage system, and controlled by a distributed computer system.

- The reason the FMS is called flexible is that it is capable of processing a variety of different part styles simultaneously at the various workstations, and the mix of part styles and quantities of production can be adjusted in response to changing demand patterns.

The FMS is most suited for the mid-variety, mid-volume production range



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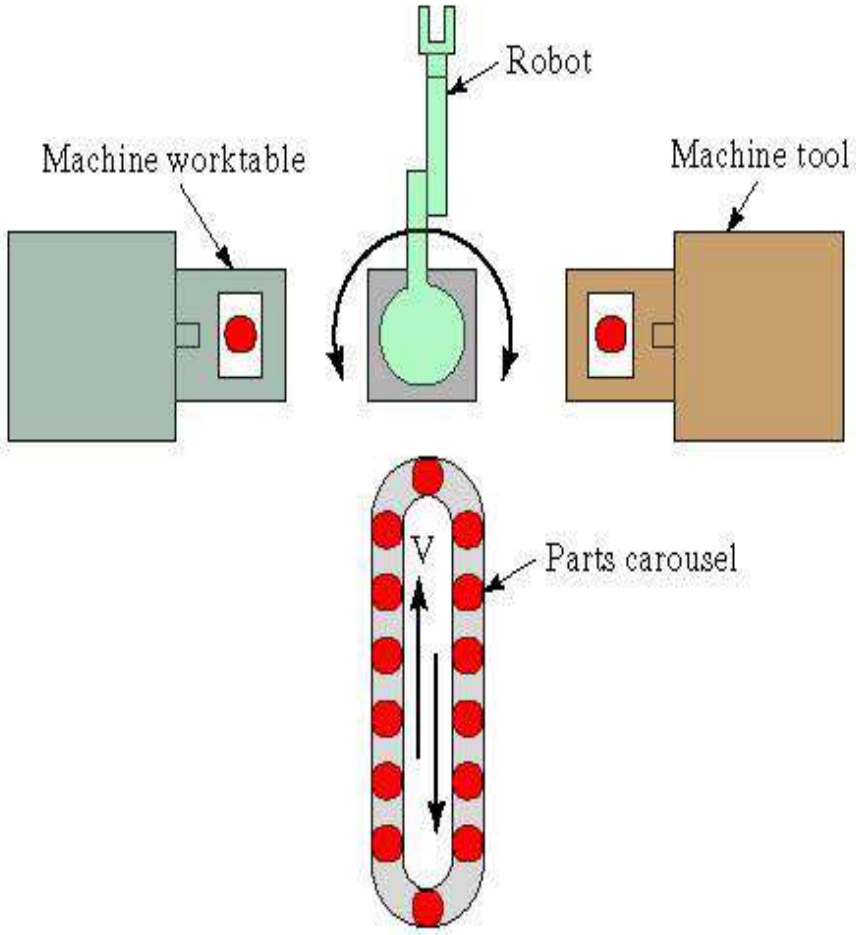
What Make It Flexible?

Three capabilities that a manufacturing system must possess to be a flexible.

1. The ability to identify and distinguish among the different part styles processed by the system.

2. Quick changeover of operating instructions, and

3. Quick changeover of physical setup.



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❑ Single machine cell

A single machine cell consists of one CNC machining center combined with a storage system for unattended operation.

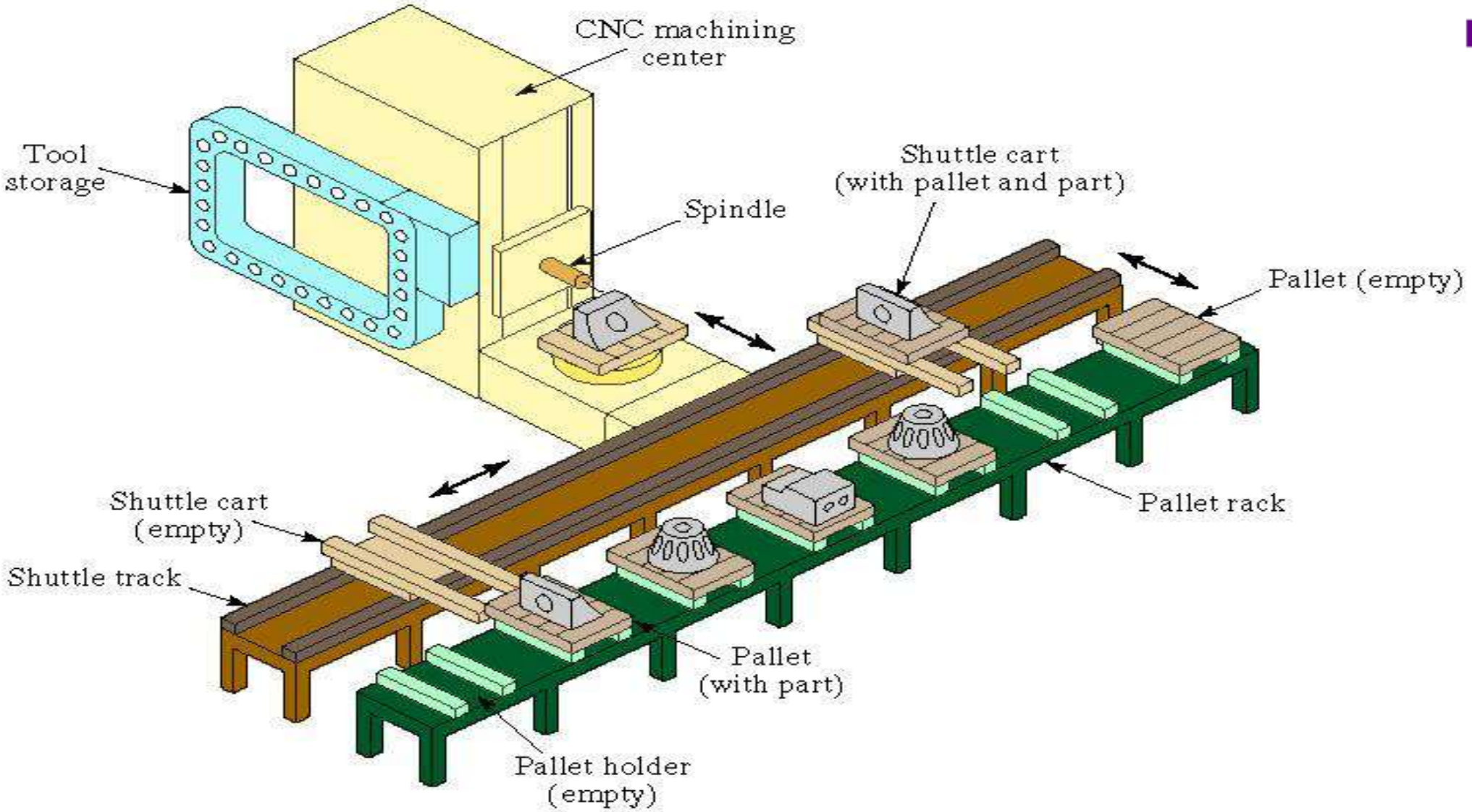
Completed parts are periodically unloaded from the parts storage unit, and raw workparts are loaded into it

- Flexible manufacturing systems can be distinguished according to the number of machines in the system. The following are typical categories:

1. Single machine cell

2. Flexible manufacturing cell

3. Flexible manufacturing system


CNC machining center
Tool storage
Spindle
Shuttle cart (with pallet and part)
Pallet (empty)
Shuttle cart (empty)
Shuttle track
Pallet rack
Pallet (with part)
Pallet holder (empty)

L-30



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Single machine cell

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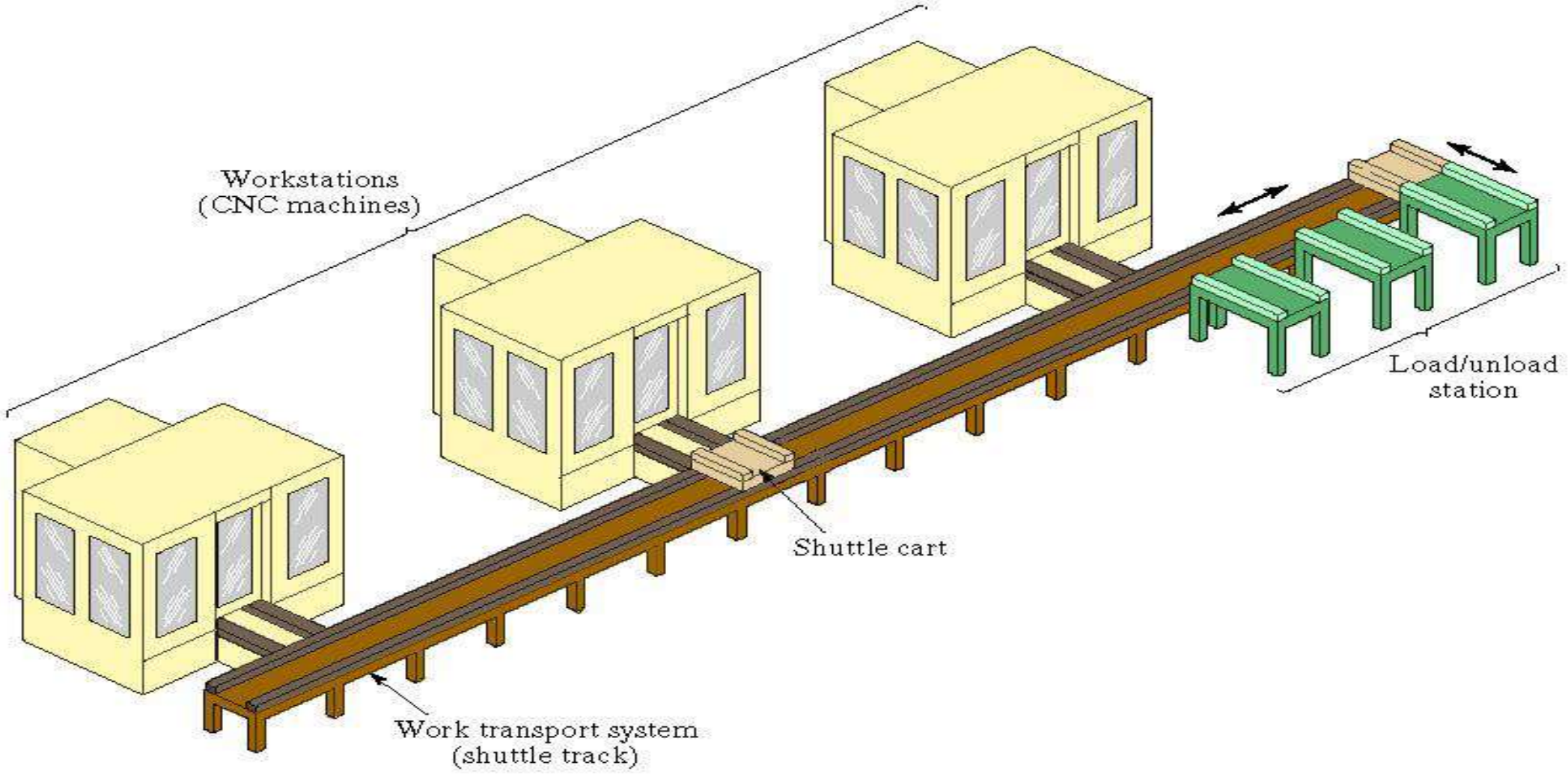


Flexible Manufacturing Cell (FMC)

A flexible manufacturing cell consists of two or three processing workstations (typically CNC machining centers) plus a part handling system.

The part handling system is connected to a load/unload station.

Flexible Manufacturing Cell (FMC)



L-30



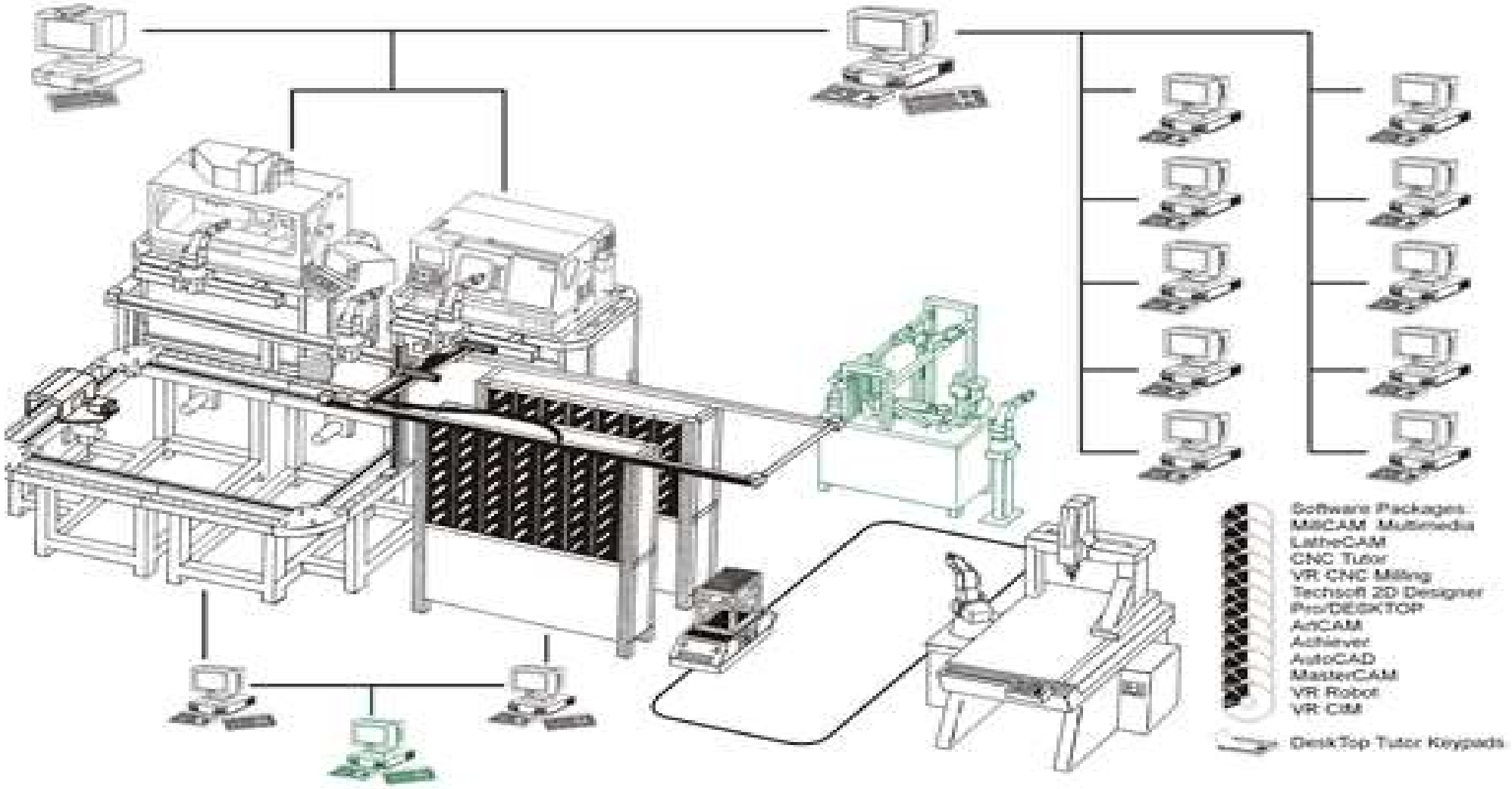
Flexible Manufacturing System (FMS)

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A flexible manufacturing system has four or more processing workstations connected mechanically by a common part handling system and electronically by a distributed computer system.

Flexible Manufacturing System (FMS)

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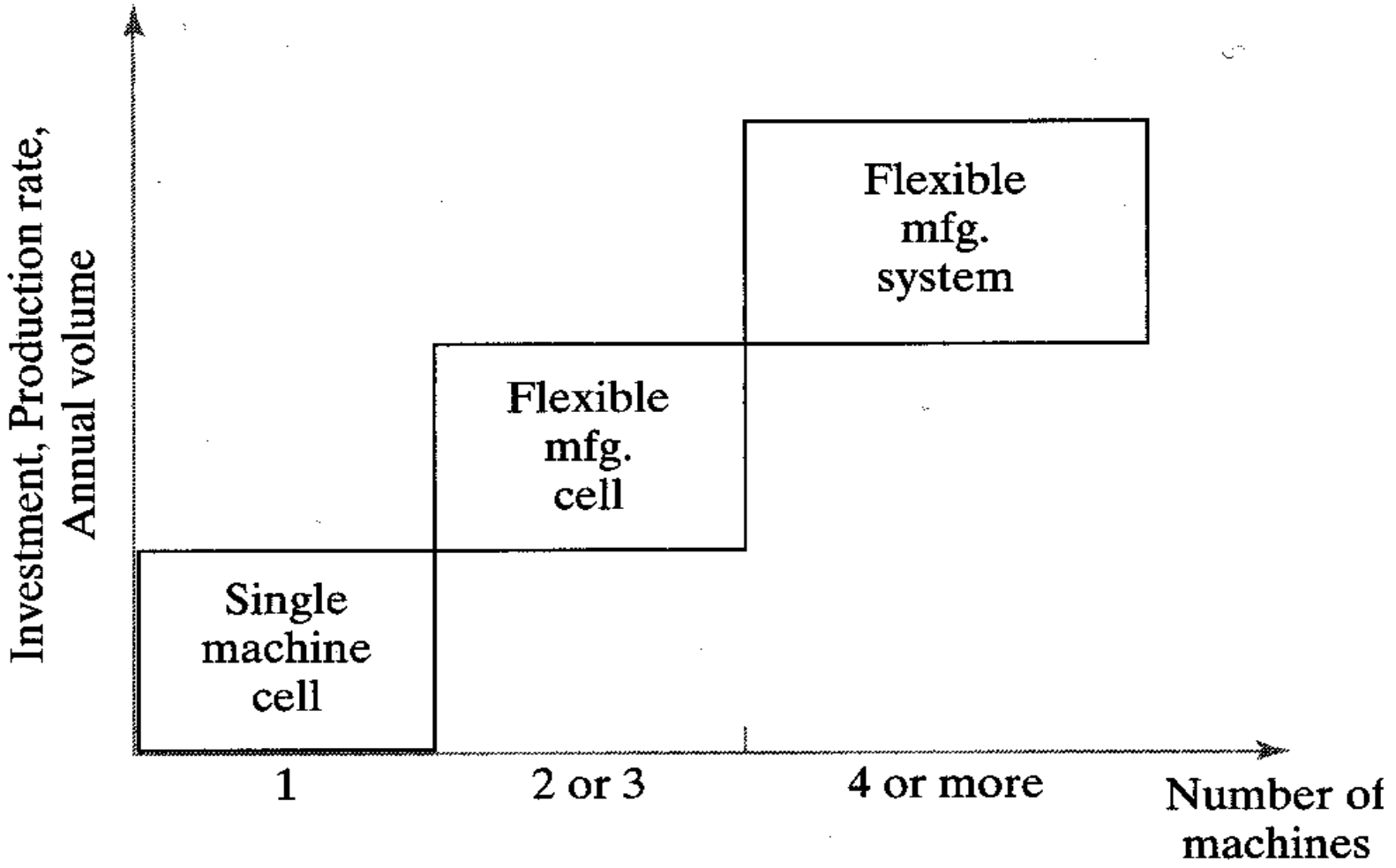




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Some of the distinguishing characteristics of the three categories of flexible manufacturing cells and systems are summarized in figure above

Flexibility Criteria Applied to the Three Types of Manufacturing C and Systems

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	Flexibility Criteria (Tests of Flexibility)			
System Type	*1. Part Variety*	*2. Schedule Change*	*3. Error Recovery*	*4. New Part*
Single machine cell (SMC)	Yes, but processing is sequential, not simultaneous.	Yes	Limited recovery due to only one machine.	Yes
Flexible manufacturing cell (FMC)	Yes, simultaneous production of different parts.	Yes	Error recovery limited by fewer machines than FMS.	Yes
Flexible manufacturing system (FMS)	Yes, simultaneous production of different parts.	Yes	Machine redundancy minimizes effect of machine breakdowns.	Yes

1. Dedicated FMS

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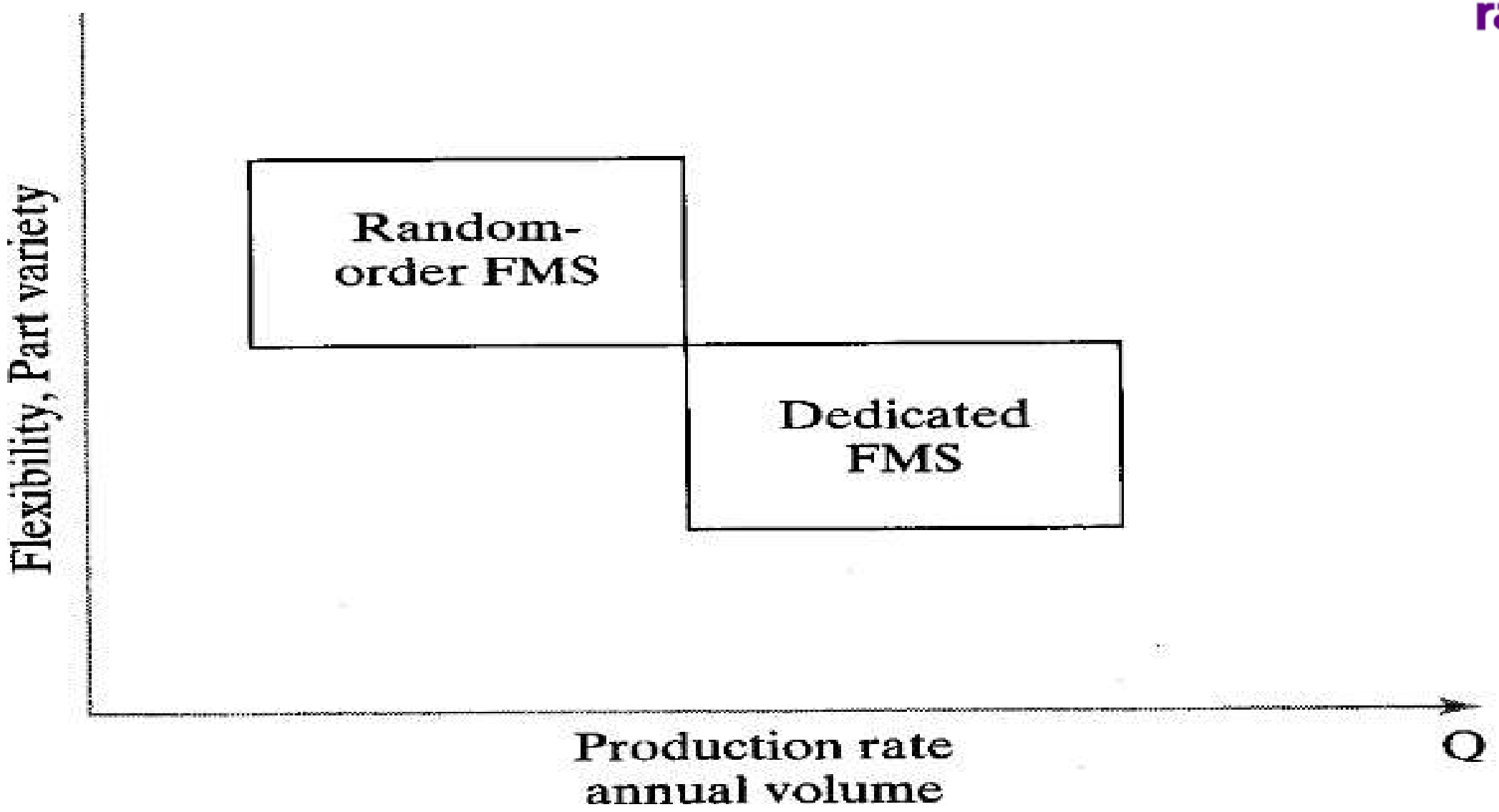
- Designed to produce a limited variety of part styles, and the complete universe of parts to be made on the system is known in advance.
- Group technology is likely to be based on product commonality rather than geometric similarity.
- Product design is relatively stable, so the system is designed with a certain amount of process specialization in place
- Machines designed for specific processes can be implemented within the system, which leads to an increased production rate from the system.
- In some cases, machine sequence may be virtually identical for all parts processed, so a transfer line may be appropriate as the system lay-out.

2. Random-order FMS

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- Designed to produce a large part family, where there are substantial variations in part configurations, and where it is likely that new part designs will be introduced into the system, with engineering changes occurring to existing parts.
- The production schedule may also be flexible, changing from day to day. The random-order FMS must be more flexible than the dedicated FMS to accommodate these requirements. It is equipped with general purpose machines to deal with product variations, and is capable of processing parts in random order.
- A more sophisticated computer control system is also required for this FMS type.

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System Type	Flexibility Criteria (Tests of Flexibility)			
	1. Part Variety	2. Schedule Change	3. Error recovery	4. New part
Dedicated FMS	Limited. All parts known in advance.	Limited changes can be tolerated.	Limited by sequential processes.	No. New part introductions difficult.
Random-order FMS	Yes. Substantial part variations possible.	Frequent and significant changes possible.	Machine redundancy minimizes effect of machine breakdowns.	Yes. System designed for new part introductions.

Components of FMS

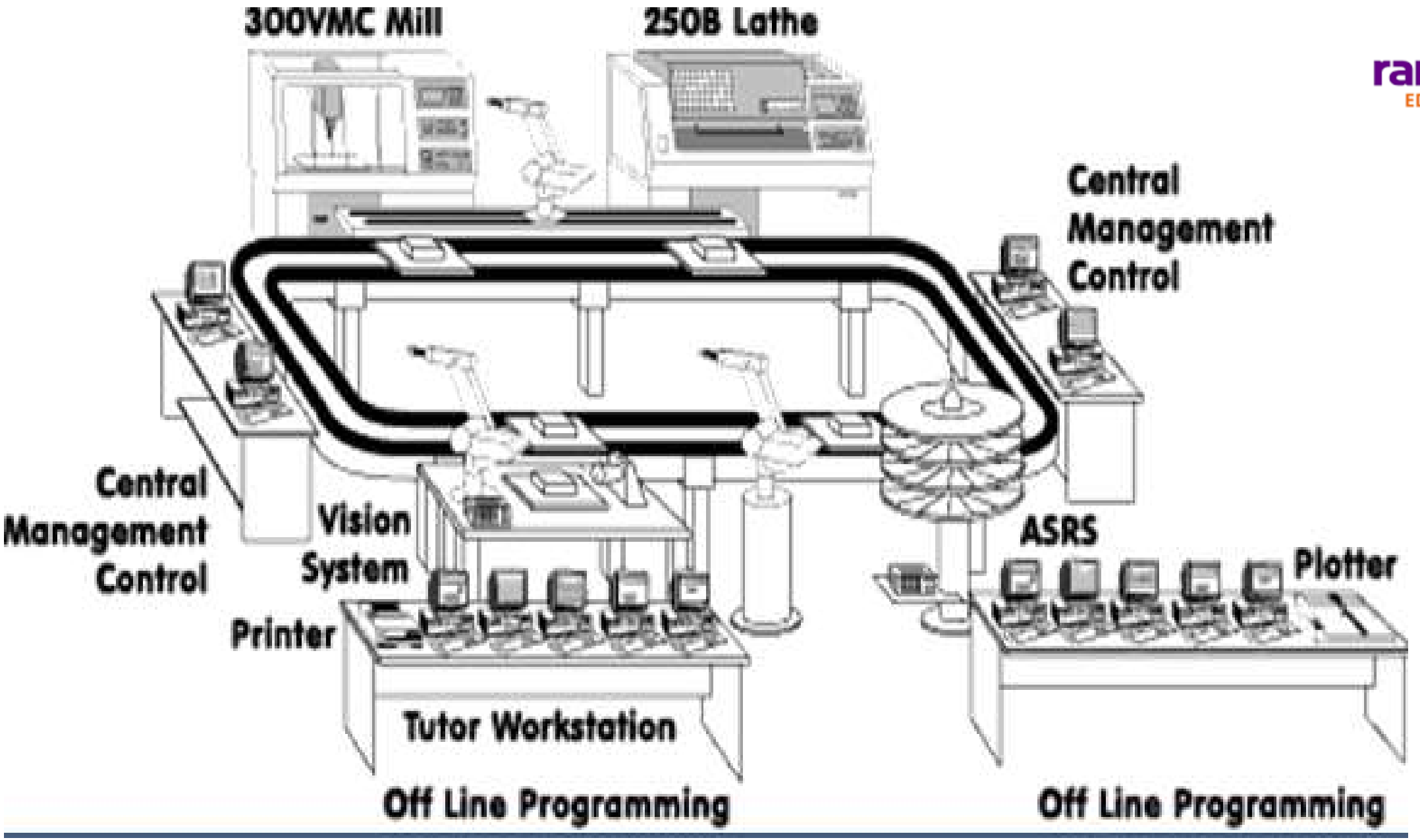
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1. Workstations.

2. Material handling and storage systems.

3. Computer control system.

4. People are required to manage and operate the system


300VMC Mill
250B Lathe
Central
Management
Control
Central
Management
Control
Vision
System
Printer
ASRS
Plotter
Tutor Workstation
Off Line Programming
Off Line Programming

Workstations:-Following are the types of workstations typic found in an FMS

1. Load/Unload Stations.

2. Machining Stations.

3. Other processing Stations. (punching, shearing, welding, etc.)

4. Assembly Station.

5. Other Stations and Equipment. (Inspection, Vision, etc)

Material Handling and Storage System:-

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Functions of the Handling System

1. Independent movement of workparts between stations.

2. Handle a variety of workpart configurations.

3. Temporary storage.

4. Convenient access for loading and unloading workparts.

5. Compatible with computer control.

- Material Handling Equipment:-

The material handling function in an FMS is often shared between systems

Primary handling system establishes the basic layout of the FMS and is responsible for moving workparts between stations in the system. (Conveyor)

Secondary handling system consists of transfer devices, automatic pallet changing, and similar mechanisms located at the workstations in the FMS.

- The function of the secondary handling system is to transfer work from the primary system to the machine tool or other processing station and to position the parts with sufficient accuracy and repeatability to perform the process or assembly operation.

Computer Control System

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The FMS includes a distributed computer system that is interfaced t the

1. Workstations
2. Material handling system, and
3. Other hardware components

A typical FMS computer system consists of a central computer and microcomputers.

1. Microcomputers controlling the individual machines and other components.
2. The central computer coordinates the activities of the components to achieve smooth overall operation of the system

Human Resources

Human are needed to manage the operations of the FMS. Func
typically performed by human includes:

Loading raw workparts into the system,

Unloading finished parts (or assemblies) from the system,

Changing and setting tools,

Equipment maintenance and repair,

NC part programming in a machining system,
and Programming and operation the computer system.

TYPES OF FMS LAYOUT CONFIGURATION

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1. In-line Layout
2. Loop Layout
3. Ladder Layout
4. Open Field Layout
5. Robot-centered Cell

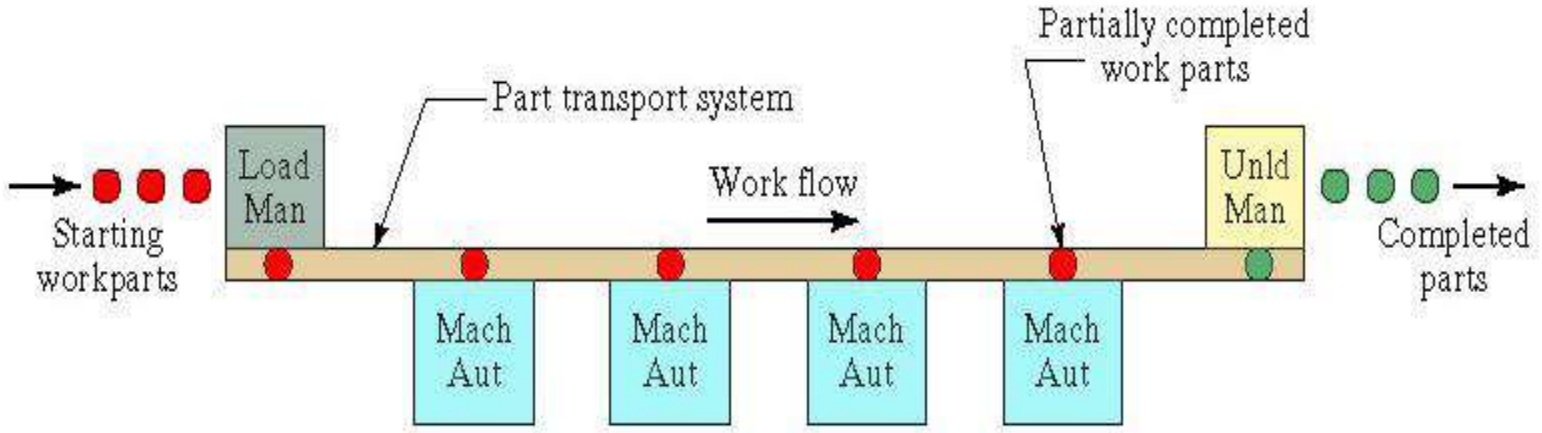
1. In-line Layout

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➢Straight line flow, well-defined processing sequence similar for all work units

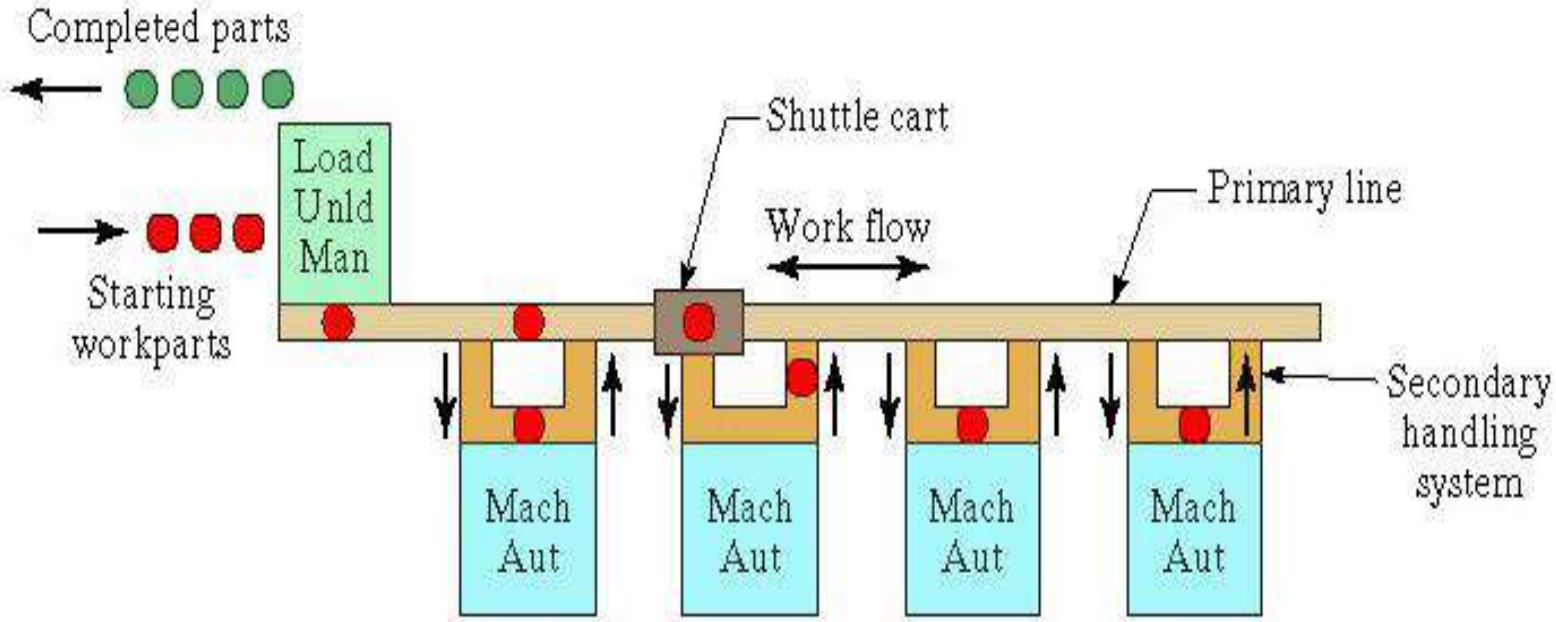
➢Work flow is from left to right through the same workstations

➢No secondary handling system



Loop Layout

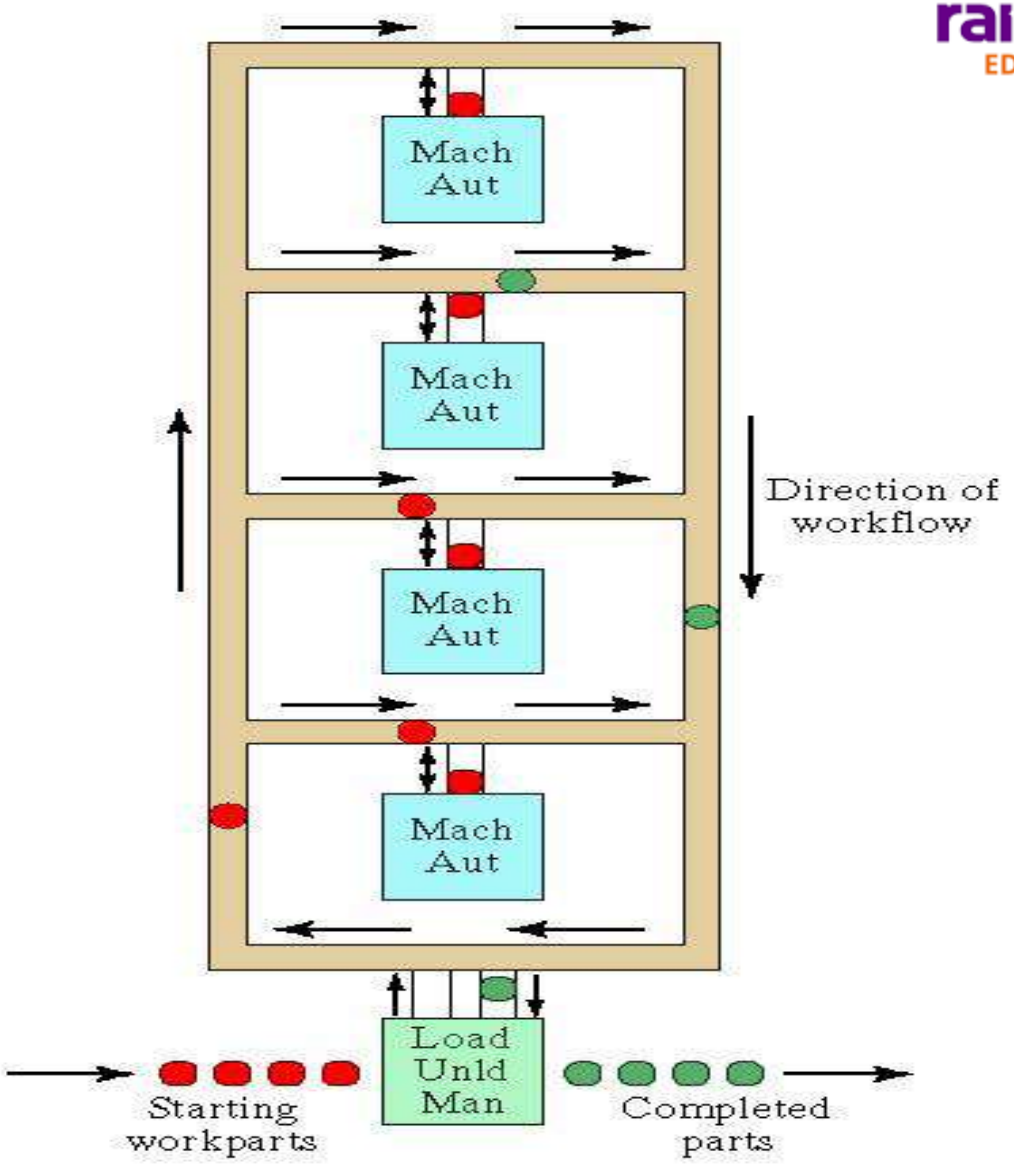
Linear transfer system with secondary parts handling system at each workstation to facilitate flow in two directions



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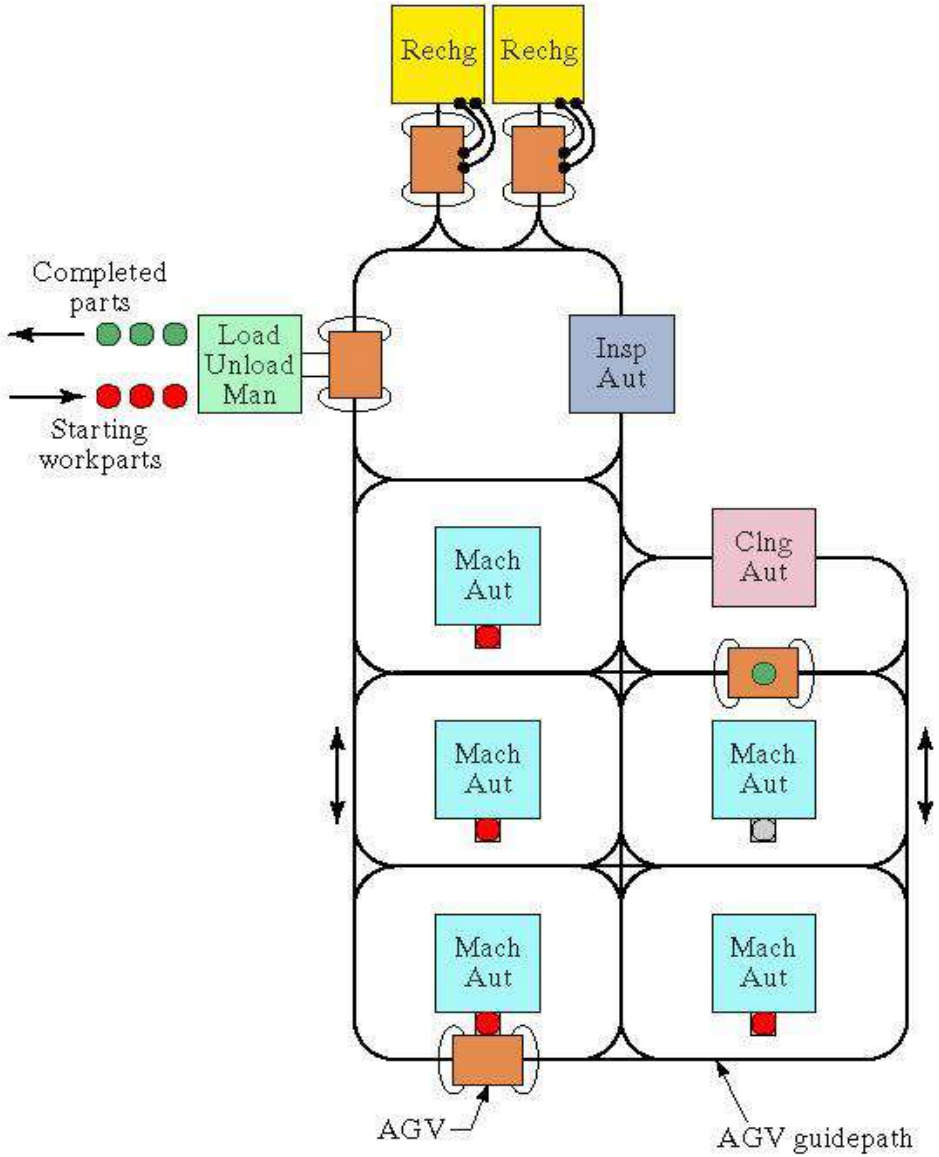
3.Ladder Layout

Loop with rungs to allow greater variation in processing sequence



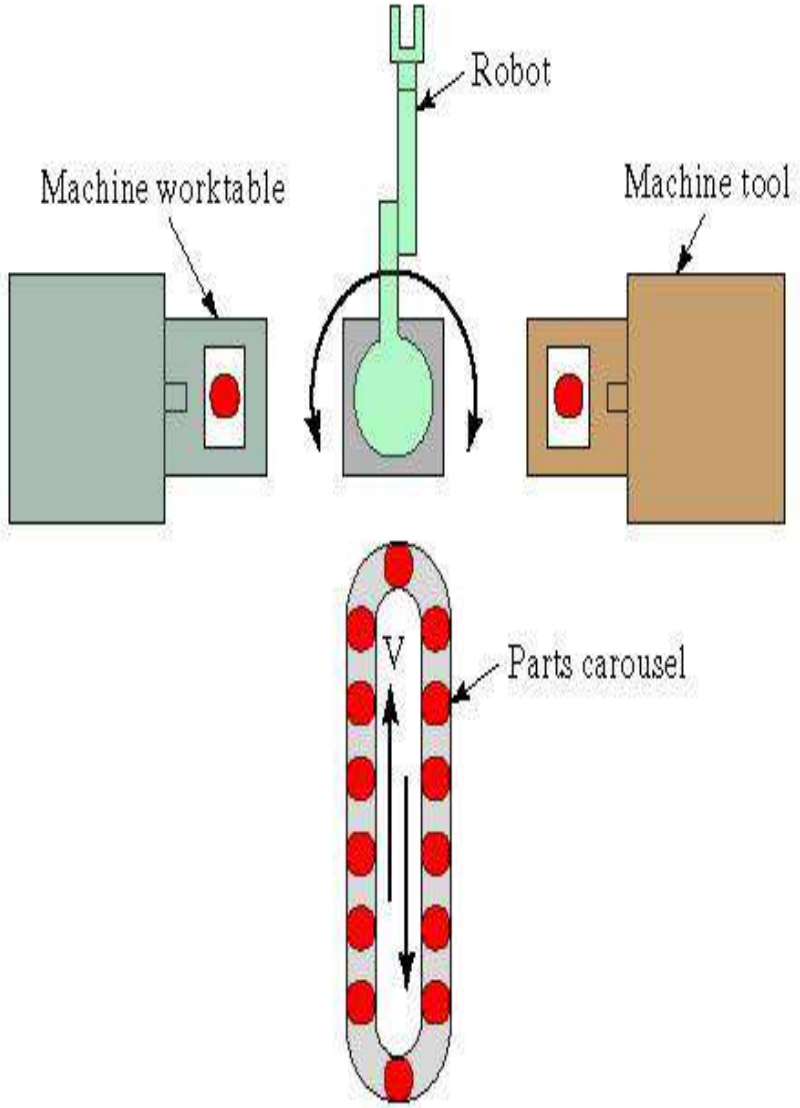
4.Open field Layout

Multiple loops and ladders, suitable for large part families



5.Robot-centered cell Layout

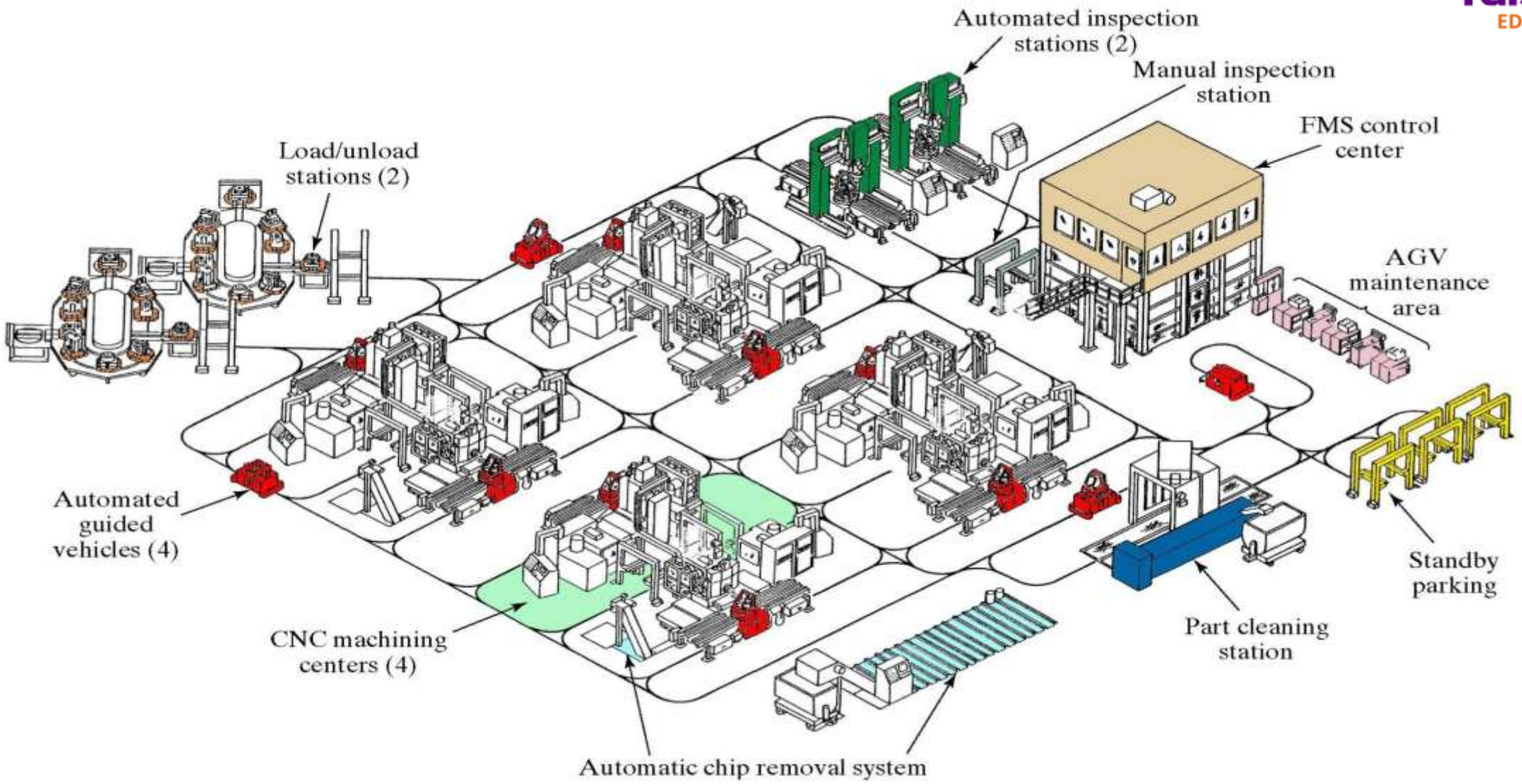
Suited to the handling of rotational parts and turning operations



FMS Applications

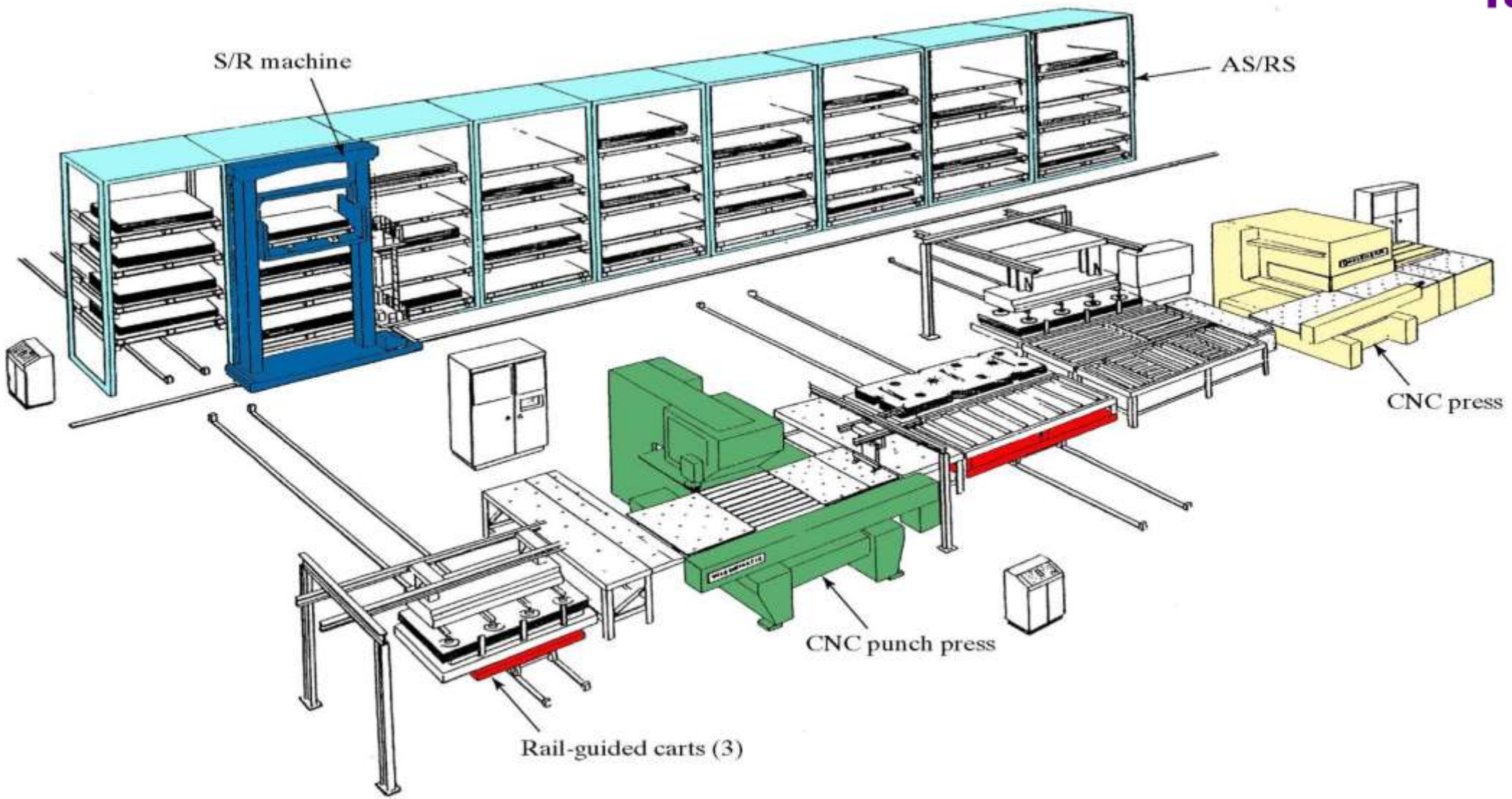
- Machining –most common application of FMS technology
- Assembly
- Inspection
- Sheet metal processing (punching, shearing, bending, and forming)
- Forging

FMS at Chance-Vought Aircraft



FMS for Sheet Metal Fabrication

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FMS Benefits

Increased machine utilization Reasons:24 hour operation likely to justify invest
Automatic tool changing, Automatic pallet changing at stations, Queues of pa
stations to maximize utilization, Dynamic scheduling of production to accoun
changes in demand

Fewer machines required

Reduction in factory floor space required

Greater responsiveness to change

Reduced inventory requirements - Different parts produced continuously rather than in batches

Conventional Storage Methods

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- Bulk storage
- Rack systems
- Shelving and bins
- Drawer storage

Storage Systems

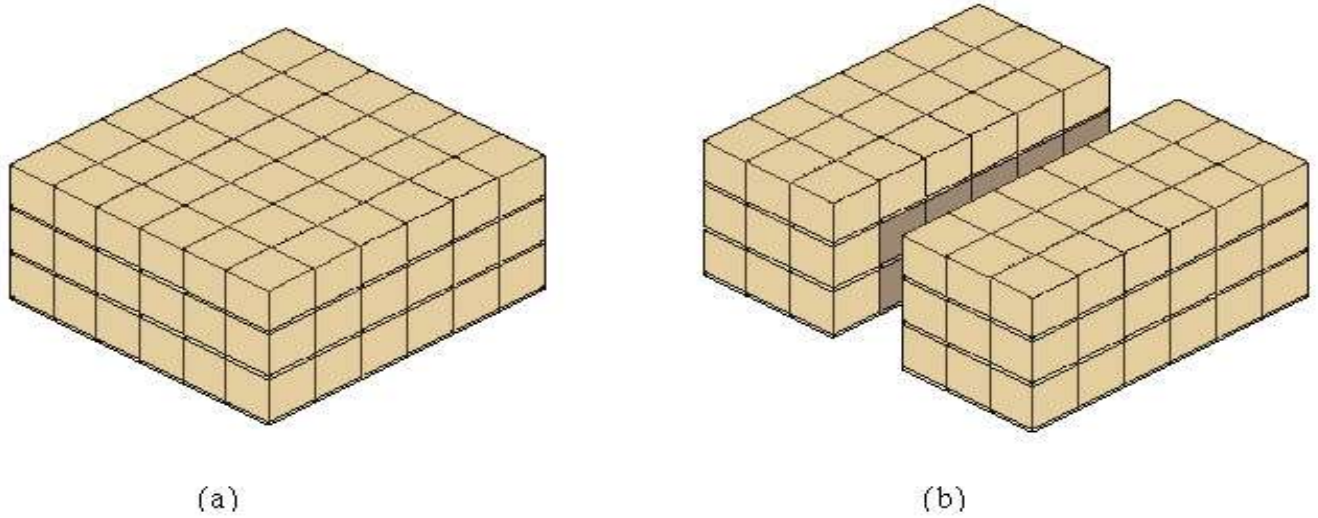
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Function – to store materials (e.g., parts, work-in-process, finished goods) for a period of time and permit retrieval when required

- Used in factories, warehouses, distribution centers, wholesale dealerships, and retail stores
- Important supply chain component
- Automation available to improve efficiency

Conventional Storage Methods

- **Bulk storage** – storage in an open floor area
  - Problem: achieving proper balance between storage density and accessibility



- Bulk storage arrangements:

(a) high-density bulk storage provides low accessibility,

(b) bulk storage with loads forming rows and blocks for improved accessibility

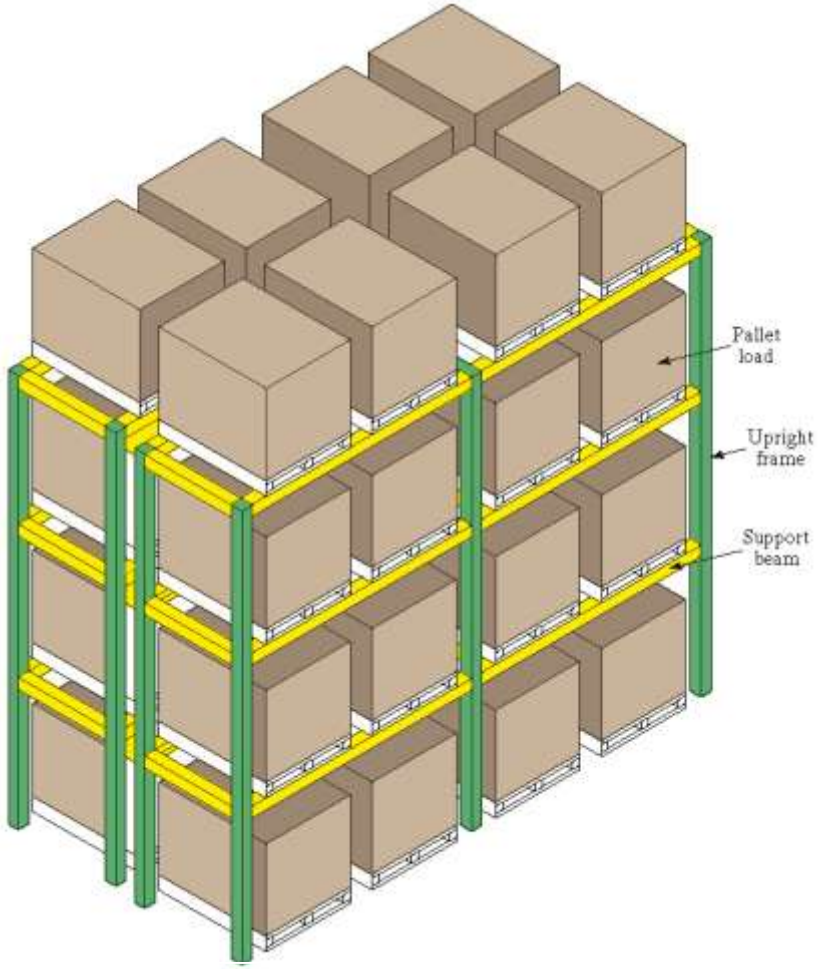
(c) Low cost per sq meter

•

Conventional Storage Methods

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- **Rack systems** –
- structure with racks for pallet loads
  - Permits vertical stacking of materials



Pallet loads placed on racks in multi-rack structure

(a) Low cost

(b) Good stroge density

(c) Good accessibility

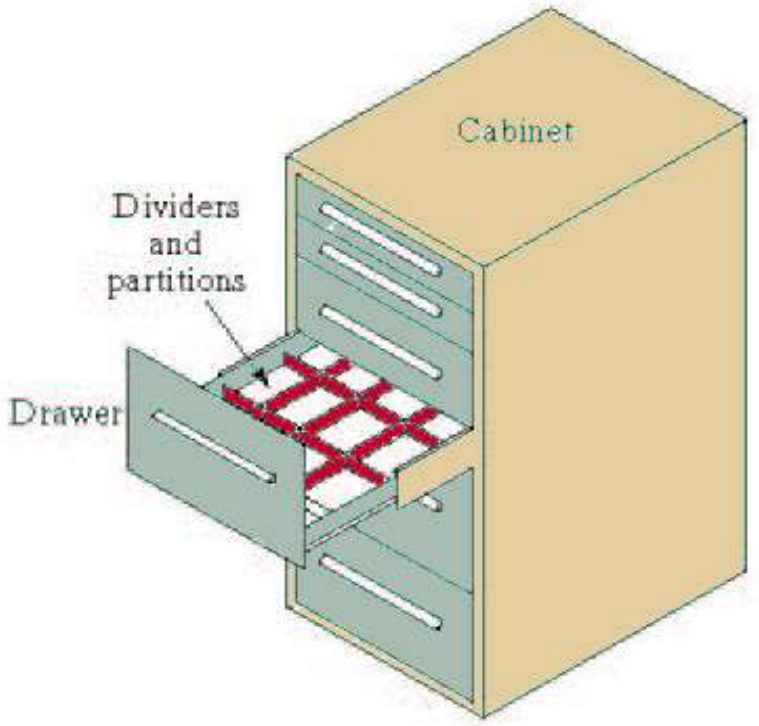
Conventional Storage Methods

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- **Drawer storage** –
- Entire contents of each drawer can be viewed

  - Contents easily visible
  - Good accessibility
  - Relatively high cost

  Small items (tools, repair parts, etc.)



Automated Storage Systems

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Mechanized and automated storage equipment to reduce the hun resources required to operate a storage facility

- Significant investment
- Level of automation varies
  - In mechanized systems, an operator participates in each storage/retrieval transaction
  - In highly automated systems, loads are entered or retrieved under computer control

Objectives and Reasons for Automating Storage Operations

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- To increase storage capacity
- To increase storage density
- To recover factory floor space currently used for WIP
- To improve security and reduce pilferage
- To reduce labor cost and/or increase productivity
- To improve safety
- To improve inventory control
- To improve stock rotation
- To improve customer service

Types of Automated Storage System

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1. Automated Storage/Retrieval System (AS/RS)

- Rack system with mechanized or automated crane to store/retrieve loads

2. Carousel Storage System

- Oval conveyor system with bins to contain individual items

AS/RS COMPONENTS AND TERMINOLOGY

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- An AS/RS consists of one or more storage aisles that are serviced a storage/retrieval (S/R) machine.
- The stored materials are held by storage racks of aisles.
- The S/R machines are used to deliver and retrieve materials in and out of inventory.
- There are one or more input/output stations in each AS/RS aisle for delivering the material into the storage system or moving it out of the system.
- In AS/RS terminology, the input/output stations are called pickup-and-deposit (P&D) stations.

AS/RS COMPONENTS AND TERMINOLOGY

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- **Storage Space**
- It is the three-dimensional space in the storage racks used to store a single load unit of material.
- **Storage Racks**
- This structural entity comprises storage locations, bays and rows.
- **Bay/Rack Height**
- It is the height of the storage rack from floor to the ceiling.
- **Row**
- It is a series of bays placed side by side.
- **Aisle**
- It is the spacing between two rows for the machine operations of AS/RS.
- **Aisle Unit**
- It encompasses aisle space and racks adjacent to an aisle.

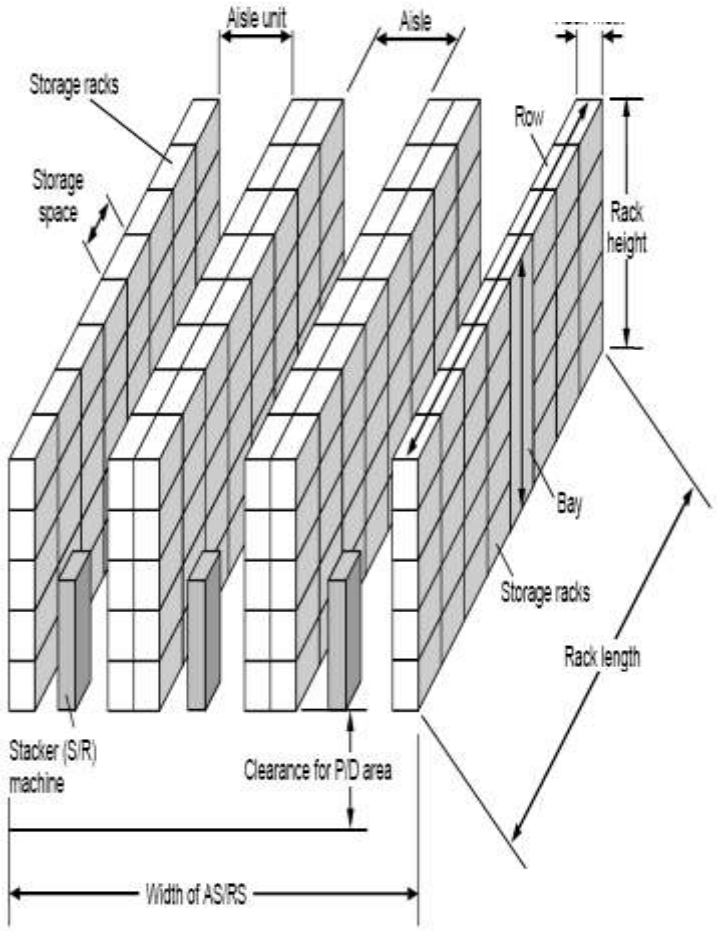


Figure 4.1 : Generic Structure of as AS/RS

AS/RS COMPONENTS AND TERMINOLOGY

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- **Storage Structure**
- It is the rack framework, made of fabricated steel that supports the loads contained in the AS/RS and is used to store inventory items.
- **Storage/Retrieval Machine**
- It is used to move items in and out of inventory. An S/R machine is capable of both horizontal and vertical movement. A rail system along the floor guides the machine and a parallel rail at the top of the storage structure is used to maintain its alignment.
- **Storage Modules**
- These are the unit load containers used to hold the inventory items. These include pallets, steel wire baskets and containers, pans and special drawers. These modules are generally made to a standard base size capable of being stored in the structure and moved by the S/R machines.
- **Pickup and Deposit (P/D) Stations**
- P/D stations are where inventory are transferred into and out of the AS/RS.

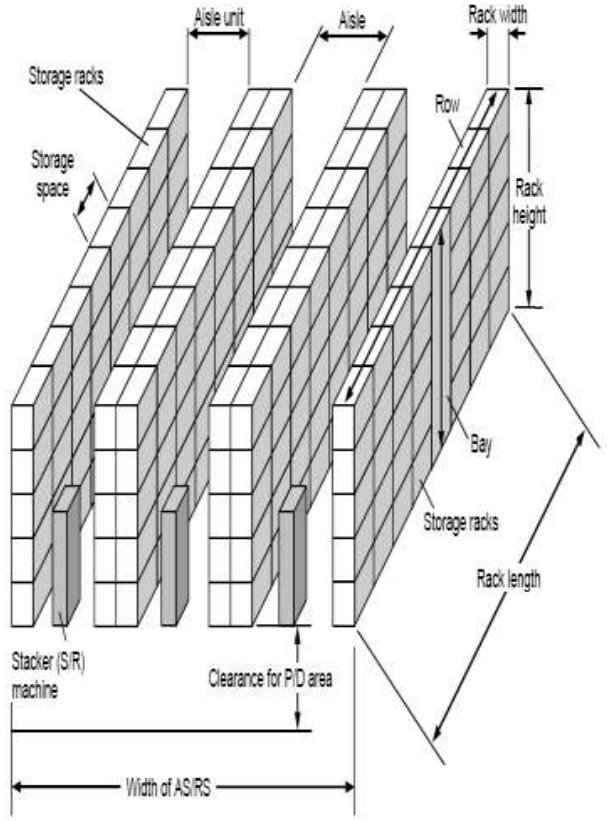


Figure 4.1 : Generic Structure of as AS/RS

AS/RS Types

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- **Unit load AS/RS** - large automated system for pallet loads
- **Deep-lane AS/RS** - uses flow-through racks and fewer access aisles
- **Miniload AS/RS** - handles small loads contained in bins or drawers to perform order picking
- **Man-on-board AS/RS** - human operator rides on the carriage to pick individual items from storage
- **Automated item retrieval system** - picks individual items
- **Vertical lift storage modules (VLSM)** - uses a vertical aisle rather than a horizontal aisle as in other AS/RS types

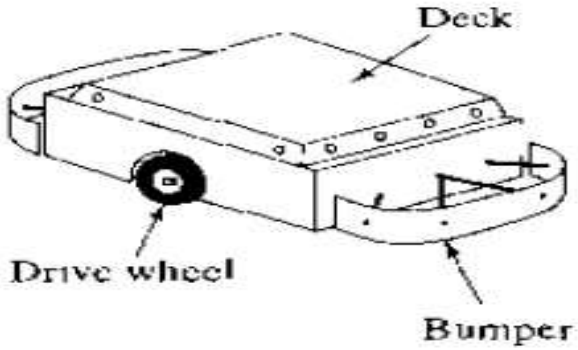
AS/RS Applications

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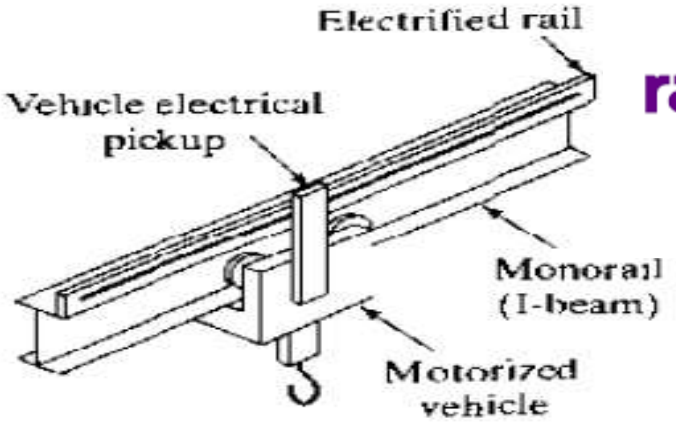
1. Unit load storage and retrieval
   - Warehousing and distribution operations
   - AS/RS types: unit load, deep lane (food industry)
2. Order picking
   - AS/RS types: miniload, man-on-board, item retrieval
3. Work-in-process storage
   - Helps to manage WIP in factory operations
   - Buffer storage between operations with different production rates
   - Supports JIT manufacturing strategy
   - Kitting of parts for assembly



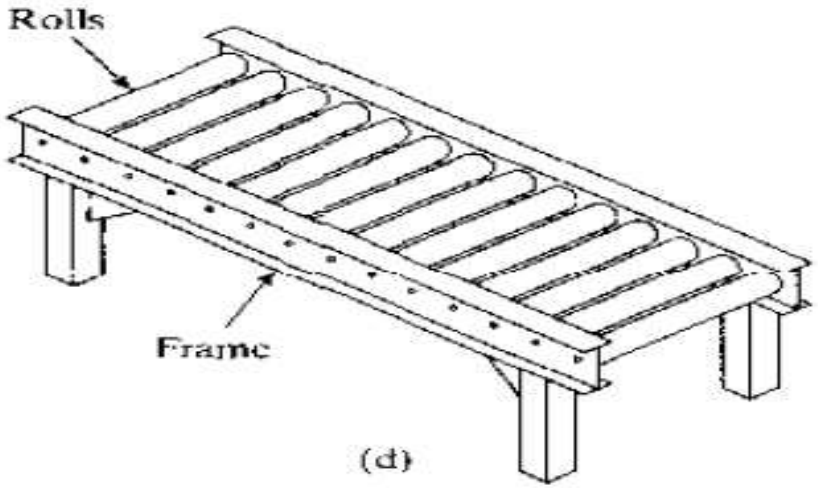
(a)



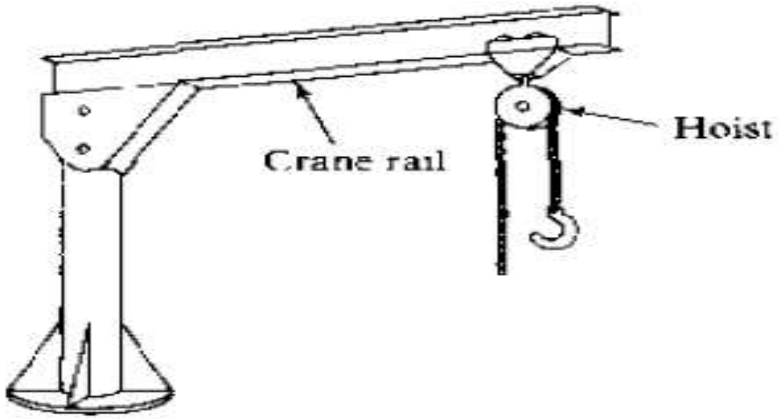
(b)



(c)



(d)



(e)

Figure 9.2 Examples of the five basic types of material handling equipment: (a) fork lift truck, industrial truck, (b) unit load automated guided vehicle, (c) monorail, (d) roller conveyor, and (e) jib crane with hoist.

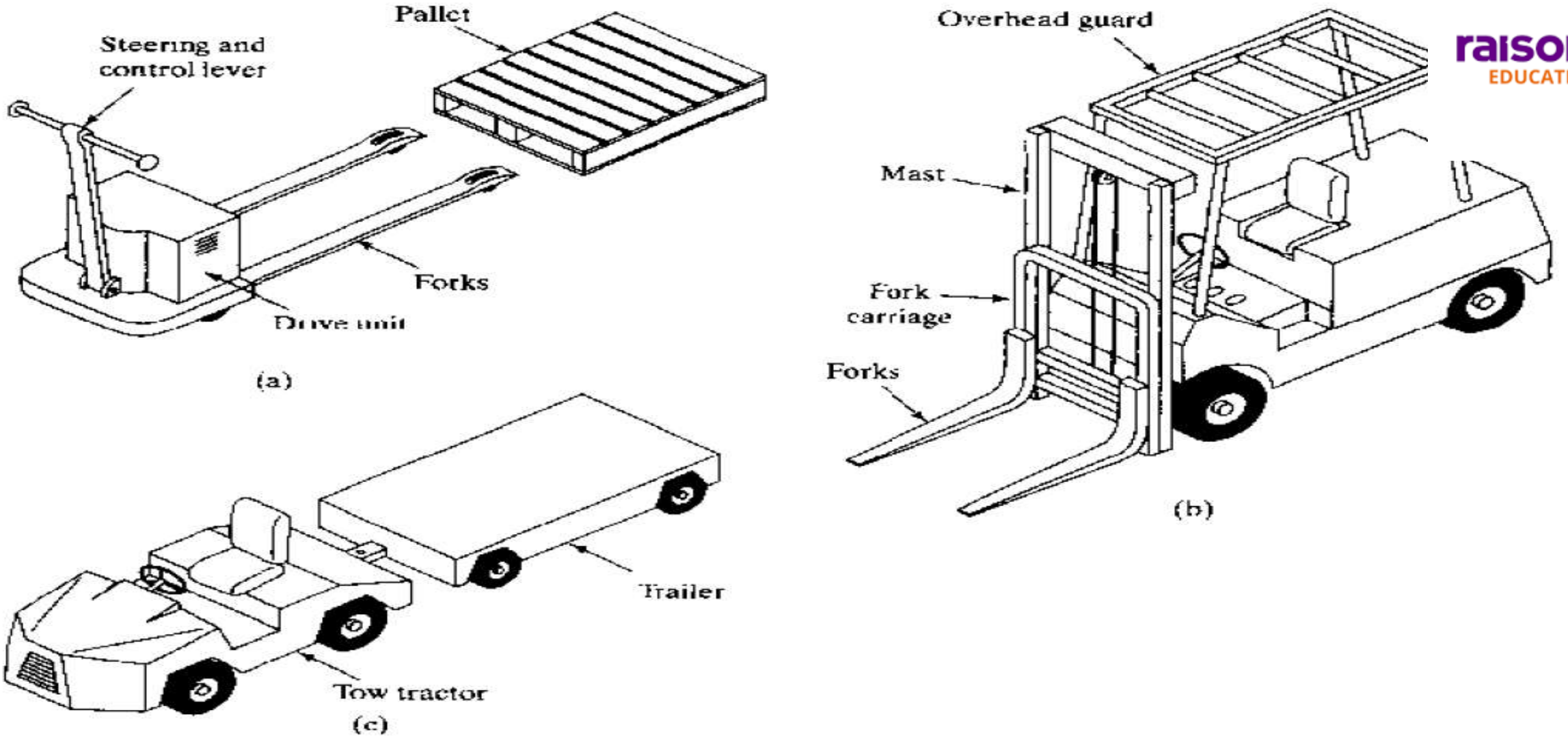


Figure 10.2 Three principal types of powered trucks: (a) walkie truck, (b) fork lift truck, and (c) towing tractor.

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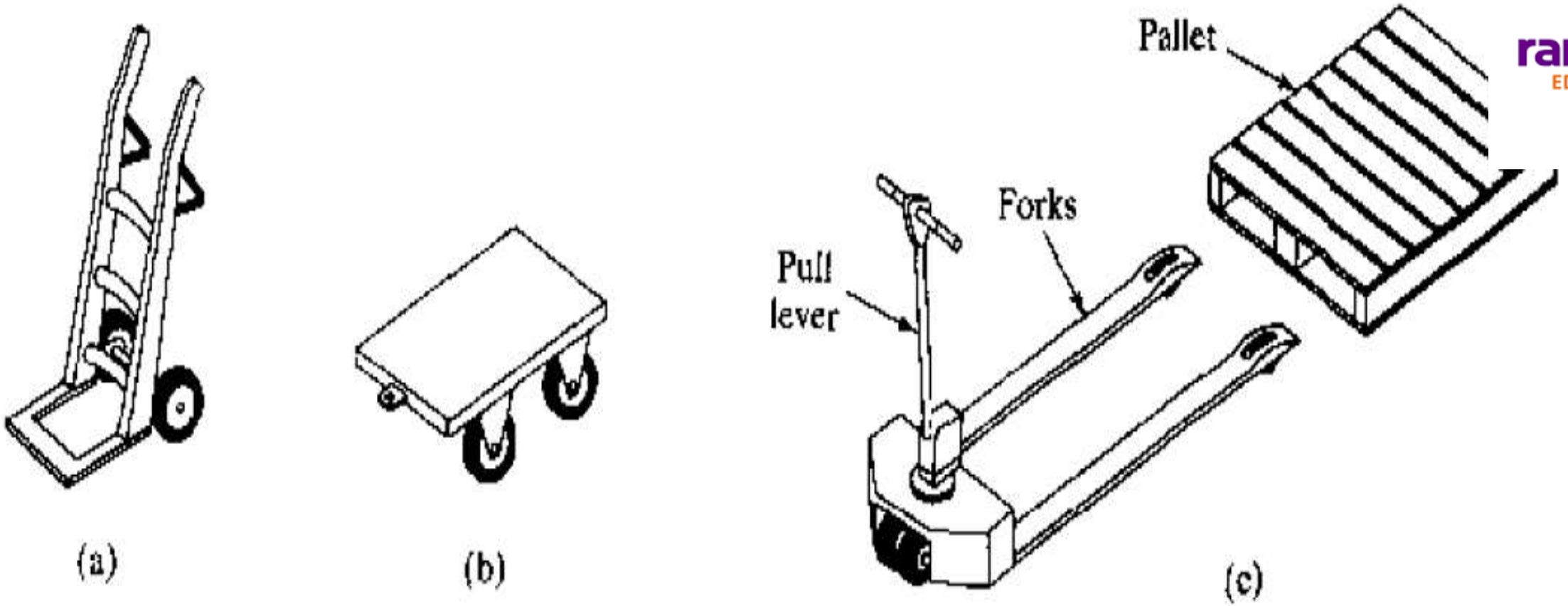


Figure 10.1 Examples of non-powered industrial trucks (hand trucks): (a) two-wheel hand truck, (b) four-wheel dolly, and (c) hand-operated low-lift pallet truck.

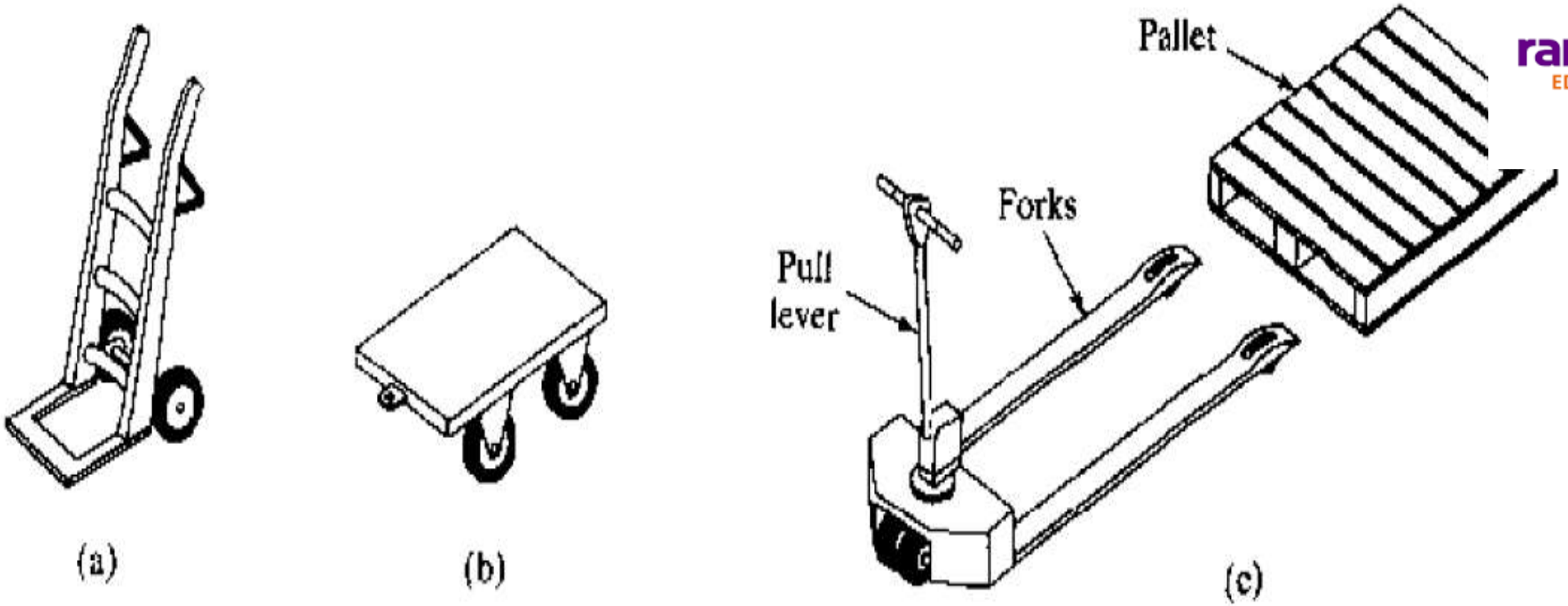


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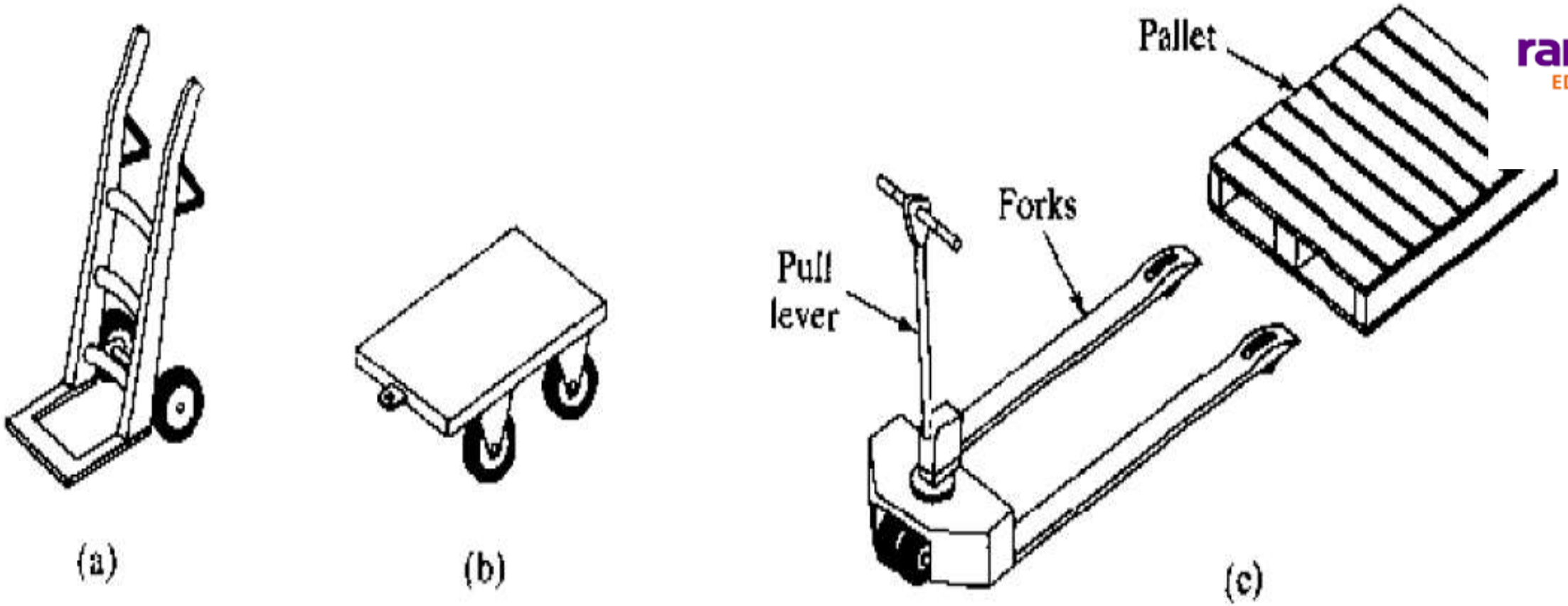


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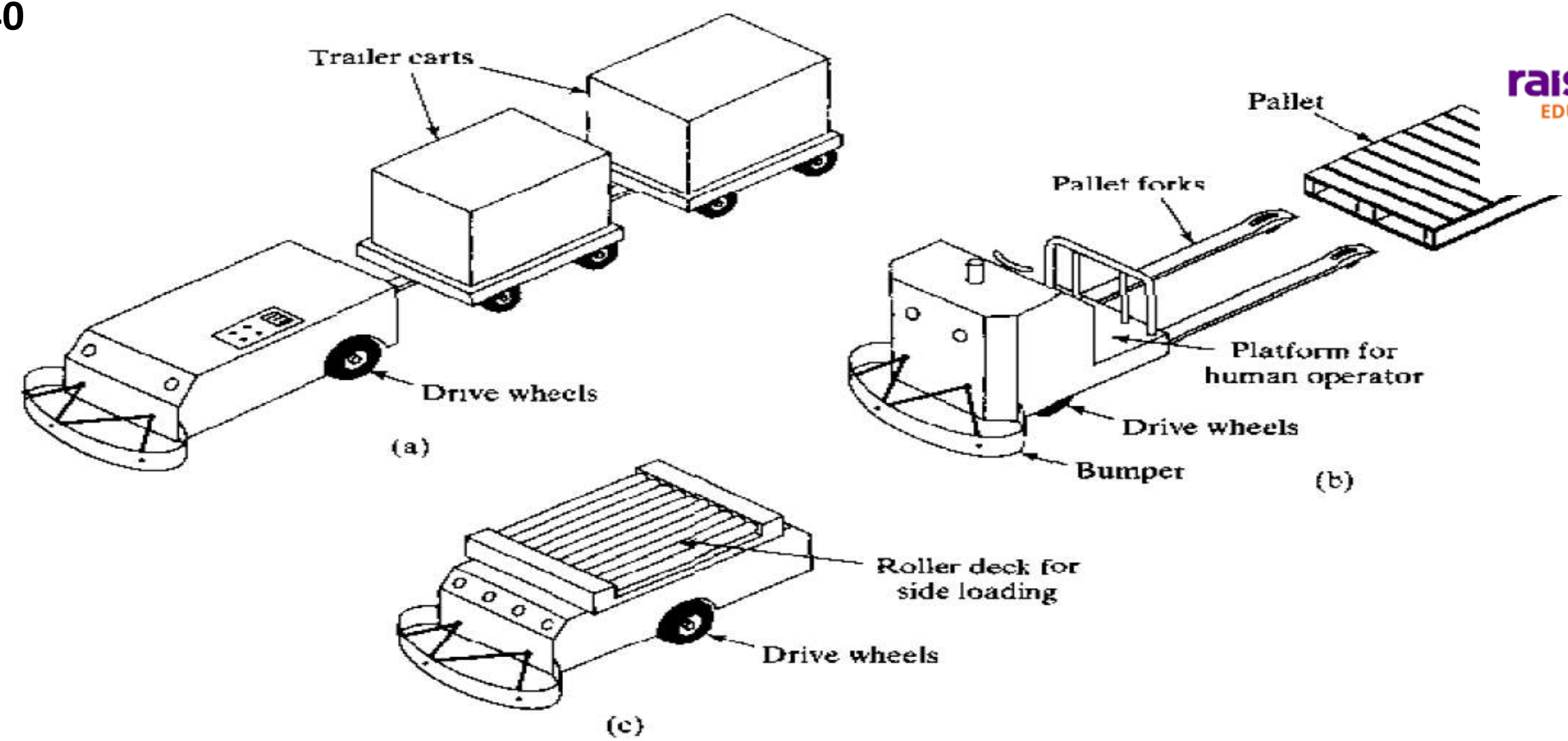


Figure 10.3 Three types of automated guided vehicles: (a) driverless automated guided train, (b) AGV pallet truck, and (c) unit load carrier.

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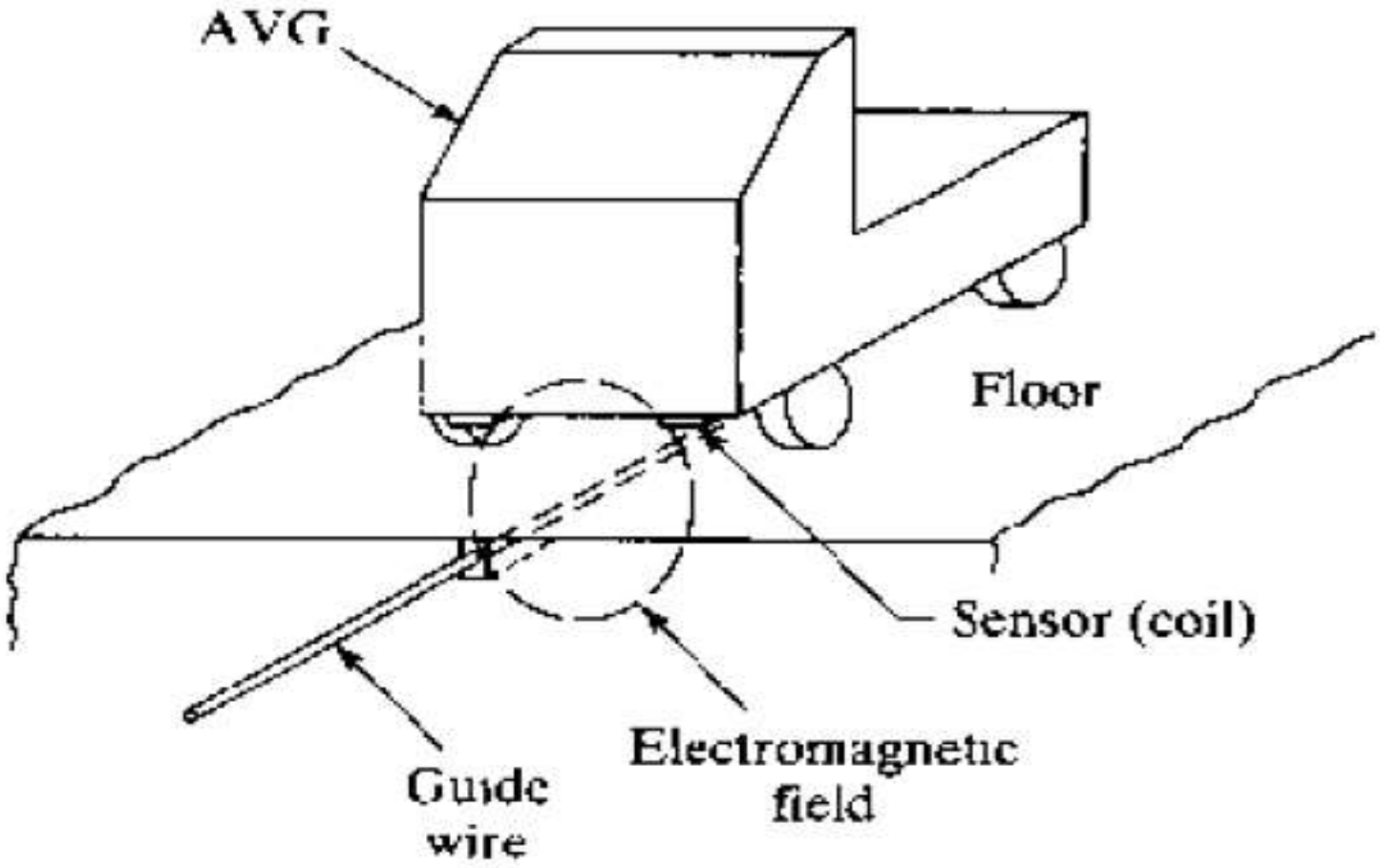


Figure 10.4 Operation of the on-board sensor system that uses two coils to track the magnetic field in the guide wire.

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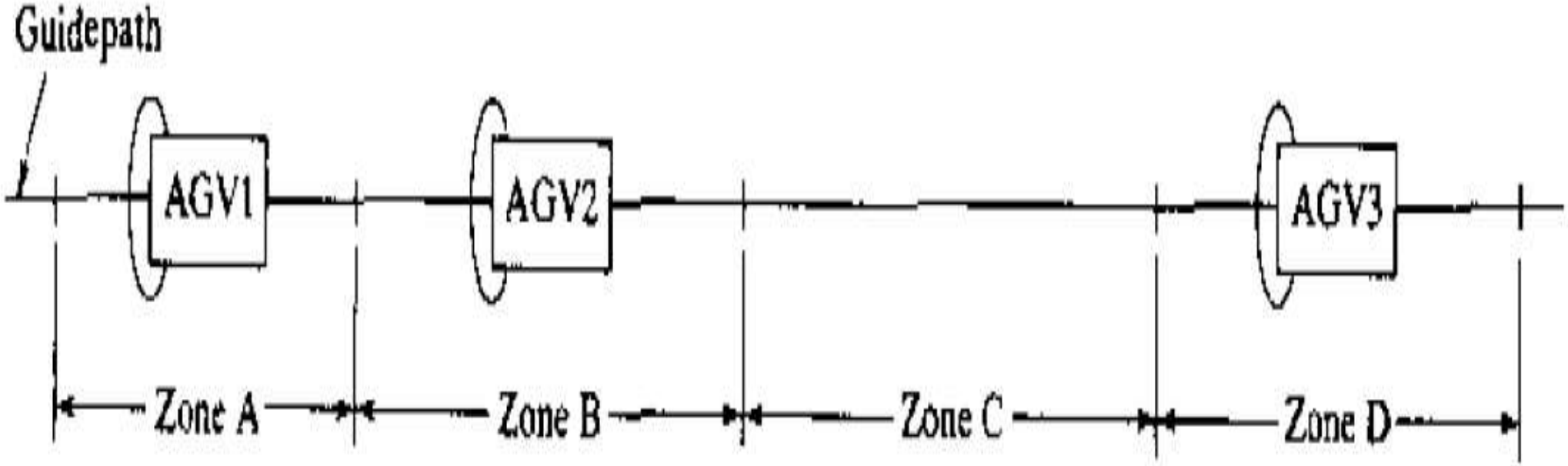


Figure 10.5 Zone control to implement blocking system. Zones A, B, and D are blocked. Zone C is free. Vehicle 2 is blocked from entering Zone A by Vehicle 1. Vehicle 3 is free to enter Zone C.

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THANK YOU