ENGINEERING PRODUCTION METHODS

BY: JITENDER JADON

SHOBHIT INSTITUTE OF ENGINEERING AND TECHNOLOGY

DEEMED TO BE UNIVERSITY

CONTENTS

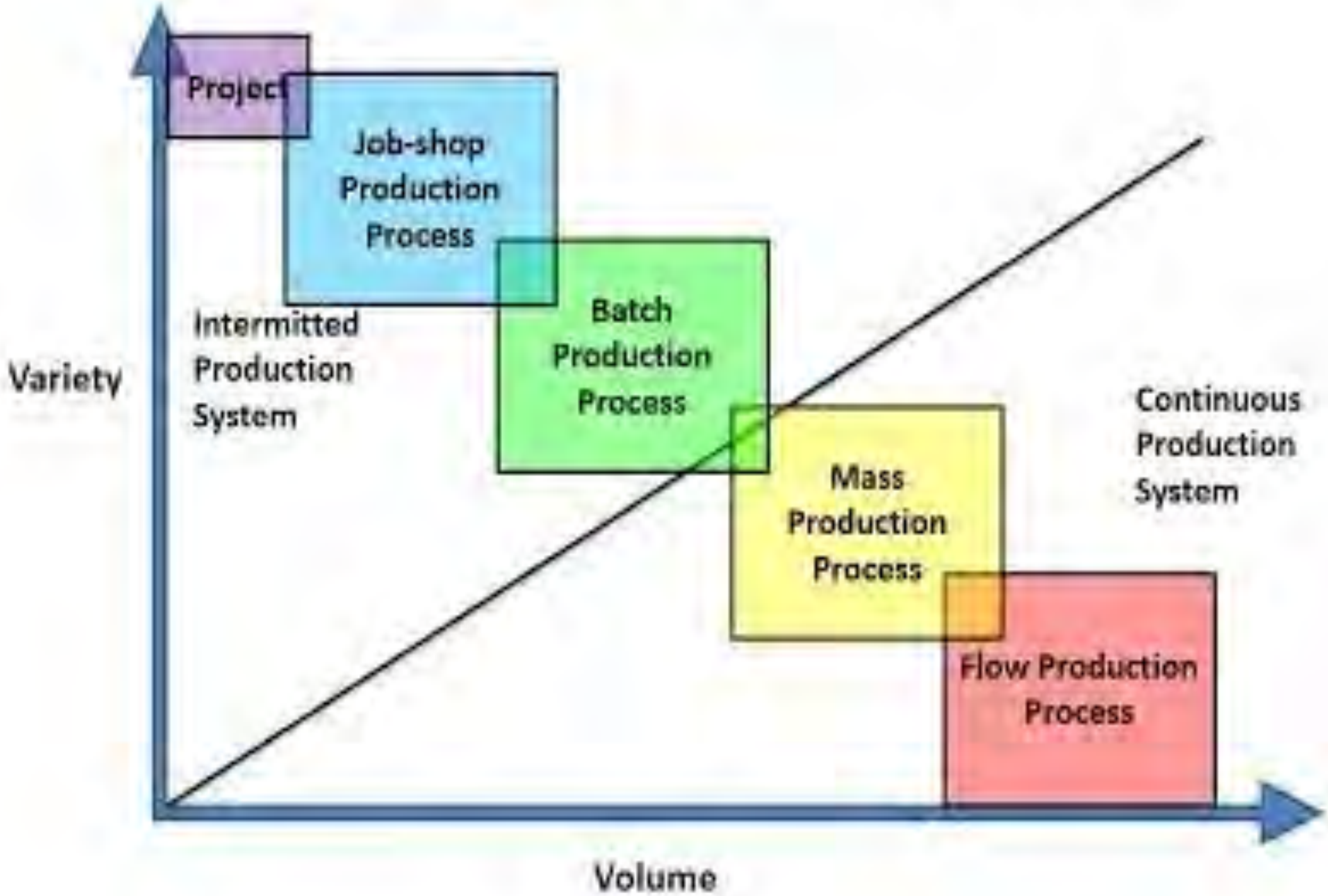
- Classifications of engineering production methods
- Major sequential steps in industrial production
- Quantity production methods of common engineering components
- Productivity
- Product quality and economy of automobile parts
- Methods of quantity production of cutting tools and tool inserts
- Small size products in large volume.

INTRODUCTION

- All production systems, when viewed at the most abstract level, might be said to be “transformation processes”—processes that transform resources into useful goods and services. The transformation process typically uses common resources such as labour, capital (for machinery and equipment, materials, etc.), and space (land, buildings, etc.) to effect a change. Economists call these resources the “factors of production” and usually refer to them as labour, capital, and land. Production managers refer to them as the “five M’s”: men, machines, methods, materials, and money.
- When viewed as a process, a production system may be further characterized by flows (channels of movement) in the process: both the physical flow of materials, work in the intermediate stages of manufacture (work in process), and finished goods; and the flow of information and the inevitable paperwork that carry and accompany the physical flow.

- The physical flows are subject to the constraints of the capacity of the production system, which also limits the system's ability to meet output expectations. Similarly, the capacity of the information-handling channel of the production system may also be an important measure of a system's output. The management of information flows, or the planning and control of the system to achieve acceptable outputs, is an important task of the production manager.
- While the capacity of the system is the major factor in determining whether output expectations can be met, the additional consideration of quality must also be seen as a limiting factor. The quality of a product, measured against some objective standard, includes appearance, performance characteristics, durability, serviceability, and other physical characteristics; timeliness of delivery; cost; appropriateness of documentation and supporting materials; and so on.

Types of Production Processes

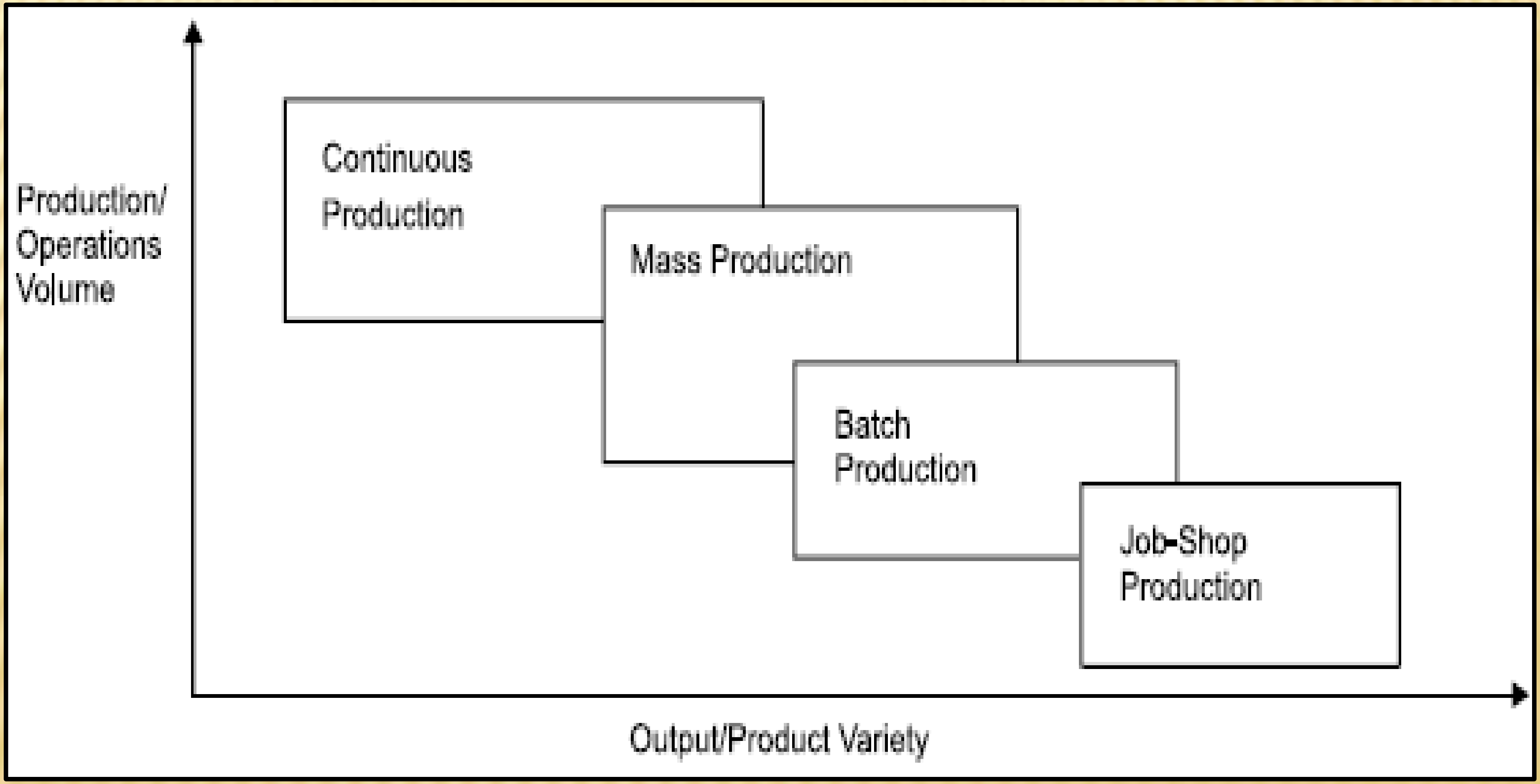


CLASSIFICATION OF ENGINEERING PRODUCTION METHODS

- The production system of an organization is that part, which produces products of an organization. It is that activity whereby resources, flowing within a defined system, are combined and transformed in a controlled manner to add value in accordance with the policies communicated by management. The production system has the following characteristics:

  - Production is an organized activity, so every production system has an objective.
  - The system transforms the various inputs to useful outputs.
  - It does not operate in isolation from the other organization system.
  - There exists a feedback about the activities, which is essential to control and improve system performance.

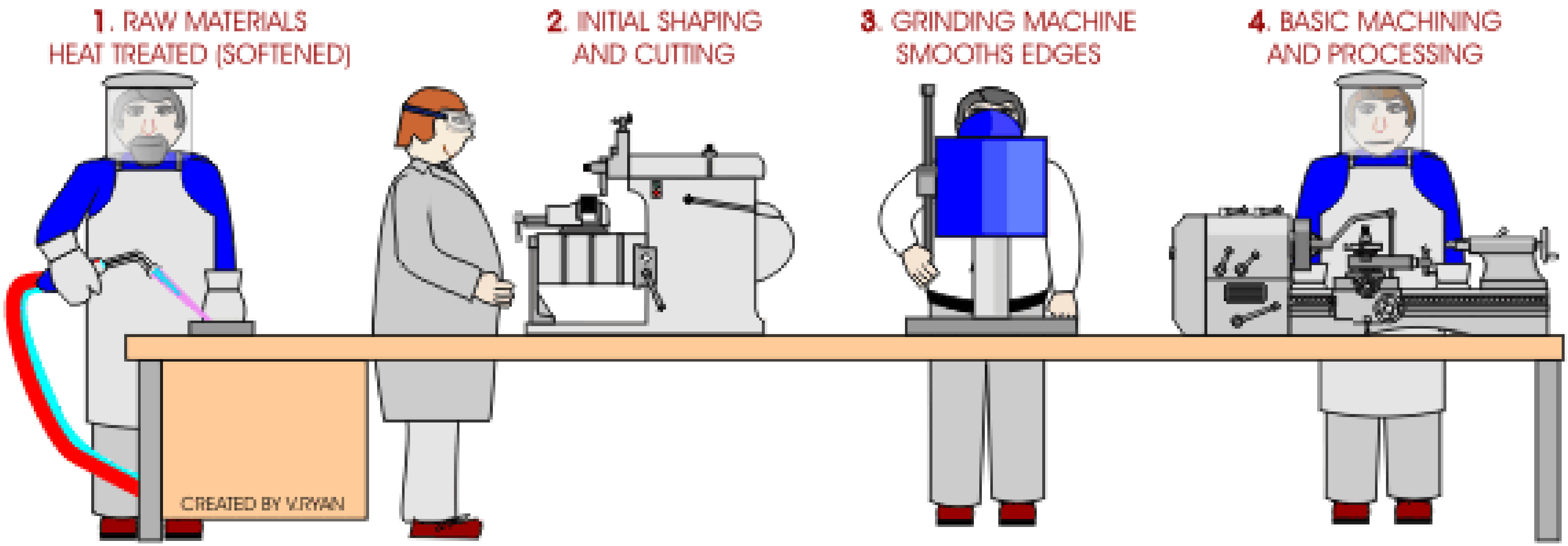
CLASSIFICATION OF ENGINEERING PRODUCTION METHODS



JOB PRODUCTION

- Under this method peculiar, special or non-standardized products are produced in accordance with the orders received from the customers. As each product is non- standardized varying in size and nature, it requires separate job for production. The machines and equipment's are adjusted in such a manner so as to suit the requirements of a particular job.
- Job production involves intermittent process as the work is carried as and when the order is received. It consists of bringing together of material, parts and components in order to assemble and commission a single piece of equipment or product.
- Ship building, dam construction, bridge building, book printing are some of the examples of job production. Third method of plant layout viz., Stationery Material Layout is suitable for job production.

JOB PRODUCTION



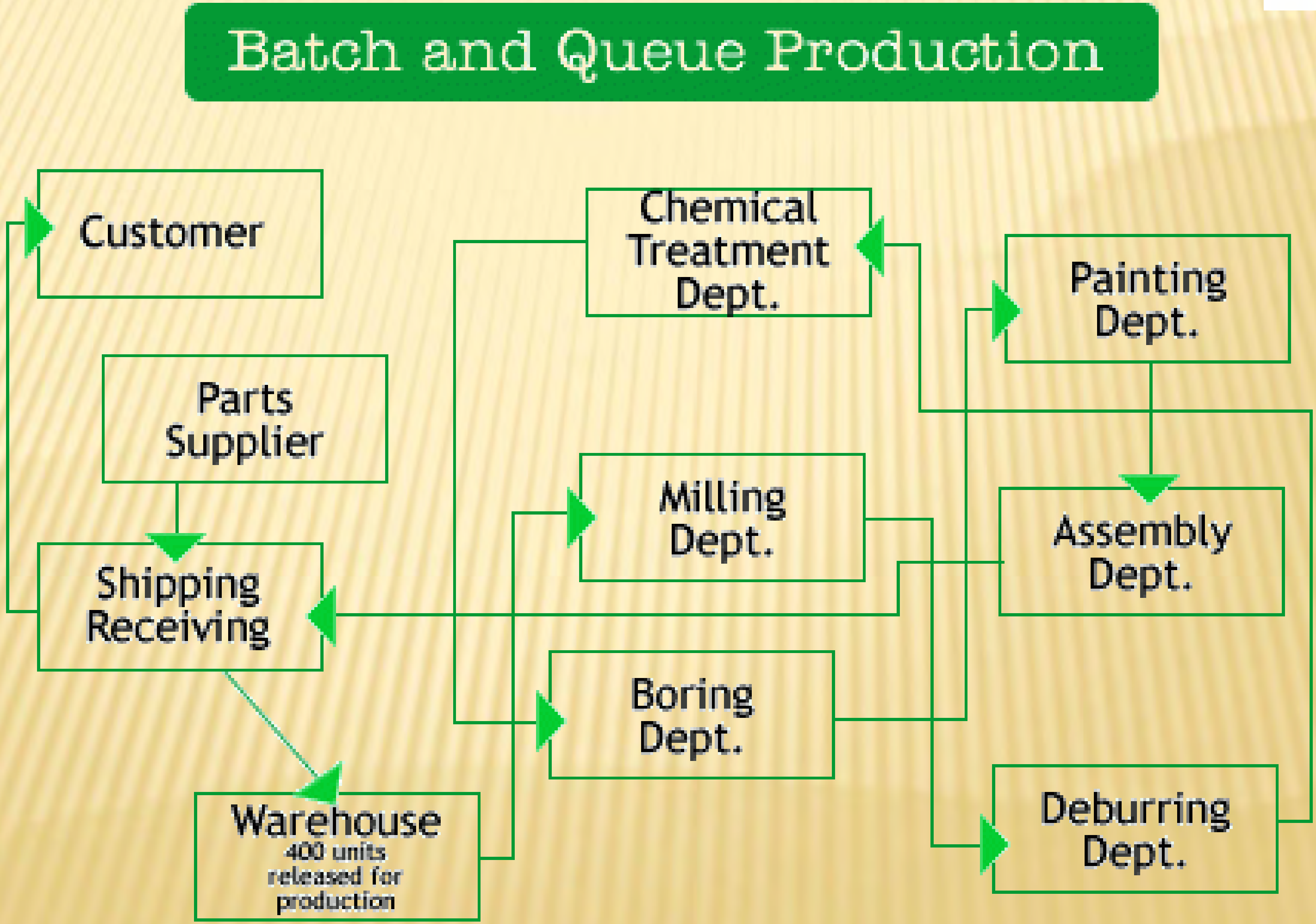
BATCH PRODUCTION

- Batch production pertains to repetitive production. It refers to the production of goods, the quantity of which is known in advance. It is that form of production where identical products are produced in batches on the basis of demand of customers' or of expected demand for products.
- This method is generally similar to job production except the quantity of production. Instead of making one single product as in case of job production, a batch or group of products are produced at one time. It should be remembered here that one batch of products may not resemble with the next batch.
- Under batch system of production the work is divided into operations and one operation is done at a time. After completing the work on one operation it is passed on to the second operation and so on till the product is completed.

BATCH PRODUCTION

- Batch production can be explained with the help of an illustration. An enterprise wants to manufacture 20 electric motors.
- The work will be divided into different operations. The first operation on all the motors will be completed in the first batch and then it will pass on to the next operation. The second group of operators will complete the second operation before the next and so on. Under job production the same operators will manufacture full machine and not one operation only.
- Batch production can fetch the benefits of repetitive production to a large extent, if the batch is of a sufficient quantity. Thus batch production may be defined as the manufacture of a product in small or large batches or lots by series of operations, each operation being carried on the whole batch before any subsequent operation is operated. This method is generally adopted in case of biscuit and confectionery and motor manufacturing, medicines, tinned food and hardware’s like nuts and bolts etc.

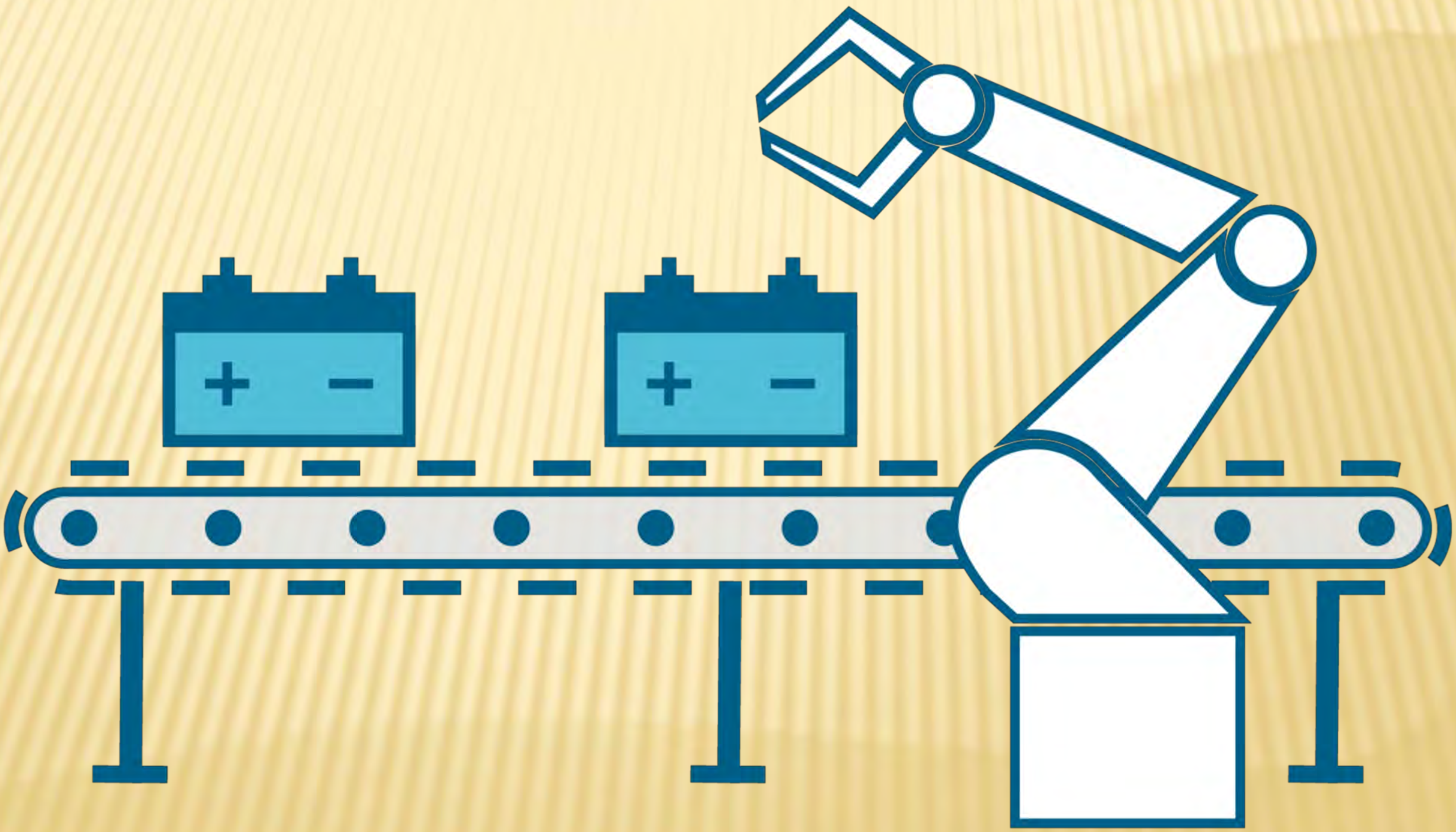
BATCH PRODUCTION



MASS PRODUCTION

- This method involves a continuous production of standardized products on a large scale. Under this method, production remains continuous in anticipation of future demand. Standardization is the basis of mass production. Standardized products are produced under this method by using standardized materials and equipment. There is a continuous or uninterrupted flow of production obtained by arranging the machines in a proper sequence of operations. Process layout is best suited method for mass production units.
- Flow production is the manufacture of a product by a series of operations, each article going on to a succeeding operation as soon as possible. The manufacturing process is broken into separate operations.
- The product completed at one operation is automatically passed on to the next till its completion. There is no time gap between the work done at one process and the starting at the next. The flow of production is continuous and progressive.

MASS PRODUCTION



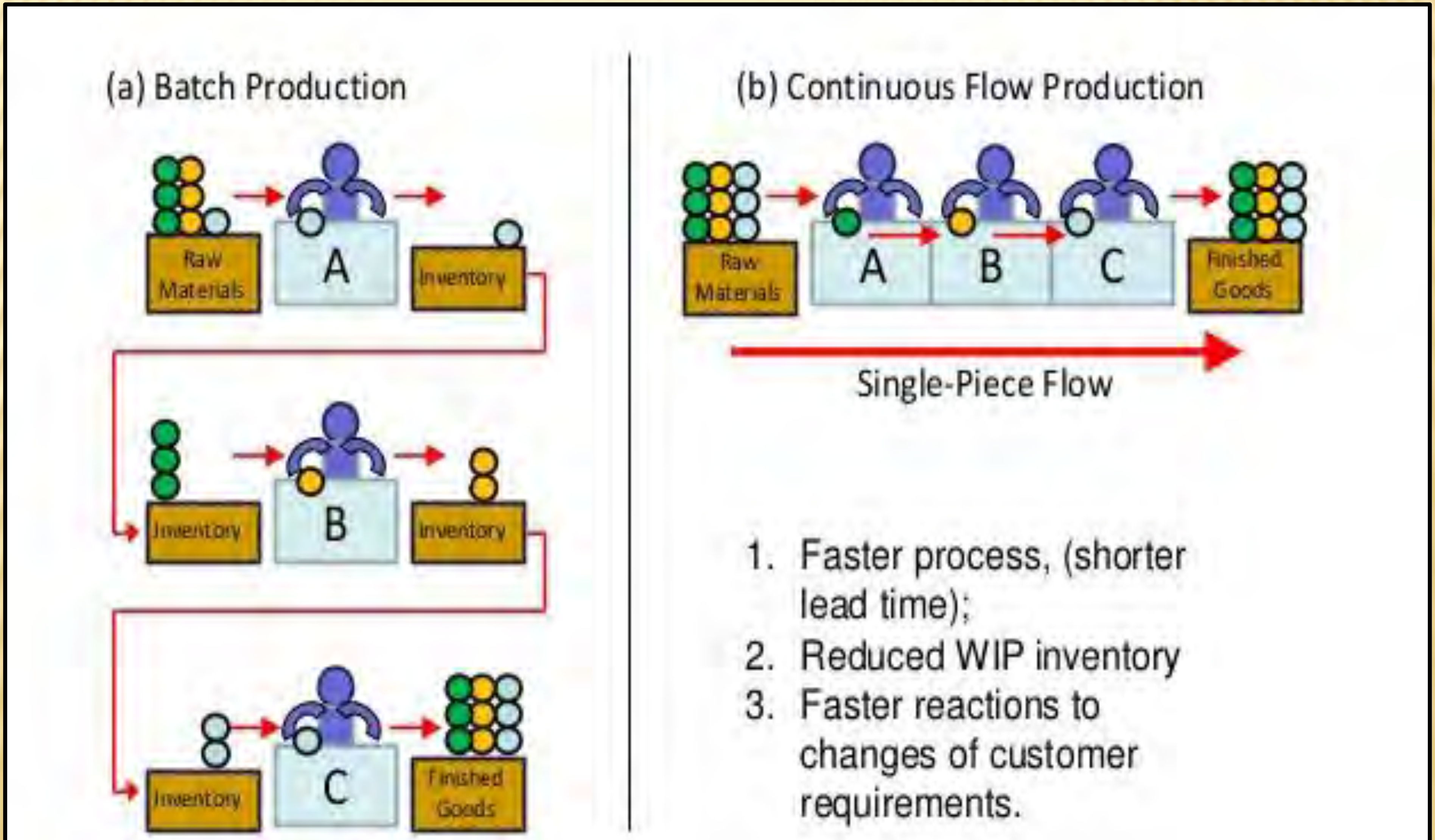
CONTINUOUS PRODUCTION

- Production facilities are arranged as per the sequence of production operations from the first operations to the finished product. The items are made to flow through the sequence of operations through material handling devices such as conveyors, transfer devices, etc.

- *Characteristics*

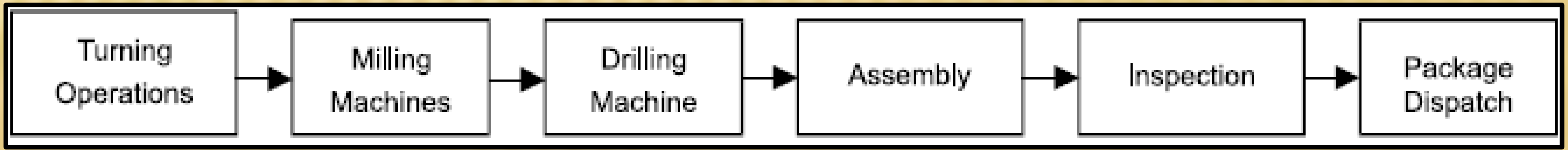
  Continuous production is used under the following circumstances:
- Dedicated plant and equipment with zero flexibility.
- Material handling is fully automated.
- Process follows a predetermined sequence of operations.
- Component materials cannot be readily identified with final product.
- Planning and scheduling is a routine action.

Batch vs Continuous Production



PRODUCT LAYOUT

- Machines and auxiliary services are located according to the processing sequence of the product. If the volume of production of one or more products is large, the facilities can be arranged to achieve efficient flow of materials and lower cost per unit. Special purpose machines are used which perform the required function quickly and reliably.
- The product layout is selected when the volume of production of a product is high such that a separate production line to manufacture it can be justified. In a strict product layout, machines are not shared by different products. Therefore, the production volume must be sufficient to achieve satisfactory utilization of the equipment. A typical product layout is shown in the following figure.



Advantages of Product Layout

- The flow of product will be smooth and logical in flow lines.
- In-process inventory is less.
- Throughput time is less.
- Minimum material handling cost.
- Simplified production, planning and control systems are possible.
- Less space is occupied by work transit and for temporary storage.
- Reduced material handling cost due to mechanised handling systems and straight flow.
- Perfect line balancing which eliminates bottlenecks and idle capacity.
- Manufacturing cycle is short due to uninterrupted flow of materials.
- Small amount of work-in-process inventory.
- Unskilled workers can learn and manage the production.

LIMITATIONS OF PRODUCT LAYOUT

- A breakdown of one machine in a product line may cause stoppages of machines in the downstream of the line.
- A change in product design may require major alterations in the layout.
- The line output is decided by the bottleneck machine.
- Comparatively high investment in equipments is required.
- *Lack of flexibility*. A change in product may require the facility modification.

QUANTITY PRODUCTION METHODS

- Refining and Alloying
- Casting
- Metal Forming
- Metal Cutting
- Welding
- Assembly
- Finishing

EVALUATING THE COST

- Cost estimation is used to predict the quantity, cost and price of the resources required by the scope of a project. The accuracy of the estimate depends heavily on the level of project scope definition: as the design and conditions of the project become better defined, so do the estimated values.
- Cost estimation is needed to provide decision-makers with the means to make investment decisions, choose between alternatives and to set up the budget during the front end of projects. For this, estimates made by vendors and contractors need to be validated by clients as well. In later phases of the product, the budget estimate is used as a baseline to assess the performance of a product.

  Related to this principle, it is always challenging to collect and read the huge amount of cost data, which doesn't help with the decision making. Analyzing and visualizing the cost data opens the doors to making the data useful and meaningful. The dashboards of a project control software system are the data-driven graphical representations of a product; dashboards can provide decision-makers with a quick overview of a product's progress and turn the data into decision points.

EVALUATING THE COST

- Estimating is done by breaking down the total scope of a project in manageable parts, to which resources and cost can be assigned. There are standardized ways of breaking down a product, like the Work Breakdown Structure (WBS) and the Cost Breakdown Structure (CBS), but depending on the needs, multiple structures are often implemented to align reporting and sharing of cost data.
- A cost estimate is more than a list of costs. It also includes a detailed Basis of Estimate (BOE) report that describes the assumptions, inclusions, exclusions, accuracy and other aspects that are needed to interpret the total product cost. Otherwise, it would be a meaningless number. The BOE is required to communicate the estimate to the various parties involved in the decision making but is also handy during closeout when the performance of the product is compared with other products.

An accurate estimation method can be the difference between a successful plan and a failed one. Keep these 4 principles in mind and you already have a framework to start making estimates. Make sure to set up the estimate in a structured way to allow for an easy transition into project cost estimating software, which will help you make more accurate estimates in the long run.

REFINING AND ALLOYING

Properties often tested for in metals:

- **TENSILE STRENGTH:** Tensile strength is the ability of a metal to resist being pulled apart by opposing forces acting in a straight line. It is expressed as the number of pounds of force required to pull apart a bar of the material 1 inch wide and 1 inch thick.
- **SHEAR STRENGTH:** Shear strength is the ability of a metal fractured by opposing forces not acting in to resist being a straight line. Shear strength can be controlled by varying the hardness of the metal.
- **COMPRESSIVE STRENGTH:** Compressive strength is the ability of a metal to withstand pressures acting on a given plane.
- **ELASTICITY:** Elasticity is the ability of metal to return to its original size and shape after being stretched or pulled out of shape

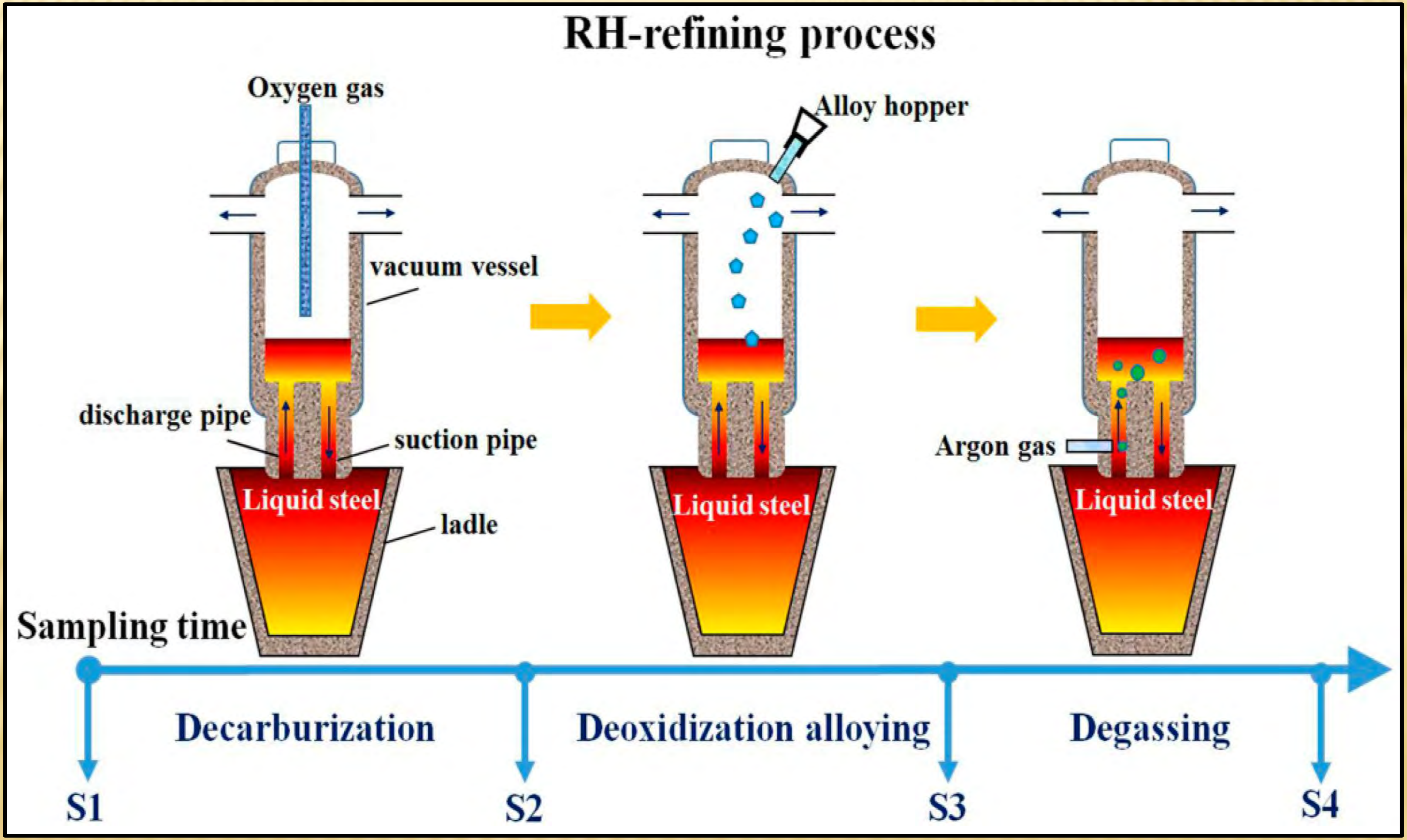
REFINING AND ALLOYING

- **DUCTILITY:** Ductility is the ability of a metal to be drawn or stretched permanently without rupture or fracture . Metals that lack ductility will crack or break before bending.
- **MALLEABILITY:** Malleability is the ability of a metal to be hammered, rolled, or pressed into various shapes without rupture or fracture.
- **TOUGHNESS:** Toughness is the ability of a metal to resist fracture plus the ability to resist failure after the damage has begun. A tough metal can withstand considerable stress, slowly or suddenly applied, and will deform before failure.
- **HARDNESS:** Hardness is the ability of a metal to resist penetration and wear by another metal or material. It takes a combination of hardness and toughness to withstand heavy pounding. The hardness of a metal limits the ease with which it can be machined, since toughness decreases as hardness increases.

REFINING AND ALLOYING

- **MACHINABILITY AND WELDABILITY:** Machinability and weldability are the ease or difficulty with which a material can be machined or welded.
- **CORROSION RESISTANCE:** Corrosion resistance is the resistance to eating or wearing away by air, moisture, or other agents.
- **HEAT AND ELECTRICAL CONDUCTIVITY:** Heat and electrical conductivity is the ease with which a metal conducts or transfers heat or electricity.
- **BRITTLENESS:** Brittleness is the tendency of a material to fracture or break with little or no deformation, bending, or twisting. Brittleness is usually not a desirable mechanical property. Normally, the harder the metal, the more brittle it is.

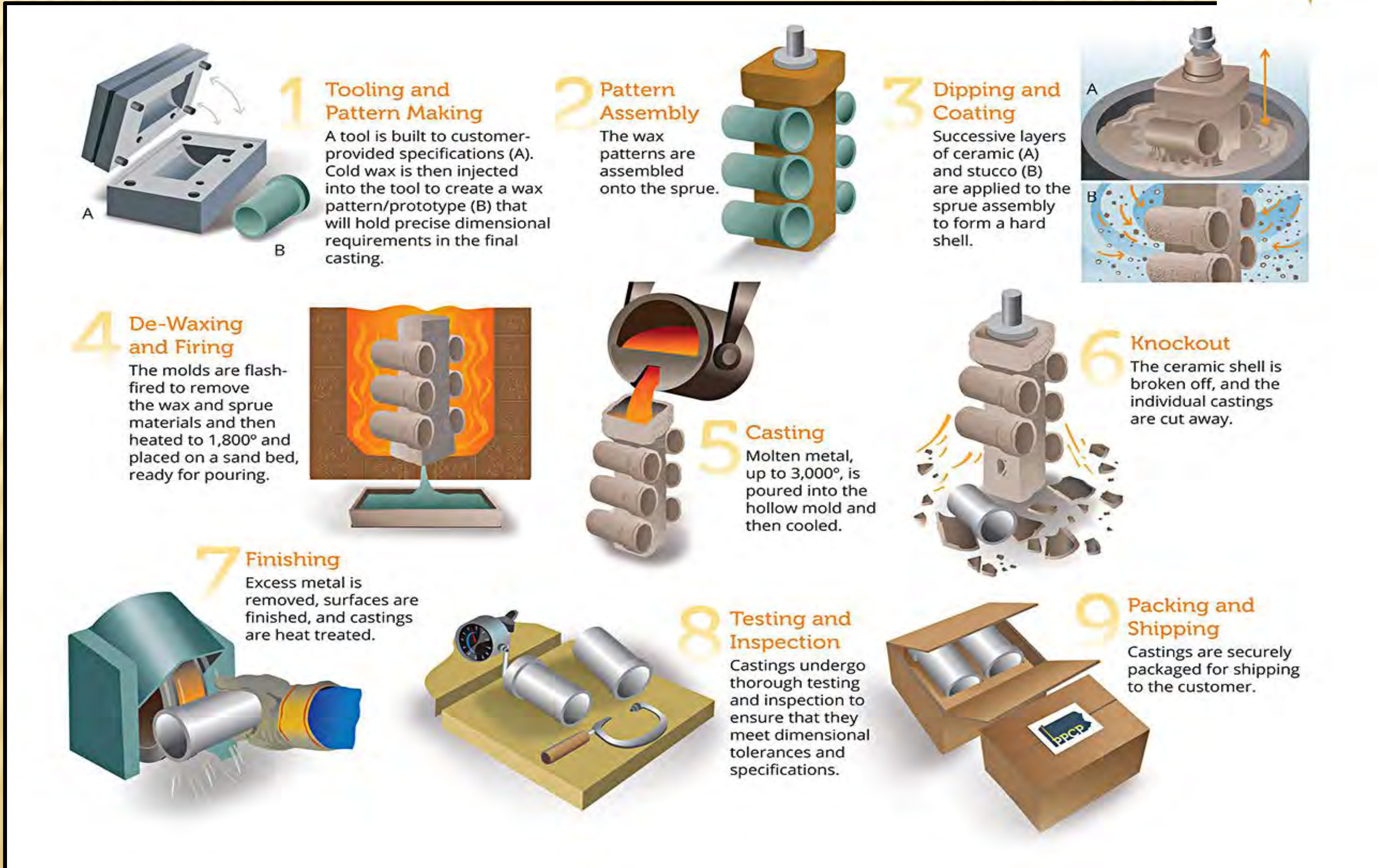
REFINING AND ALLOYING



CASTING

- Casting is a process by which a material is introduced into a mold while it is liquid, allowed to solidify in the shape inside the mold, and then removed producing a fabricated object, part, or casing.
- Casting is often used for creating one or more copies of an original piece of sculptural (three-dimensional) artwork. It is also used extensively in the automobile manufacture industry, such as the casting of engine blocks or cylinder heads, or vacuum-forming of plastics and in the lost core process.
- Casting may be used to form hot, liquid metals or meltable plastics (called thermoplastics), or various materials that cold set after mixing of components such as certain plastic resins (e.g. epoxy), water setting materials such as concrete or plaster, and materials that become liquid or paste when moist such as clay, which when dry enough to be rigid is removed from the mold, further dried, and fired in a kiln.

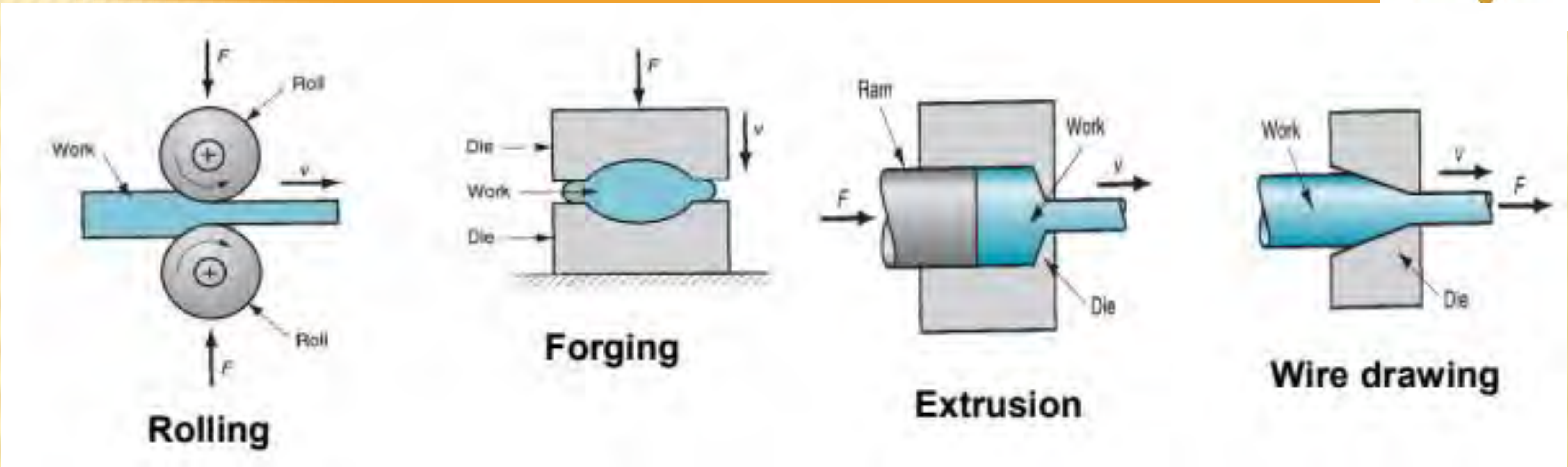
CASTING


1 Tooling and Pattern Making
A tool is built to customer-provided specifications (A). Cold wax is then injected into the tool to create a wax pattern/prototype (B) that will hold precise dimensional requirements in the final casting.
A
B
2 Pattern Assembly
The wax patterns are assembled onto the sprue.
3 Dipping and Coating
Successive layers of ceramic (A) and stucco (B) are applied to the sprue assembly to form a hard shell.
A
B
4 De-Waxing and Firing
The molds are flash-fired to remove the wax and sprue materials and then heated to 1,800° and placed on a sand bed, ready for pouring.
5 Casting
Molten metal, up to 3,000°, is poured into the hollow mold and then cooled.
6 Knockout
The ceramic shell is broken off, and the individual castings are cut away.
7 Finishing
Excess metal is removed, surfaces are finished, and castings are heat treated.
8 Testing and Inspection
Castings undergo thorough testing and inspection to ensure that they meet dimensional tolerances and specifications.
9 Packing and Shipping
Castings are securely packaged for shipping to the customer.

METAL FORMING

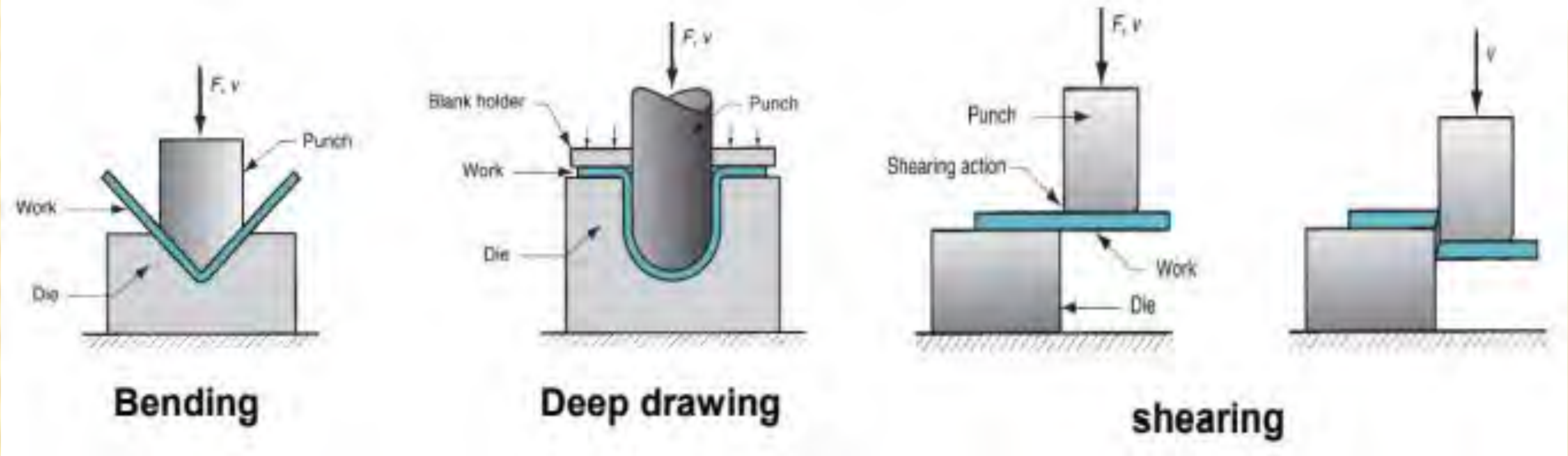
- **Metal forming:** Large set of manufacturing processes in which the material is deformed plastically to take the shape of the die geometry. The tools used for such deformation are called die, punch etc. depending on the type of process.
- **Plastic deformation:** Stresses beyond yield strength of the workpiece material is required.
- **Categories:** Bulk metal forming, Sheet metal forming

CLASSIFICATION OF BASIC BULK FORMING PROCESSES



- **Rolling**: In this process, the workpiece in the form of slab or plate is compressed between two rotating rolls in the thickness direction, so that the thickness is reduced. The rotating rolls draw the slab into the gap and compresses it. The final product is in the form of sheet.
- **Forging:** The workpiece is compressed between two dies containing shaped contours. The die shapes are imparted into the final part.
- **Extrusion:** In this, the workpiece is compressed or pushed into the die opening to take the shape of the die hole as its cross section.
- **Wire or rod drawing:** similar to extrusion, except that the workpiece is pulled through the die opening to take the cross-section

CLASSIFICATION OF BASIC SHEET FORMING PROCESSES



- **Bending:** In this, the sheet material is strained by punch to give a bend shape (angle shape) usually in a straight axis.
- **Deep (or cup) drawing:** In this operation, forming of a flat metal sheet into a hollow or concave shape like a cup, is performed by stretching the metal in some regions. A blank-holder is used to clamp the blank on the die, while the punch pushes into the sheet metal. The sheet is drawn into the die hole taking the shape of the cavity.
- **Shearing:** This is nothing but cutting of sheets by shearing action.

METAL CUTTING

- Metal cutting is "the process of removing unwanted material in the form of chips, from a block of metal, using cutting tool". A person who specializes in machining is called a machinist. A room, building or company where machining is done is called a Machine Shop.
- **The basic elements involved in this process are:**
- (i) A block of metal (work piece). (ii) Cutting Tool.
- (iii) Machine Tool. (iv) Cutting Fluid.
- (v) Cutting speed (Primary Motion).
- (vi) Feed (Secondary Motion).
- (vii) Chips.
- (viii) Work holding and Fixturing.
- (ix) Force and Energy Dissipated, and
- (x) Surface Finish.

Types of Cutting Processes (Operations):

(i) Turning: Turning is used to generate a cylindrical shape. In this process, the work piece is rotated and cutting tool removes the unwanted material in the form of chips. The cutting tool has single cutting edge. The speed motion is provided by the rotating work piece, and the feed motion is achieved by the cutting tool moving slowly in a direction parallel to the axis of rotation of the work piece.

(ii) Drilling: Drilling is used to create a round hole. In this process, the cutting tool is rotated and feed against the work piece fixed in a holding device. The cutting tool typically has two or more cutting edges. The tool is fed in a direction parallel to its axis of rotation into the work piece to form the round hole.

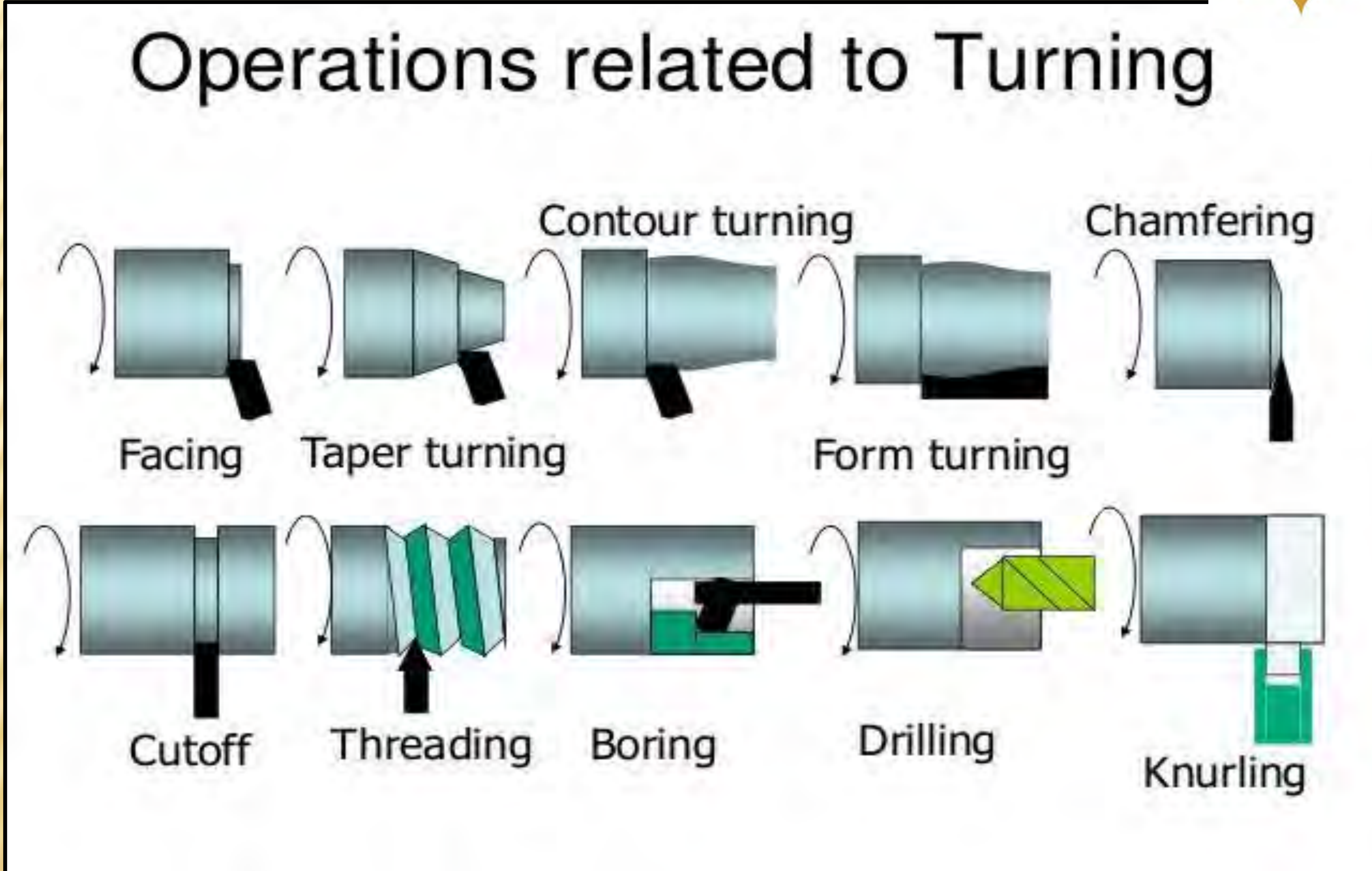
Types of Cutting Processes (Operations):

(iii) Boring: Boring is used to enlarge an already drilled hole. It is a fine finishing operation used in the final stage of product manufacture.

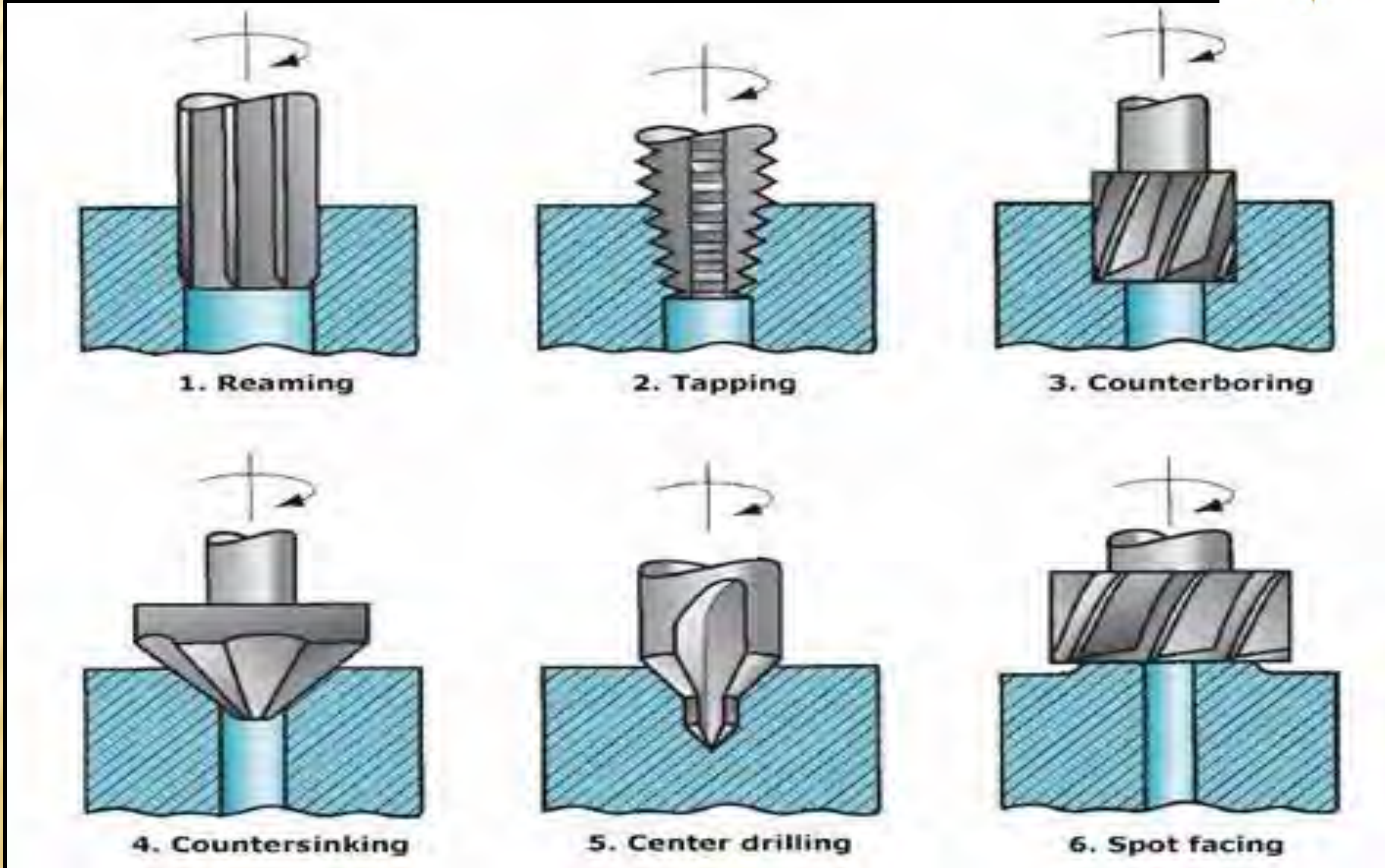
(iv) Milling: Milling is used to remove a layer of material from the work surface. It is also used to produce a cavity in the work surface. In the first case it is known as slab-milling and in second case it is known as end- milling. Basically, the milling process is used to produce a plane or straight surface. The cutting tool used has multiple cutting edges. The speed motion is provided by the rotating milling cutter. The direction of the feed motion is perpendicular to the tool's axis of rotation.

(v) Cutting-Off: Cutting-off is used to cut the metal into two parts. In this operation, the work piece is rotated and cutting tool moves radially inward to separates the components.

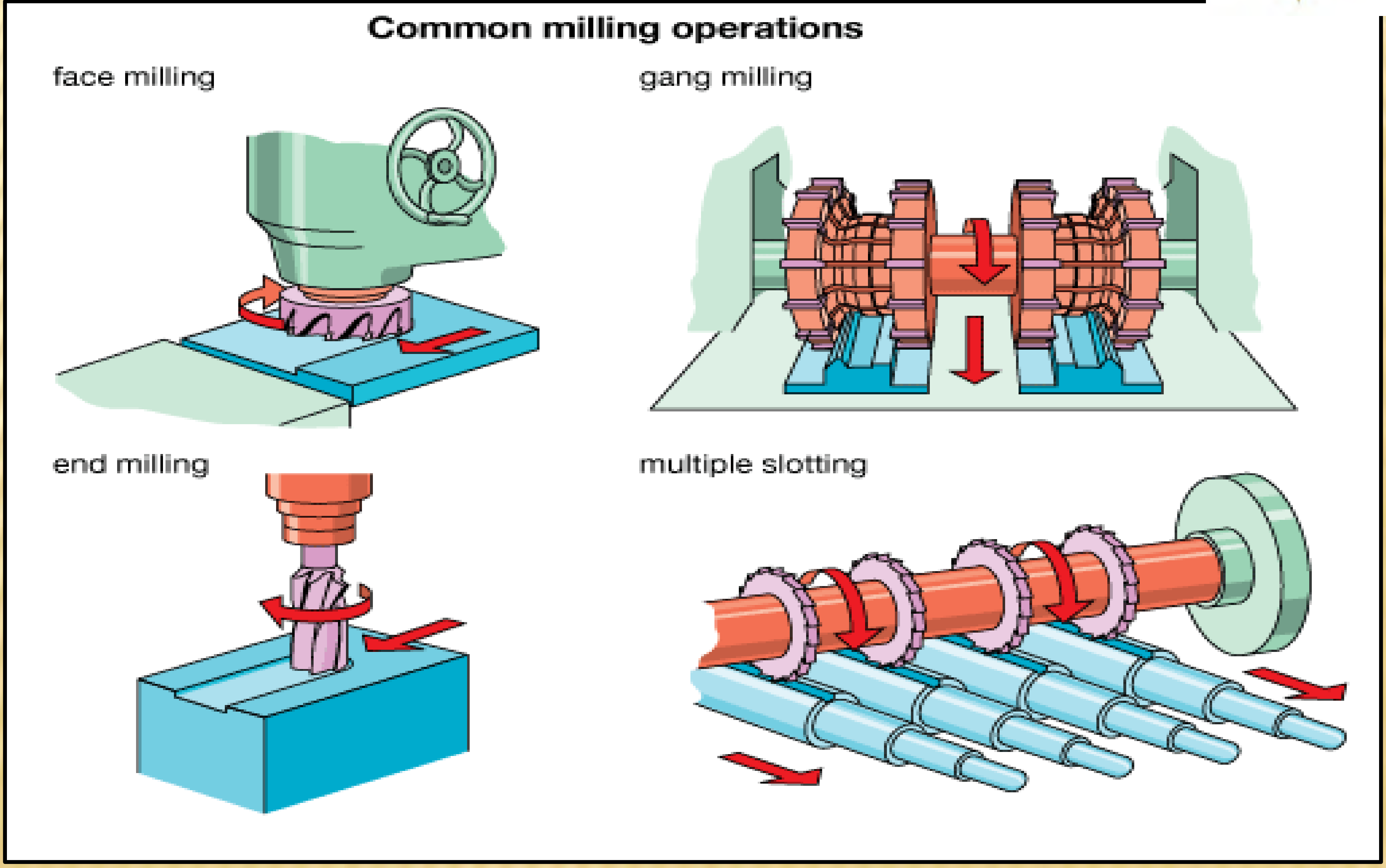
TYPES OF CUTTING PROCESSES (TURNING):



TYPES OF CUTTING PROCESSES (DRILLING):



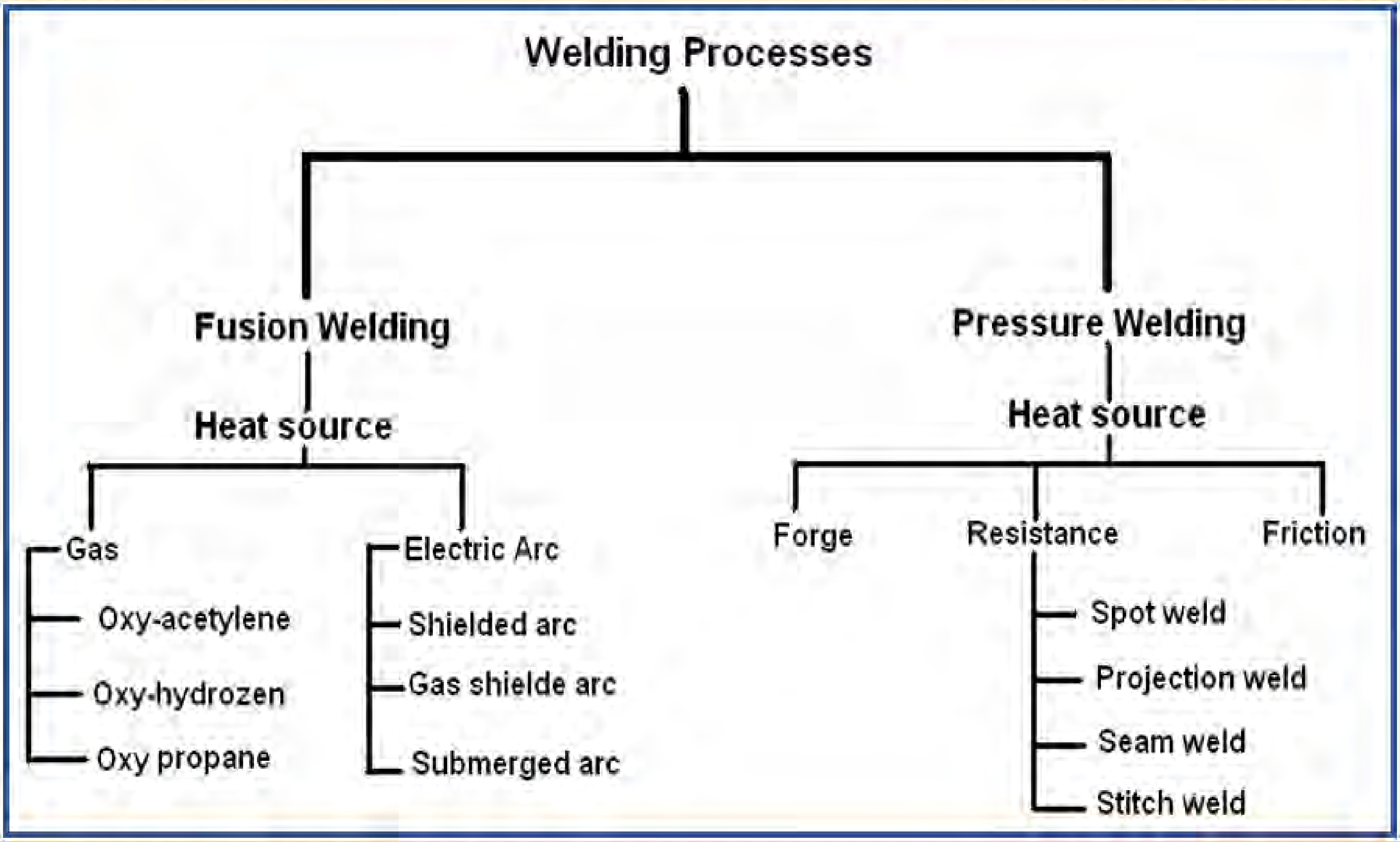
Types of Cutting Processes (Milling):



WELDING

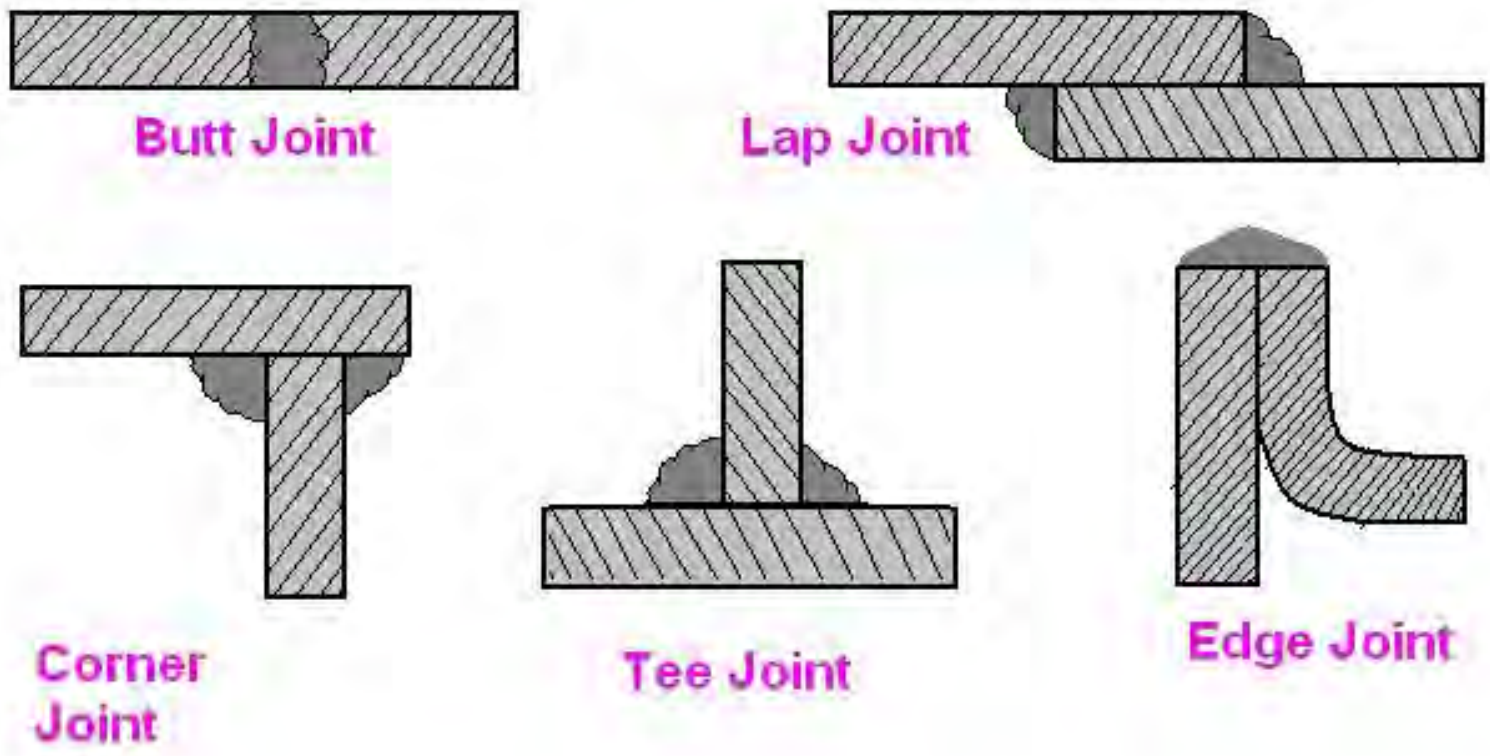
- **Welding**, technique used for joining metallic parts usually through the application of heat. This technique was discovered during efforts to manipulate iron into useful shapes. The process of carburization of iron to produce hard steel was known at this time, but the resultant steel was very brittle. The welding technique—which involved inter-layering relatively soft and tough iron with high-carbon material, followed by hammer forging—produced a strong, tough blade.
- A weld can be defined as a coalescence of metals produced by heating to a suitable temperature with or without the application of pressure, and with or without the use of a filler material.
- In fusion welding a heat source generates sufficient heat to create and maintain a molten pool of metal of the required size. The heat may be supplied by electricity or by a gas flame. Electric resistance welding can be considered fusion welding because some molten metal is formed.
- Solid-phase processes produce welds without melting the base material and without the addition of a filler metal. Pressure is always employed, and generally some heat is provided. Frictional heat is developed in ultrasonic and friction joining, and furnace heating is usually employed in diffusion bonding.

WELDING


Welding Processes
Fusion Welding
Heat source
Gas
Oxy-acetylene
Oxy-hydrozen
Oxy propane
Electric Arc
Shielded arc
Gas shielde arc
Submerged arc
Pressure Welding
Heat source
Forge
Resistance
Spot weld
Projection weld
Seam weld
Stitch weld
Friction

WELDING

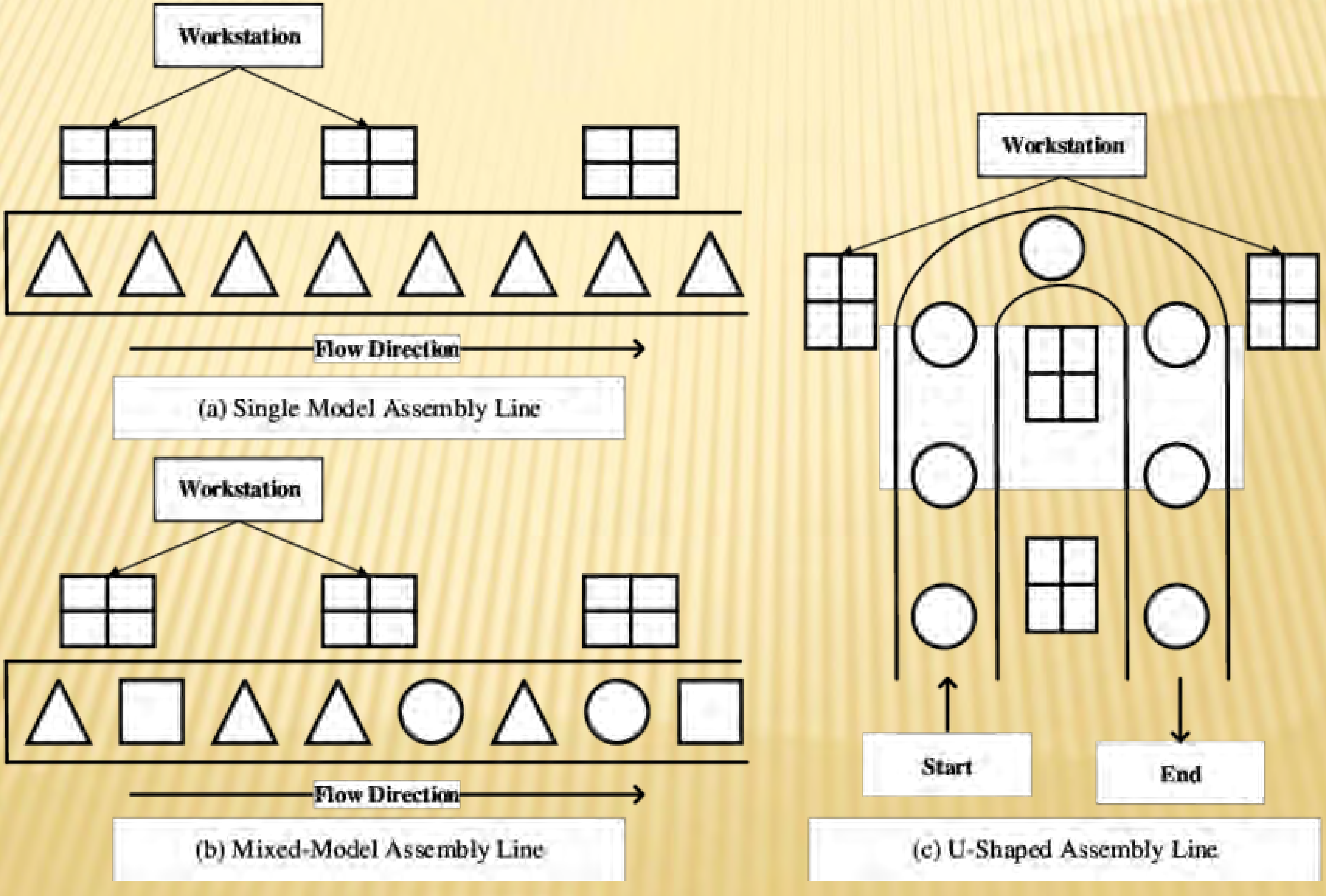
Welding Joints



ASSEMBLY

- An **assembly** is a manufacturing process (often called a *progressive assembly*) in which parts (usually interchangeable parts) are added as the semi-finished assembly moves from workstation to workstation where the parts are added in sequence until the final assembly is produced. By mechanically moving the parts to the assembly work and moving the semi-finished assembly from work station to work station, a finished product can be assembled faster and with less labor than by having workers carry parts to a stationary piece for assembly.
- Assembly lines are designed for the sequential organization of workers, tools or machines, and parts. The motion of workers is minimized to the extent possible. All parts or assemblies are handled either by conveyors or motorized vehicles such as fork lifts, or gravity, with no manual trucking. Heavy lifting is done by machines such as overhead cranes or forklifts. Each worker typically performs one simple operation.

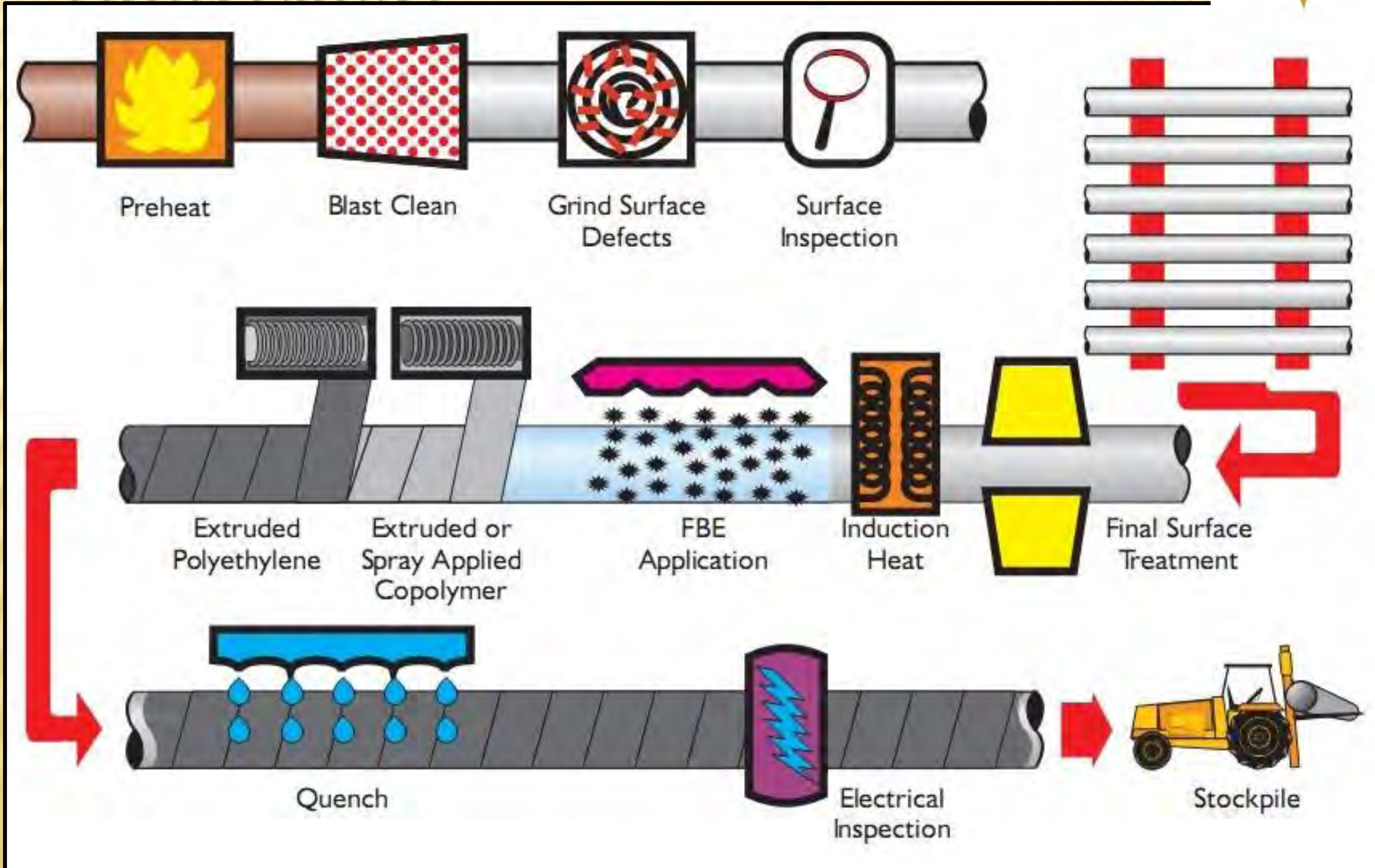
COMMON TYPES OF ASSEMBLY LINE



FINISHING

- Metal finishing comprises a broad range of processes that are practiced by most industries which manufacture metal parts. Typically, manufacturers perform the finishing after a metal part has been formed. Finishing can be any operation that alters the surface of a workpiece to achieve a certain property. Common metal finishes include paint, lacquer, ceramic coatings, and other surface treatments. This manual mainly addresses the plating and surface treatment processes.
- The metal finishing industry generally categorizes plating operations as electroplating and electroless plating. Surface treatments consist of chemical and electrochemical conversion, case hardening, metallic coating, and chemical coating.
- In general, objects to be finished undergo three stages of processing, each of which involves moving the workpiece through a series of baths containing chemicals designed to complete certain steps in the process.

FINISHING AND SURFACE TREATMENT



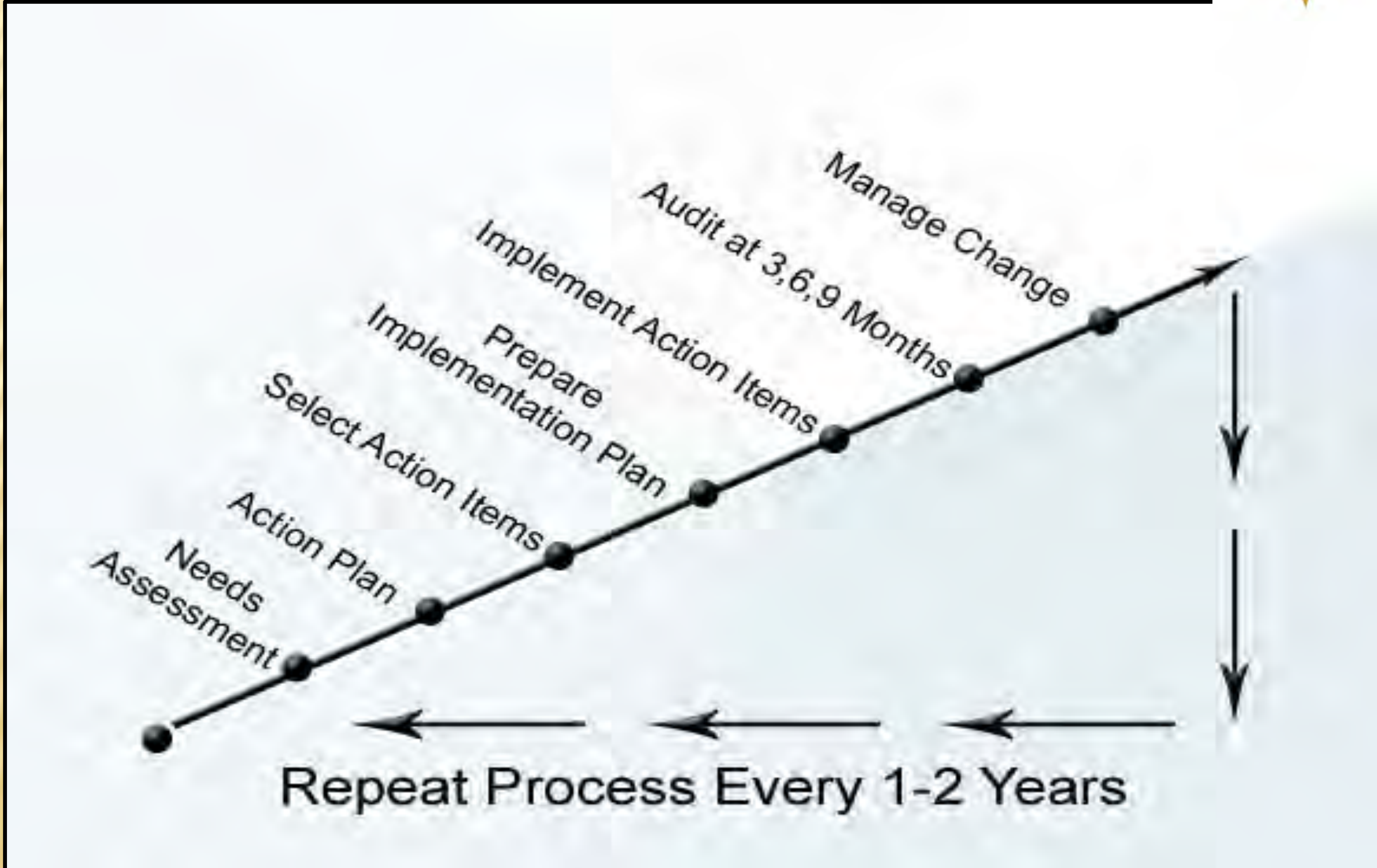
PRODUCTIVITY

- **Productivity** is the ratio of what is produced to what is required to produce it. Usually this ratio is in the form of an average, expressing the total output of some category of goods divided by the total input of labour or raw materials.
- In principle, any input can be used in the denominator of the productivity ratio. Thus, one can speak of the productivity of land, labour, capital, or subcategories of any of these factors of production. One may also speak of the productivity of a certain type of fuel or raw material or may combine inputs to determine the productivity of labour and capital together or of all factors combined. The latter type of ratio is called “total factor” or “multifactor” productivity, and changes in it over time reflect the net saving of inputs per unit of output and thus increases in productive efficiency.

PRODUCTIVITY

- It is sometimes also called the residual, since it reflects that portion of the growth of output that is not explained by increases in measured inputs. The partial productivity ratios of output to single inputs reflect not only changing productive efficiency but also the substitution of one factor for another—e.g., capital goods or energy for labour.
- Labour is by far the most common of the factors used in measuring productivity. One reason for this is, of course, the relatively large share of labour costs in the value of most products. A second reason is that labour inputs are measured more easily than certain others, such as capital. This is especially true if by measurement one means simply counting heads and neglecting differences among workers in levels of skill and intensity of work.

IMPROVING PRODUCTIVITY



PRODUCT QUALITY OF AUTOMOBILE PARTS

- For a component to be automotive qualified, manufacturers have to meet specific industry standards throughout the manufacturing and testing process. Three key standards are **IATF 16949, AEC-Q100** and **AEC-Q200:**
- **IATF 16949.** The global automotive industry standard for quality management systems. The automotive industry generally expects parts to be manufactured, assembled and tested in IATF 16949-qualified facilities.
- **AEC-Q100 & AEC-Q200.** During the qualification phase before the release of the device, each component must survive a battery of industry-standard tests:
  - **AEC-Q100** defines the standard tests for **active components** such as switches and power amplifiers (PAs).
  - **AEC-Q200** covers similar tests for **passive devices** such as RF filters used in Wi-Fi and cellular communications.

PRODUCT QUALITY OF AUTOMOBILE PARTS

- Some of these tests are unique to the automotive industry and aren't conducted at all on parts intended for commercial use. Examples are the test for early life failure rate (ELFR), which subjects multiple samples of 800 components to temperatures of at least 125°C, and the power temperature cycling (PTC) test, which repeatedly cycles between extremely high (125°C) and extremely low (-40°C or even lower) temperatures.
- Other tests are conducted under harsher conditions — such as higher temperatures — than when testing commercial parts, or using larger lot sizes to provide greater statistical confidence in the reliability of production components.
- Also, because cars last much longer than other electronic devices, manufacturers typically must ensure a supply of each automotive component will be available for 10 years.

ADDITIONAL TESTING FOR AUTO-QUALIFIED PARTS

- In addition to the standard tests applied to commercial parts, automotive components undergo further testing at each major stage in the production process, from wafer level to finished part:
- **Wafer level and assembly.** Each die gets four optical inspections to uncover any lurking defects that might lead to failure once components are built into vehicle electronic systems.
- **Final test, tape and reel.** With even the best-designed manufacturing processes, there's a chance that rare and unexpected events can result in anomalies that lead to early part failure. The automotive component manufacturing process includes **additional screening to identify these "outlier" parts and batches** before they find their way into customer products.
- **Reliability testing and documentation.** In addition to the AEQ stress tests, component makers must follow a product quality program known as **Advanced Product Quality Planning (APQP)**. This includes producing an extensive documentation package covering the entire manufacturing process, test records, design/process failure mode and effect analysis (FMEA), and other information.

ECONOMY OF AUTOMOBILE PARTS

- Since the tests of automobile components are very costly and it is necessary to test each part before implementation of the part in automobile. The cost of overall automobile becomes large.
- However, similar tests on large scale makes it little cheaper.
- The large number of failure rate in automobile part testing can drastically increase the cost therefore, it is mandatory to produce the automobile parts with special care and continuous testing should be done to ensure the quality of the parts.
- Early stage rejection of defective or weak parts make it more economical as this saves the cost to be invested in further manufacturing processes.
- Also, after final product is delivered to the customer the automobile is maintained for its performance by doing the periodic maintenance.

QUANTITY PRODUCTION OF CUTTING TOOLS

From Ore to Insert: Tungsten carbide, often called simply "carbide," is a familiar material around the shop. This compound of tungsten and carbon has revolutionized the metal-cutting world over the decades, enabling increased speeds and feeds and providing longer tool life. Tungsten carbide was first investigated as a cutting tool material in 1925, by Dr. Samuel Hoyt, a scientist at General Electric's Lamp Department. Later GE opened the Carboloy division to produce tungsten carbide cutting tools. In the late 1930s, Philip M. McKenna, founder of Kennametal, discovered that adding a titanium compound to the mix made the tools work better at higher speeds. This began the march toward today's lightning-fast cutting speeds.

"Cemented tungsten carbide," the material that makes up the tools and inserts, is actually grains of tungsten carbide, along with particles of other materials, cemented together using the metal cobalt as a binder.

QUANTITY PRODUCTION OF CUTTING TOOLS

It starts in the ground: There are several tungsten ores that can be mined and refined into tungsten or made into tungsten carbide. Wolframite is the best known. The ore is crushed, heated and treated with chemicals. The result: tungsten oxide.

Then, the fine particles of tungsten oxide are carburized, turning them into tungsten carbide. In one method, the tungsten oxide is mixed with graphite (carbon). This mixture is heated to over 1200˚ C (2200˚ F) and a chemical reaction occurs that removes the oxygen from the oxide and combines the carbon with the tungsten to yield tungsten carbide.

QUANTITY PRODUCTION OF CUTTING TOOLS

Grain size is key: The size of the carbide grains determines the mechanical properties of the final product. The size of the grains will depend on the size of the tungsten oxide particles, and how long and at what temperature the oxide/carbon mixture is processed.

The tungsten carbide particles are a fraction of the size of a grain of sand. They are likely to range in size from half a micron, to as large as 10 microns. A series of sieves sorts out the different grain sizes: less than one micron, one and one half microns, and so forth.

At this point, the tungsten carbide is ready for blending into “grade powder.” In the tungsten carbide industry, one speaks of grades rather than alloys, but they mean the same thing.

The tungsten carbide goes into a mixing vessel with the other components of the grade. Powdered cobalt metal will act as the “glue” to hold the material together. Other materials, such as titanium carbide, tantalum carbide and niobium carbide are added to improve the properties of the material when cutting. Without these additives, when cutting ferrous materials, the tungsten carbide tool may experience a chemical reaction between the tool and the chips of the work piece that leaves craters in the tool, especially at high cutting speeds.

QUANTITY PRODUCTION OF CUTTING TOOLS

Mix it up: All these ingredients are blended with a liquid such as alcohol or hexane and placed in a mixing vessel, often a rotating drum called a ball mill. In addition to the grade ingredients, cemented balls 1/4″ to 5/8″ in diameter are added, to help the process of adhering the cobalt to the carbide grains. A ball mill may be as small as five inches in diameter by five inches long, or as large as a 55-gallon drum.

When the mixing is complete, the liquid must be removed. This typically happens in a spray dryer, which looks like a stainless steel silo. An inert drying gas, nitrogen or argon, is blown from the bottom up. When all the liquid is removed, the remaining dry material is "grade powder," which looks like sand.

For cutter inserts, the grade powder goes into insert shaped molds specially designed to allow for the shrinkage that will happen later on in the process. The powder is compressed into the molds, in a process similar to how pharmaceutical tablets are formed.

QUANTITY PRODUCTION OF CUTTING TOOLS

Taking the heat: After pressing, the form looks like oversized inserts and is fairly delicate. They are removed from the molds and placed on graphite or molybdenum trays, and go into a sintering furnace where they are heated in a low-pressure hydrogen atmosphere to 1100-1300˚ C (about 2000- 2400˚ F). The cobalt melts, and the insert consolidates into a solid, smaller size.

After the inserts are removed from the furnace and cooled, they are dense and hard. After a quality control check, the inserts are usually ground or honed to achieve the correct dimensions and cutting edge. Honing to a radius of 0.001″ is typical, though some parts receive a cutting-edge radius of half a thousandth or as large as 0.002″, and some are left "dead sharp," as sintered. Some types and designs of inserts come out of the sintering furnace in their final shape and in-spec, with the correct edge, and don't need grinding or other operations.

The process for manufacturing blanks for solid carbide tools is very similar. The grade powder is pressed to shape and then sintered. The blank or stock may be ground to size afterward before shipping to the customer, who will form it by grinding or perhaps EDM. Inserts bound for most non-ferrous applications may be ready to package and ship at this point. Those destined for cutting ferrous metals, high temperature alloys or titanium, will need to be coated.

QUANTITY PRODUCTION OF CUTTING TOOLS

Introducing Tungsten: Tungsten, in its elemental form, is a silver colored metal. Its atomic number is 74 and its average atomic mass is 183.85. One of the densest metals, it is more than twice as dense as steel. And it has the highest melting temperature of any metal: 3422˚ C (over 6000˚ F).

We call it “tungsten,” which means “heavy stone” in Swedish. So why is its chemical symbol “W”? That comes from its other name, wolfram.

Coatings finish the job: To prolong tool life under challenging cutting conditions, many types and combinations of coatings have been developed. They can be applied in two ways: by chemical vapor deposition (CVD) or physical vapor deposition (PVD). Both types are applied in furnaces.

Quantity Production of Cutting Tools

Chemical vapor deposition: For CVD, the coating is usually 5- 20 microns thick. Milling and drilling inserts usually receive 5–8 microns, as these operations require better surface finish, and they encounter more impact, so they require greater edge toughness. For turning applications, the coatings tend to be in the range of 8–20 microns. In turning, heat and abrasion tend to be more of a concern.

Most, but not all, CVD coatings are made up of multiple layers, usually three distinct layers.

Each company has its own "recipe" for coatings. Here is a typical scheme, building up three layers.

Here is a typical scheme, building up three layers.

- one layer of titanium carbo-nitride for hardness and abrasion resistance
- one layer of aluminum oxide, which retains hardness at higher temperatures and is chemically very stable

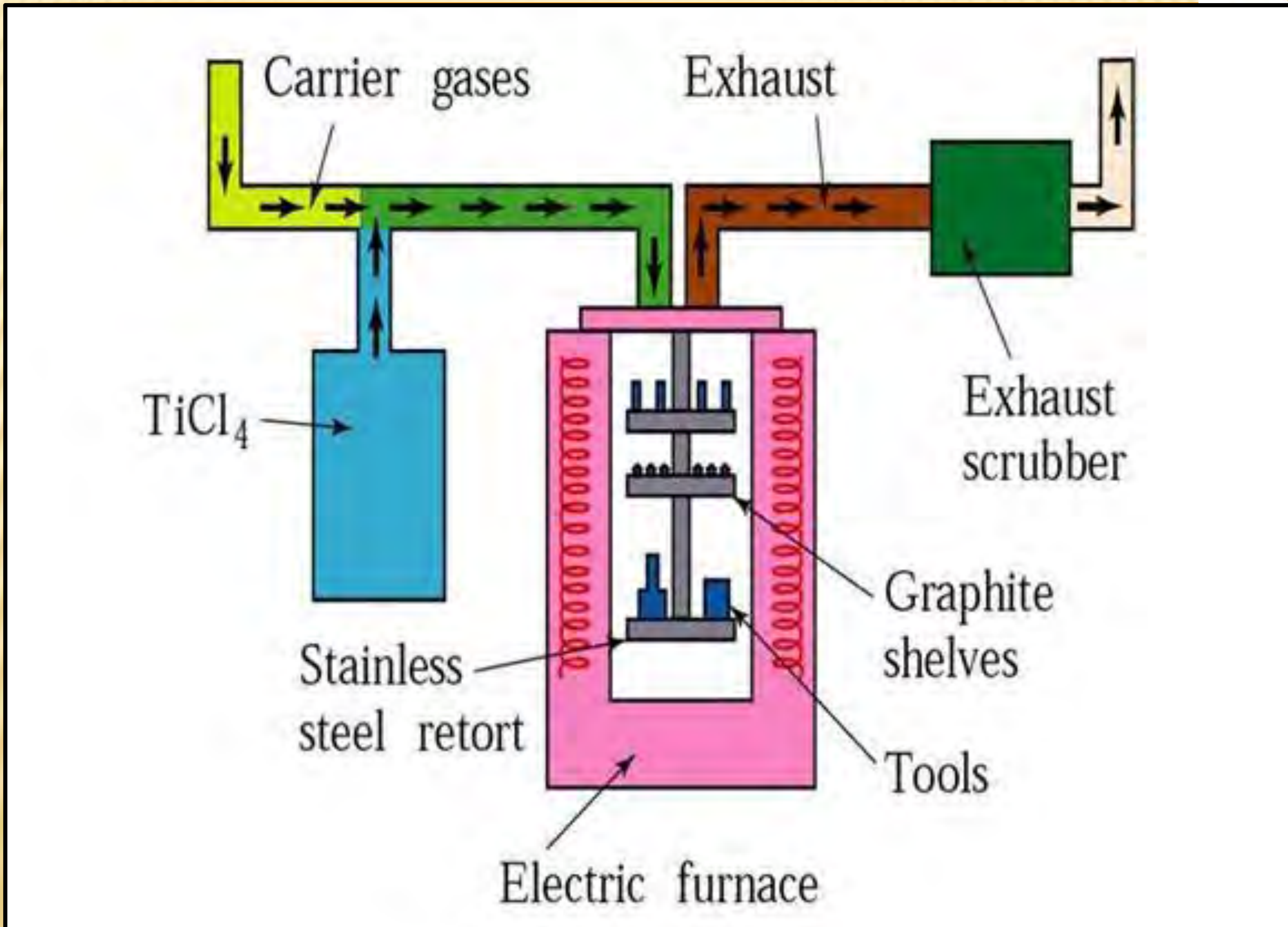
QUANTITY PRODUCTION OF CUTTING TOOLS

- one layer of titanium nitride, which prevents metal buildup from fragments of the workpiece welding to the tool. This coating is gold-colored and makes it easy to observe wear of the edge. To apply a CVD coating, the parts are placed on trays and sealed in a furnace. The furnace is drawn down to a vacuum.

For each layer, the appropriate gases are introduced into the furnace, such as hydrogen, titanium tetrachloride, methane, nitrogen, aluminum chloride. A chemical reaction occurs, depositing the layer of coating on the inserts.

The aluminum oxide provides thermal protection, keeping heat out of the body of the insert, important for high speed applications. For low speed applications, an insert may not need an aluminum oxide layer.

Chemical Vapor Deposition



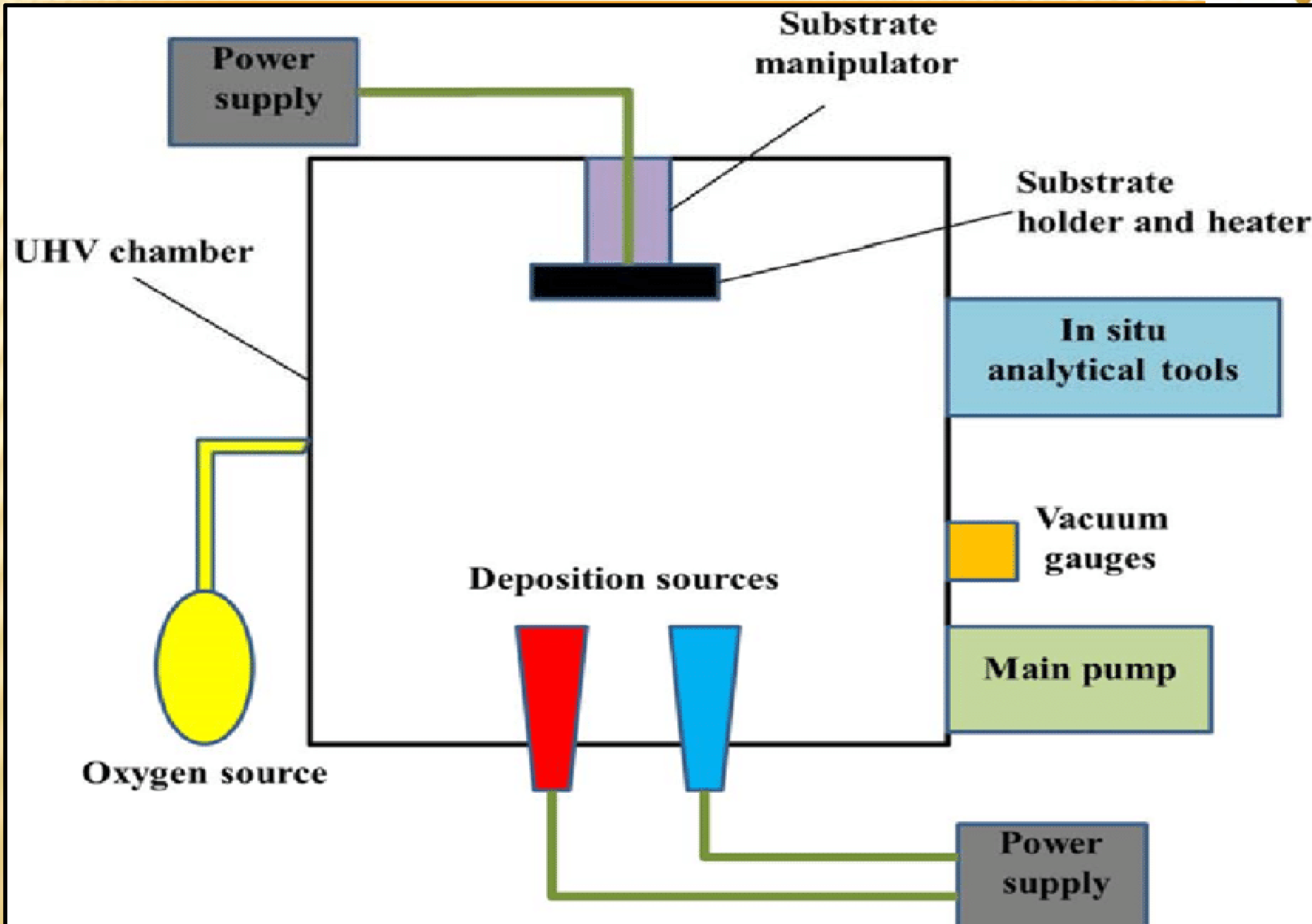
Quantity Production of Cutting Tools

Physical vapor deposition: PVD coatings are typically about 2-4 microns thick. Different manufacturers use different numbers of layers. These PVD coatings are well-suited to applications cutting high temperature, nickel-based, cobalt-based or titanium-based materials, and sometimes steel and stainless steel.

Titanium carbo-nitride, titanium nitride and titanium aluminum nitride are widely used as PVD coatings. The latter is the hardest and most chemically stable PVD coating.

The inserts are mounted on racks so they are separated from each other. Each rack rotates and the whole assembly of racks revolves within the furnace, so every surface of the inserts is exposed to the deposition process. The furnace is evacuated.

PHYSICAL VAPOR DEPOSITION



QUANTITY PRODUCTION OF CUTTING TOOLS

Strong negative charge is applied to the inserts. A piece of titanium, or titanium and aluminum is installed on the wall or floor of the furnace. The metal is vaporized by either an electric arc or an electron beam, liberating the positively charged metal ions. These ions are attracted to the negatively charged inserts. Nitrogen and methane are added as appropriate, to achieve the different types of coatings.

When the inserts are removed from the furnace they may be ground again, or directly packaged and shipped.

Tools are meeting the pressures for ever increasing feeds and speeds, and the need for longer tool life and lower costs, by continually improving in designs of tungsten carbide cutting tools by developing better and better coating technologies.

QUANTITY PRODUCTION OF CUTTING TOOLS

SMALL SIZE PRODUCTS IN LARGE VOLUME

- This type of production is generally done by using the mass production technique where, a continuous production of standardized products is done on a large scale. Here, production remains continuous in anticipation of future demand. Standardization is the basis of mass production. Standardized products are produced under this method by using standardized materials and equipment. There is a continuous or uninterrupted flow of production obtained by arranging the machines in a proper sequence of operations.
- Flow production is the manufacture of a product by a series of operations, each article going on to a succeeding operation as soon as possible. The manufacturing process is broken into separate operations.
- The product completed at one operation is automatically passed on to the next till its completion. There is no time gap between the work done at one process and the starting at the next. The flow of production is continuous and progressive.
- It is seen that the small engineering parts such as nuts, bolts, screws, etc., are required continuously thus mainly manufactured using this type of production.

THANK YOU