6.1 Introduction

During the past 100 years, there have been vast changes in the worldwide approach to manufacturing. Of particular importance is the change in the United States since 1985 when the revolution in manufacturing dramatically improved the position of American manufacturing. Today, America is competitive with the best manufacturing practices found in Asia and Europe in the production of finished goods for industrial as well as consumer consumption.

The National Association of Manufacturers published the following facts:

- Manufacturing contributed 29 percent of economic growth [i.e., real Gross Domestic Product (GDP) adjusted for inflation] between 1992 and 1997. This is the largest of any sector. By comparison, services contributed 19 percent; transportation and utilities, 10 percent; and finance, insurance and real estate, 13 percent.
- Manufacturing’s share of the gross domestic product has held to 20% to 23% over the past 45 years. During expansions, manufacturing grows more rapidly than GDP; during recessions, it contracts more rapidly. The overall share remains the same over the business cycle.
Manufacturing’s share of goods at the intermediate level for use in producing other goods and services accounts for 39% of the national total.

- Manufacturing is the more significant multiplier of economic activity in contrast to services.
- Manufacturing enjoys a lower inflation rate. The prices of manufactured goods rose by 1.2% while the overall inflation rate was 2.4%. The lower inflation rate is a byproduct of higher productivity.
- Productivity growth in manufacturing has been consistently strong since the early 1980s, growing by 3.4 percent annually since 1983. In the 1990s, there was a further rise, with manufacturing productivity surpassing 4.7 percent per year from 1996 to 1999.

US manufacturing now involves a wide variety of manufacturing processes, some of which are very common, while others are specialized and unique. The level of world class manufacturing expertise capability will vary from customer to customer based on their needs. Therefore, the sales approach must change to meet new, distinct “world class” requirements.

The role of the computer in the integration of these processes is a major step in the implementation of modern manufacturing techniques. Starting with raw materials in the form of rough castings, forgings, weldments or metal stock, parts are processed by metalcutting and metalforming operations. Beyond these metal removal and forming operations there are the additional operations of welding, joining, assembly, heat treatment, inspection, and cleaning. This chapter will address each of these points in a brief manner. Many of these processes are discussed further in other chapters of this Study Guide.

This review is organized into the following sections: 1) Manufacturing Processes, 2) Manufacturing Systems and 3) Manufacturing Software. It is intended to be a brief overview of each area. Additional, independent study in each area is recommended to be properly prepared for the certification exam.
6.2 Glossary

5S – The five S’s focus on eliminating waste through workplace organization. Sort, Set, Shine, Standardize and Sustain.

Alloy - A metal containing additions of other metallic or non-metallic elements to enhance specific properties such as strength and corrosion resistance.

Andon - A horizontal set of lights stationed over a workcenter – Red, Yellow and Green. They provide a highly visual status of the workcenter.

Annealing - A heat treatment process to reduce hardness or brittleness, relieve stresses, improve machinability, facilitate cold working, or produce a desired microstructure or properties. The process consists of heating to a suitable temperature, which is dependent upon the type of annealing, followed by slow cooling.

Automated assembly - Assembly by means of operations performed automatically by machines. A computer system may monitor the production and quality levels of the assembly operations.

Automated guided vehicle system (AGVS) - Vehicles equipped with automatic guidance equipment, which follow a prescribed guide path that interface with workstations for automatic or manual, loading and unloading. In flexible manufacturing systems, guided vehicles generally operate under computer control.

Automated handling systems - System(s) used to automatically move and store parts and raw materials throughout the manufacturing process and to integrate the flow of work pieces and tools with the manufacturing process. In flexible manufacturing systems, the automated material handling system operates under computer control.

Batch manufacture – The production of parts in discrete runs or batches, mixed with other production operations or runs of other parts.

Bill of material - A listing of all parts that make up an assembled product. This listing can show materials, parts, or sub-assemblies and can be created in various degrees of accuracy for either rough-cut or detailed planning.

Business process - A complete set of activities necessary to execute a major element of business, such as customer order-to-delivery.

CAD (computer-aided design) - The use of a computer to capture the design geometry of a part or product. This design is then stored electronically in an engineering database.
CAE (computer-aided engineering) - The use of a variety of computer-based analytical software to analyze a part's design, for example, finite element modeling analysis to analyze for mechanical stress and strain.

CAM - The acronym for “Computer Aided Manufacturing” in which elements of machining or manufacturing processing are computer controlled or directed by computers.

Capacity planning - The function of setting limits or levels of manufacturing operations in the future with consideration being given to sales forecasts and the requirements availability of personnel, machines, materials, and finances.

Capacity requirements - The projected future production capacity needs expressed in terms of personnel, machines, and facilities.

CAPP (computer-aided process planning) - Variant CAPP is computer-based process or routing planning that can take advantage of standard sequences of manufacturing operations for part families classified under group technology concept. Generative CAPP selects operations based on part features (geometry) and other specifications.

Cellular Manufacturing - A manufacturing production system that groups and organizes manufacturing equipment, tools, and people to perform an entire sequence of manufacturing operations in one contiguous physical location (cell). They can quickly be adapted for a family of parts or components of similar shapes and materials, but with minimum or no changeover time.

Cell – A grouping of different types of machines with a defined flow. The cell will complete an entire operation or major manufacturing step.

Changeover (Setup) time - The time required to modify or replace an existing facility of workplace, usually including both teardown time for the existing condition and setup for the new condition. Setup or changeover time is the time between the last good piece off one production run and the first good piece off the next run.

CIM (computer-integrated manufacturing) - The integration of all information (engineering, business, and process control) involved in the total spectrum of manufacturing activity.

Control chart – Refer to Chapter 12 – Machine Tool Accuracy.

Cross-functional - A process cutting across more than one internal function, for example, from sales through manufacturing.

Cycle time - 1) The period of time from the start of a machine operation and the start of another operation, as in a pattern of continuous repetition.

DBMS (data base management system) - The application software that manages data in an information system. It usually includes a data dictionary to define the data and the relationship of each data element to another.
**Direct numerical control (DNC)** - A system connecting a set of numerically controlled machines to a common memory for part-program or machine program storage, with provision for on-demand distribution of data to the machines.

**Economic order quantity (EOQ)** - A method of calculating order quantity (lot size) that relates ordering cost to holding cost given the assumption of constant demand for the product. Specifically, the economic order quantity equals the square root of \[
\sqrt{\frac{2 \times \text{annual demand} \times \text{ordering cost}}{\text{annual holding cost}}}.
\]

**Extrusion forging** - 1. Forcing metal into or through a die opening by restricting flow in other directions. 2. A part made by the operation.

**Family of parts** - A collection of parts with similar geometric characteristics (i.e., line, circle, ellipse) but differing in physical measurement (i.e., height, width, length, angle). When the designer pre-selects the desired parameters, a special CAD program creates the new part automatically, with significant timesavings.

**First in-first out (FIFO)** - A system of inventory control that designates material to be disbursed in the same order as received.

**File server** - A computer that serves as a data storage and management device in a local area network.

**Finite capacity planning** - Loading a factory or work center only to its capacity. This process automatically schedules lower-priority items into the next available time period if the current time period's capacity is fully utilized.

**Flexible manufacturing system (FMS)** - A group of machine tools clustered in a work cell that has automated material handling and will produce multiple parts using multiple process steps via computer control.

**Forging** - 1. The process of deforming to the desired shape by forming in presses, hammers, rolls, upsetters, and related machinery. 2. The product resulting from this deformation process.

**Forming** - In the context of this Study Guide, the term forming covers all operations required to form a flat sheet into a part. These operations include deep drawing, stretching, bending, buckling, etc.

**Forward scheduling** - Scheduling a process from a start date forward by operation time to arrive at a finish or ship date.

**Gantt chart** - The earliest and best-known type of control chart designed to graphically illustrate the relationship between planned performance and actual performance. Named after its originator, Henry L. Gantt, a scientific management pioneer. The chart is used mainly for machine loading, where one horizontal line is used to represent capacity and another to represent load against that capacity. It is also used for following job progress.
where one horizontal line represents the production schedule and another parallel line represents the actual progress of the job against the schedule in time.

**Group technology** - A method by which classification and coding schemes are used to identify and aggregate related part numbers so that design and manufacturing efforts can take advantage of their similarities.

**Hardening** - Any process of increasing hardness of metal by suitable treatment, which usually involves heating and cooling.

**Infinite capacity planning** - Loading a factory or work center without regard to its capacity. Used to show where overloads exist so they can be corrected by planner intervention.

**International Organization for Standardization (ISO)** - The major body for the development and certification of international standards. The ISO is comprised of national standards bodies from various countries that work to establish and promote development of standards to facilitate international exchange of goods and services.

**Inventory turns** - How often in a period of time the inventory "turns over" or is used, calculated by dividing sales at cost by the average inventory dollar amount.

**Job shop** - A discrete parts manufacturing facility characterized by a mix of products of relatively low volume production in batch lots. Job shops are generally set up to handle custom-made parts or small production quantities for specific customers.

**Just in time (JIT)** - A manufacturing philosophy that seeks to eliminate all waste in the manufacturing business process while utilizing a "pull" production system.

**Kaizen** – A manufacturing process that focuses on the identification and elimination of waste. Work is organized into its component steps to facilitate the waste identification process.

**Kanban** – A Japanese term for “card” or “tag”. It is a just-in-time scheduling or signaling system to dramatically reduce the work-in-process inventory by the delivery of raw materials, parts and subassemblies to production in small batches, as they are needed.

**Laser cutting** - The use of a laser beam to perform plate and sheet shape-cutting operations. Normally, the beam path is programmed and servo-controlled by means of a CNC control.

**Last in first out (LIFO)** - A system of inventory control that designates material be disbursed in the reverse order as received.

**Lead time** - The moment raw materials enter the manufacturing process until the moment the finished product is delivered to the customer. Lead time includes: run-time, down-time, queuing, and transport.
**Lean manufacturing** – A manufacturing philosophy to eliminate waste from production systems found in: inventory, storage, movement, rework, labor and overhead through an ongoing commitment.

**Line production** - A method of plant layout in which the machines and other equipment required, regardless of the operations they perform are arranged in the order that they are used in the process.

**Lot-for lot** - A lot sizing algorithm where the quantity to be produced exactly reflects the amount needed in the time period with no considerations for safety stock or producing any overstock.

**Machinability** - The relative ease with which materials can be shaped by cutting, drilling, or other chip-forming processes. Various codified machinability rating systems can be found in machinists’ handbooks.

**Manufacturing automation protocol (MAP)** - A communications standard developed to promote compatibility among automated manufacturing systems produced by different vendors.

**Manufacturing cell** - A factory unit consisting of two or more workstations or machine systems and the materials transport mechanisms and storage buffers that interconnect them.

**Manufacturing resource planning (MRP)** - The complete application software package that contains modules including forecasting, order entry, master production scheduling, capacity planning, material requirements planning, procurement, shop floor control, and cost accounting. MRP II packages contain integrated accounting and financial reporting functions as well.

**Mass production** - The large-scale production of parts or material in a continuous process uninterrupted by the production of other parts or materials.

**Master production schedule (MPS)** - A statement of the products a manufacturing enterprise will produce in a given time period, after taking into account the products' supply and demand.

**Materials requirements planning (MRP)** - An order-scheduling mechanism that sets and maintains order priorities for manufactured or purchased parts. The basis for the scheduling is the explosion of required product quantities (determined by the time-phased master production schedule) through each product's bill of materials to determine gross part requirements, and then netting these requirements against parts on hand and due in (scheduled receipts).

**Muda** – This term means “waste”. It defines waste in terms of: 1) motion, 2) waiting, 3) time, 4) over production, 5) processing, 6) defects, 7) inventory, and 8) transportation.
**Noise factors** - Factors that influence the response of a process but cannot be economically controlled, such as dust, weather conditions, vibration, and machine wear, and so forth.

**Normalizing** - A process in which an iron-base alloy is heated to a temperature above the transformation range and subsequently cooled in still air at room temperature.

**Parameter design** - The optimization process in Taguchi methods that makes a design as robust as possible - as insensitive to uncontrolled or expensive-to-control variations of noise factors in the factory or field.

**Poka-yoke** – A method of fool-proofing an operation and often checking for quality errors at the same time. An example would be the use of a matching slot and tang on mating parts to facilitate only one possibility of correct assembly.

**Press** - A machine having a stationary bed and a slide (ram), which has a controlled reciprocating motion toward and away from the bed surface and at a right angle to it, the slide being guided in the frame of the machine to give a definite path of motion.

**Product** - The physical item produced along with a set of value-added services that do or could accompany it.

**Pull production** – This is production initiated by the actual consumption of product by: 1) an upstream work center or, 2) the customer.

**Push production** – This is production that is initiated based on forecasts of customer usage, current production orders and inventories.

**Processing time** – In a manufacturing environment, the time a product is worked on in production, as well as the time an order is actually being processed. Typically, processing time is a small fraction of “throughput time” and “lead time”. Also, Processing Time includes value adding and non-value adding activities.

**Quality loss function** - Genichi Taguchi's statement that losses mount exponentially the further a given characteristic is from its target value.

**Rapid Prototyping** - A relatively new process that is becoming more popular, used in the production of tooling, molds and dies as well as individual part pieces, using computer generated data for part piece shapes in a variety of materials such as polymer, paper or metal. One process uses slices of CAD data to solidify layers of polymer by scanning the surface of a liquid polymer with a laser.

**Stamping** - In its broadest interpretation, the term stamping encompasses all pressworking operations on sheet metal. In its narrowest sense, stamping is the production of shallow indentations in sheet metal.

**Statistical Process Control (SPC)** - SPC is a process control method that allows measured data from the process to be plotted, statistically analyzed, and projected in order to keep the process under control.
Stock-keeping unit (SKU) - A part or product kept in stock as a uniquely identified item.

Taguchi methods - A quality engineering tool that uses the quality loss function as a way to explain quality issues to top management and emphasizes parameter design to design products, and processes of robust quality that are insensitive to expensive-to-control noise factors.

Takt – This is the time, per part, being consumed or sold per unit of operating time. Based on “available” time, not cycle time; it is a method of matching the pace of production to consumer consumption.

Total quality management/Total quality control (TQM/TQC) - A complete philosophy of company-wide quality control that includes the use of many lesser quality tools such as quality function deployment, Taguchi methods, and statistical quality control, among others, to achieve world class quality performance.

Total preventative maintenance (TPM) – A systemized management technique to track the maintenance of critical manufacturing equipment and keep it in optimal operating condition.

Toyota production system (TPS) – This term is generally used to mean Lean Manufacturing.

Transfer line/machine - Group of workstations closely connected together by an automated material handling system and designed for high-volume production of a single part or similar parts.

World Class Manufacturing - A phrase describing the American Manufacturing Revolution of the past 15 years. Prime ingredients are “Total Quality Control” - “Cellular Manufacturing” - “Just in Time Inventory Controls” - “Manufacturing Teams” - “Continuous Improvement” - “Statistical Process Control” and “Set up Reduction”
6.3 Manufacturing Processes

TRADITIONAL MACHINING

The principles of machining are based on applying a tool to a workpiece, to remove the unwanted material (producing chips) and leaving a finished workpiece. Common traditional metalcutting machining operations include turning, drilling, reaming, tapping, milling, boring, grinding, broaching, threading, and sawing. Several of these processes are discussed in the "Cutting Tool Technology" (chapter 9) of this Study Guide. In traditional machining everything revolves around the cutting tool. In a real sense, the machine structure and members, electronics, motion control, drives, fixtures, lubricants, and coolants are support devices to the cutting tool. Knowledge of cutting tool capabilities will enhance the machine tool sales engineer's position as a problem-solver with customers.

Basic Metalcutting Operations

**Boring** - A precision machining process for generating internal cylindrical forms by removing metal with single point or multiple-edge tools. The process is most often used with the workpiece held stationery with a rotating cutting tool.

**Broaching** - A metal removal technique for internal or external machining of flat, round or contoured surfaces using a multi-tooth cutting tool that is pushed or pulled in relation to the workpiece being machined. Each tooth on the cutting tool (broach) is generally higher than the preceding tooth and as a result the depth of cut increases as the operation progresses.

**Burnishing** - The very heavy rubbing of two surfaces, where one is much harder than the other. The result being that the softer surface has been flattened and its surface finish altered. Normally utilized in high production finishing operations (i.e., hole finishing via roller burnishing).

**Drilling** - The production or enlarging of holes by rotary relative motion of the workpiece and a sharpened tool known as a drill bit. The cutting tool, the workpiece, or both may rotate, with the tool generally being fed along its long axis.

**Grinding** - Removing material from a workpiece with a grinding wheel or coated abrasives.
**Milling** - A machining process that removes material from a workpiece by relative motion between a workpiece and a rotating cutter having multiple cutting edges.

**Polishing** - Removing material from a workpiece with one of several light abrasive mediums (liquid, belts and wheels). Improving workpiece finish is generally the goal.

**Reaming** - Reaming is a machining function using rotary, fluted cutting tools (reamers) to enlarge, smooth or finish size holes. Normally, a secondary operation after drilling. The finish hole size is determined by the diameter of the reamer. Light chip loads and high rigidity are basic needs in this machining operation.

**Tapping** - Forming an internal screw thread in a hole or other part by means of a tap.

**Threading** - Any of several processes used to produce standard spiral grooves on a cylindrical internal or external surface. Turning, boring, milling, grinding, or rolling may produce threads.

**Turning** - A machining process in which a workpiece is held and rotated against a single point tool to form flat or contoured surfaces concentric with the longitudinal axis of the workpiece.

**Multiple Machine Operations**

Another trend to watch in the manufacturing evolution is the development of more multi-function machines. The growth of CNC machine tools has expanded the role and flexibility of stand-alone machines. However, adding new machining functions to stand alone machines is a popular trend. For example, a CNC turret lathe with live tooling can now perform light milling, drilling, and tapping operations. This approach may save one or more setups and save the part from going to an additional workstation. In a like manner, adding additional spindles, turrets or cutting axes to a machine can also increase its functional use.

**Workpiece Processing**

This is the heart of the manufacturing planning process. Each workpiece must be processed, which includes logical step-by-step instructions for holding, handling, machining and inspection. The metalcutting process is complex and involves the interaction of many variables such as:

1. Detailed consideration of the workpiece material and "rough" part conditions.
2. Analysis of tolerance requirements.
3. Required fixturing and tooling.
4. Part orientation in initial and subsequent set-ups.
5. Type of machining operations.
6. Estimated feeds, speeds and depths of cut per operation.
8. Verification of part machining. Frequently the machine tool supplier will be required to produce acceptable workpieces on the machine prior to final acceptance and payment.

**NON-TRADITIONAL MACHINING**

Non-traditional machining includes a host of unique machining processes, which are quite varied, and too special to be included in this portion of the Study Guide. A listing of most of the known and in use process is provided below.

**Mechanical**
- HDM - Hydromechanic - (Water Jet Machining)
- USM - Ultrasonic

**Electrical**
- EDM - Electrical Discharge Machining
- ECG - Electrochemical Grinding
- ECH - Electrochemical Honing
- ECM - Electrochemical Machining

**Thermal**
- EBM - Electron Beam Machining
- EDG - Electrical Discharge Grinding
- LBM - Laser Beam Machining
- PAM - Plasma Arc Machining

**Chemical**
- ECM - Chemical Milling
- Photochemical Milling

A complete description of each process is provided in the “Tool and Manufacturing Engineers Handbook”, Volume 1 - published by The Society of Manufacturing Engineers.

The four common non-traditional processes are discussed in Chapter 9 (Cutting Tool Technology). They are:

1. (LBM) - Laser Beam Machining.
2. (HDM) - Water Jet Machining.
3. (EDM) - Electrical Discharge Machining.
4. (ECM) - Electrochemical Machining.

The machine tool sales engineer should be aware of the capabilities of non-traditional machining methods as they offer creative and productive solutions for specific manufacturing problems.
FORMING

Metalforming is a broad term used to encompass the metalworking processes of blanking, forming, stretching, shrinking, roll forming, spinning, bending, shearing, trimming, punching, drawing, stamping, extruding, upsetting, swaging, forging and casting. In many cases the workpiece is deformed into a new shape by the use of high pressure and forming dies. In other cases, the workpiece is taken beyond its fracture limits and separation occurs.

Forming is discussed in Chapter 11 (Metalforming) of this Study Guide.

CASTINGS & FORGING

Casting of parts is one of the first steps in the manufacturing process. It is where the metal assumes its initial form and functional characteristics. Casting can be divided into two types - reusable mold casting and those that require a single-use mold for each cast part. Single-use mold castings are normally sand and plaster mold castings. This type of mold uses a pattern that is inexpensive but lacks accuracy and resulting surface finish.

Multiple-use castings normally include: 1) permanent mold castings and, 2) die castings. Multiple-use molds are usually machined into shaped cavities for producing precise and complex parts. A simple example involving a sand casting could be described as follows: The pattern, in the shape of the desired part is surrounded with sand. The pattern is withdrawn from the sand leaving a negative cavity. The molding process then involves pouring a molten metal into the sand cavity relying on gravity to fill the void. After the part has solidified, the sand can be removed, leaving the part. Additional information on machine tool structural castings can be found in Chapter 10 (Machine Tool Design).

Forging is one of the oldest forms of metalworking. Forging has some distinct advantages over other types of metalworking. The workpiece is first heated above its recrystallization temperature. At this temperature, any impact forming that takes place on the workpiece will also change its crystalline structure or grain flow, allowing the grain to flow with the form of the part. This allows for increased strength, ductility and resistance to impact and fatigue. Forging equipment can perform upsetting, extruding, deep-piercing, splitting, and bending operations. However, the most common forms of forging are upsetting and extruding. Forging is performed on both ferrous and non-ferrous materials. Forging is discussed in the "Metalforming" (chapter 11) of this Study Guide.
WELDING & JOINING

Welding and joining systems are part of the manufacturing process. Sub-components must be joined together to complete an assembly. In some cases it is more economical to join two simple parts together than to manufacture one complex part. Some parts require a means to adjust components for alignment or fit. Permanent joining systems include: 1) welding, brazing, soldering, 2) crimping, 3) fasteners and, 4) adhesives. Mechanical joining (primarily screws and rivets) can be considered either detachable or permanent.

There are over 50 different types of welding processes. Each has its unique application in the joining of varied materials under different conditions. Welding quality and integrity is of prime importance since these qualities are not always visible to the eye, yet determine the integrity of the assembly. Part configuration and material play an important role in welding quality. Be aware that high welding can change or distort the workpiece, requiring post-welding stress relieving. Welding done prior to machining is a consideration for the person selecting tooling to accommodate welded workpieces.

ASSEMBLY PROCESSES

It is not the intent of this Study Guide to educate the machine tool sales engineer on the methods of assembly. However, assembly is many times directly affected by the outcome of the metalworking and metalforming process.

When a customer presents a machining opportunity to the machine tool sales engineer, any subsequent assembly or subassembly of the workpiece must be considered. Several questions should be asked of the customer:

1. What is the function of the workpiece?
2. How, where and when will it be assembled to other components?
3. How do the workpiece tolerances (e.g. size and location) relate to the assembly of other components and/or product performance?

Relating the assembly needs to the machining needs may reveal opportunities to improve the customer’s process, save time, reduce costs and improve end-product quality and reliability. Typical situations are:

- Bearing race pressed into a bored hole - If the hole isn’t machined round, (within specification) the race will be distorted and bearing life will be reduced. Bearing noise will be higher and shaft runout may be excessive. Excessive heat may be another side effect.
- Mating surfaces (milled or ground) – If two parts are mated together such as a gear case cover to a gear case, the surfaces may require a specified flatness and surface finish to prevent joint leakage. Location tolerances may also be required (e.g. bolt holes or locating pins) if a rotating gear shaft protrudes through the gear case cover. Incorrect cover location could
cause misalignment of the shaft with subsequent gear noise and premature gear/shaft failure.

Size, location and tolerance all have a direct impact on the assembly process. As each part is assembled into a subassembly, a built-up of tolerances is experienced. If some parts are machined on the low side of the tolerance band and others are machined at the high side, the assembly will vary from part to part. In most cases, customers want all parts to be identical. Also, the customer should be asked if they have a preference with regard to the high side or low side of the tolerance.

As an example of how part tolerance might vary depending on the final application consider the following:

Engine components in racing cars are normally designed to run “looser” than production vehicles. This allows the engine to run faster, with less friction and heat. However, the overall life would be reduced, which is not an issue with a racing engine only used in one race.

Aircraft or medical components may have zero tolerance for error based on their critical application.

Some final products are used in environments not convenient for after-sale service. These might be military hardware or products used on oil platforms at sea. Therefore, the product must be manufactured and assembled to exacting specifications due to the cost or consequence of field service.

Observing assembly details can reveal opportunities to differentiate your company by offering customers additional assembly-related solutions. This can bring significant economic savings and increased product performance to the customer. In some cases, neglecting the assembly process can be an accident waiting to happen.

Another consideration is the growing practice of partial or complete assembly being performed within the flexible manufacturing cell. When assembly operations are required between machining operations, the cell operator may assemble components as well as operate a machine tool. Specialized automated assembly equipment may be specified as part of a machine tool order. Machine tool suppliers who can accommodate such requests are in a better position to serve the needs of the customer.

High-production manufacturers may use specialized transfer line machines, which are special-purpose, multi-function machines designed to perform machining, gauging, work-piece repositioning, assembling, washing and other selected operations. These machines represent the high-end of manufacturing automation and can be configured as either in-line or rotary dial transfer configurations.
HEAT TREATMENT

Prior to machining, the workpiece has been pre-formed into a basic shape (bar, block, raw shape, etc.). The two basic forms are 1) cast, and 2) wrought:

Cast
The process consists of pouring molten metal into a mold to arrive at a near component shape requiring minimal or no machining. Most metal alloys can be cast and techniques vary greatly. Molds Types are:
- Sand
- Plaster
- Metals
- Other

Wrought
Hammering or forming metal (hot or cold) into pre-manufactured shapes such as:
- Bar
- Billets
- Rolls
- Sheets
- Plates
- Tubing

This process is normally be categorized into several manufacturing processes:
- Forging
- Rolling
- Drawing
- Extrusion

The above processes can create undesirable characteristics in the raw workpiece. Heat-treating is used to change the properties of the metal, without changing its shape, to make it more machinable or suitable for its application. Heat treatment is sometimes done unintentionally due to manufacturing processes that either heat or cool the metal such as welding or forming. Both ferrous and non-ferrous metals can be heat-treated.

The main heat-treating methods are categorized below based on their main effect on the workpiece.
Each heat treatment process affects a different characteristic in the metal such as:
1. improving machinability.
2. increasing or reducing hardness.
3. relieving stresses.
4. increasing or decreasing ductility.
5. increasing or decreasing malleability.
6. increasing or reducing wear resistance.
7. increasing or reducing brittleness.
8. increasing shock resistance.

The Sales Engineer should be familiar with all types of heat treatment. The Study Guide will review the most common processes.

**Annealing**

If a metal part has been through a hot or cold working process (e.g. casting, forging or rolling), it must be softened before it can be machined. Many types of annealing exist. The most common are: 1) full process, 2) normalizing, 3) spheroidizing, 4) stress relieving and 5) tempering. Annealing can be performed on ferrous and non-ferrous alloys.

Characteristics:
- Improves machinability due to softer condition.
- Generally reduces strength or hardness.
- Improves toughness.
- Restores ductility.
- Reduces residual stresses.
Full Process Annealing
The part is heated slowly to a range above Austenitic temperature (Hypoeutectoid steels: < 0.77% Carbon) or to a temperature above Austenite-Cementite range (Hypereutectoid steels: > 0.77% Carbon). It is held at that temperature until all of the material transforms into Austenite or Austenite-Cementite. At that point it is cooled slowly at a prescribed rate. This leaves a uniform softening throughout the part.

Characteristics:
- Improves machinability due to softer condition.
- Predictable machining due to uniform softness.
- Becomes soft and ductile.

Normalizing
The part is heated to until it reaches austenizing transformation (830 - 950 degrees C) at which point it is recrystallized and then removed from the furnace and allowed to freely air cool. Normalizing is used to create a more uniform grain structure – one that was made coarse during hot working. This process is less expensive than full annealing. However, the softening may not be as uniform as full annealing. Since heating is carried out in open air, subsequent machining or surface preparation is required to remove the scale or decarburized layers. Tool steels and stainless steels are generally not normalized because they would become too hard in an air-cooled process.

Characteristics:
- Finer more homogenous structure than hot worked material.
- Improves toughness.
- Predictable machinability is achieved.
- Helps prepare metal for additional heat treatment.

Stress-Relief Annealing
This is a low temperature process to relieve internal stresses in large castings, welded parts and cold-formed parts. These internal stresses are undesirable as they can relieve during machining and cause workpiece distortion. The part is heated to temperatures between 150 to 900 degree C, depending on the material being processed, and held constant for over one-hour then slowly cooled in non-moving air.

Characteristics:
- Reduces internal stresses.
- Does not affect machinability to a significant degree.
Recrystallization (or Softening) Annealing
Generally, this annealing process is performed on cold worked steel. The material is heated to normalizing temperature and then step cooled: 1) Air cooled to 700-600 degrees C
2) Furnace cooled to 500-600 degrees C then, 3) Cooled to room temperature. The material may need to be softened as a secondary operation.

Characteristics:
- Stiffens the structure.

Spheroidization
This annealing type is used for high-carbon steels (> 0.6% Carbon) that need subsequent machining. The material is heated to just below the Ferrite-Austenite range (approx. 1340 degrees F). It is then cycled above and below this temperature line and allowed to slowly cool. This creates a Spheroidite structure that is simply Cementite in the form of small globules (spheroids) mixed within a ferrite matrix.

Characteristics:
- Improves machinability in continuous cutting operations. (e.g. lathes)
- Improves resistance to abrasion.

Tempering
This process is usually performed immediately after quench hardening which leaves them brittle. The brittle condition is due to the large amount of Martensite in the steel and can be removed by tempering. During the cool-down cycle of quench hardening the part reaches 104 degrees F it is reheated to between 302 to 752 degrees F in a bath of oil or nitrate salts. In many cases, tempering is done as an integral part of the hardening process.

Characteristics:
- Results in an optimal combination of hardness, ductility, toughness, strength and structural stability (stress relieving).
- Designers’ use as a method to reduce workpiece weight and increase strength.

Austempering
This process is a quenching technique and can be applied to thin sections of certain medium- or high-carbon steels or to alloy-containing steels of thicker section. It requires a high-temperature quench and hold (above the temperature when Martensite forms - approx. 600 degrees F), usually in molten salt and results in low distortion combined with a tough structure.
**Martempering**
This process is also known as “marquenching” and is similar to Aустempering with the exception that the part is slowly cooled through the martensite transformation in molten salt or hot oil. This creates a condition less prone to distortion and cracking. The process is limited to select alloy-containing steels and suitable section sizes.

**Hardening**
Hardness is dependent on the carbon content of the steel. Therefore, the material must have sufficient carbon and alloy content. If sufficient carbon is present the part can be **directly hardened**, if not, it must be hardened with a **diffusion treatment** (surface hardening), which enriches the surface with carbon.

**Hardening – Directly Hardened**
Steels are heated to their appropriate hardening temperature (usually between 800 – 900 degrees C), held at temperature, then “quenched” (rapidly cooled), often in oil or water. The hardness is a result of quenching the part from the austenitic to the martensite temperature range at a prescribed cooling rate.

When the material is quenched, most of the hardening occurs at the surface. The measure of how deep full hardness is achieved is called “hardenability”. It is related to the type and amount of alloying elements and the hardening process.

Quenching is the act of rapidly cooling the hot steel. Depending on the hardening process, the quenching agent can be: 1) Water, 2) Salt water, 3) Oil, 4) Polymer quench or 5) Cryogenic quench.

Generally, parts are soft-machined then hardened. However, hard machining is employed in a growing number of applications. These applications require rigid machine tools, rigid fixturing and specialized cutting tools.

Typical hardening applications include a wide range of manufactured components.

Characteristics:
- Hardening is used to increase strength and wear properties.
**Diffusion Treatment - Case Hardening (Carburizing & Carbonitriding)**

This is a thermochemical process usually conducted at a temperature range of 800 – 940 degrees C. These processes change the chemical composition of the surface of a low-carbon steel component so that subsequent fast cooling by quenching produces a hard “case” combined with a softer and tougher core. A low-temperature tempering or stress relieving process normally follows quenching.

In carburizing, controlled levels of carbon are introduced at the surface and allowed to diffuse to a controlled depth. In carbonitriding, nitrogen is also imparted, along with the carbon to improve case hardening.

Case hardening depth varies widely depending on material and process. Typically, case hardening can range from 0.1 mm up to depths of 7.5 mm (e.g. transmission gearing).

Any additional machining after case hardening (e.g. grinding) should be avoided or very limited.

Characteristics:
- Improved strength and wear properties.
- Can be used to improve inexpensive parts.
- Generally applied to near-finished parts.
- Improves fatigue strength.

Typical applications range from simple mild steel pressings to heavy-duty, alloy-steel transmission components.

**Diffusion Treatment - Nitriding**

This is a low-temperature, low-distortion, thermochemical process of diffusing Nitrogen into the surface of steel. This is usually performed on finished or near-finished ferrous components. After heat-treating and tempering, the parts are cleaned and heated in a special furnace for 10 to 90 hours where Nitrogen is diffused into the steel to form nitride alloys up to a depth of 0.25 inches. Quenching is not part of this process. The case is hard and the distortion is low. Additional machining, such as grinding, is not recommended.

Characteristics:
- Improved wear properties.
- Generally applied to near-finished or finished parts.
- Improves fatigue strength.
- Minimal process distortion.

Typical applications:
Camshafts and crankshafts.
- Bearing shafts and cages.
- Gears.
- Bushings and liners.
- Plastic mold and extrusion dies and tooling.
- Pump components.

**Selective Hardening - Induction & Flame Hardening**

Flame, induction, electron beams, and laser beam can do the selective hardening processes. The process allows heat treatment of a selected area instead of the entire part. Materials can include: 1) cast iron, 2) carbon steel, 3) tool steel and 4) alloy steel.

**Flame hardening**

The selected part surface is heated via a gas-oxygen flame. Hardness depth is dependent on factors such as heating time and flame intensity. Using a spray or immersion can cool the part. This process is cost effective and available without a great deal of special equipment. Caution must be used to avoid distortion and loss of ductility. For example, gears perform best with a hard surface and a softer, more ductile core.

This is widely used in deep hardening for large substrates. Typical applications are machine guideways, cams, gears, and plate material.

**Induction hardening**

The surface is heated via a high-frequency coil. By adjusting the power and frequency of the coil, hardness depth is controlled. This process is more controllable than flame hardening. Applications include rotating parts such as spindles, gears, shafts, etc. It is also suitable for small parts in production lines. Induction hardening equipment is now available in configurations capable of integration into a manufacturing cell or production line.

Many times heat-treating is a major factor in determining the machinability of a workpiece. With the implementation of flexible manufacturing cells, heat-treating equipment is being integrated into workpiece processing on the shop floor. Definitions of some heat-treating process can be found in the glossary and text of the "Cutting Tool Technology" (Chapter 9) of this Study Guide.
INSPECTION

Traditionally the inspection process was treated as a separate manufacturing department. It had its own set of goals and performed an after-the-fact, watch dog role over vendor-supplied components and production from the shop floor. In the new "total quality" philosophy it now becomes an integral part of a plant-wide effort to ensure continued product improvement. Inspection is becoming a closed-loop, systematic, well-defined process of detecting potential problems and correcting them before scrap parts are made.

There is a trend to delegate more inspection responsibility to the machine tool operator. The operator can observe and correct potential problems, which widen their responsibility and accountability over product quality. Also, there is an ongoing discussion over the virtues of locating a coordinate measuring machine in a temperature controlled inspection facility or placing it in the shop environment. Refer to the discussion of workpiece temperature considerations in the "Cutting Tool Technology" (chapter 9) and the discussion of coordinate measuring machines in the "Machine Tool Accuracy" (chapter 12) for considerations regarding this discussion. Customary shop inspection tools and coordinate measuring machines are discussed in the "Machine Tool Accuracy" (chapter 12) of this Study Guide.

Statistical Process Control (SPC) is discussed in the "Machine Tool Accuracy" (chapter 12) of the Study Guide. It has established a consistent statistical process for dealing with inspection data. Statistical process control is a process control method that allows measured data from the process to be plotted, statistically analyzed, and projected in order to keep the process under control before scrap is made.

The machine tool sales engineer should become familiar with Total Quality Management and Total Quality Control (TQM/TQC) concepts. These encompass a complete philosophy of company-wide quality control that includes the use of many lesser quality tools such as quality function deployment, Taguchi methods, and statistical quality control, among others, to achieve world-class quality performance. The Taguchi method is a quality engineering tool that uses the quality loss function as a way to explain quality issues to top management and emphasizes parameter design to design products and processes of robust quality that are insensitive to expensive-to-control noise factors.

CLEANING

The manufacturing environment is a place where workpieces are created by removing unwanted material, leaving the desired form. Various processes create their own type of contamination and undesirable residue. For example, casting and welding operations produce slag, scale, and sand deposits. Grinding, machining, deburring and such leave abrasives, metal chips, dust, coolant and lubricant residue. All these, and others, combine with normal shop dirt, dust and grease to cause concerns, which must be addressed. Most parts require cleaning before application of sealers and finish coatings such as paints.
Today's emphases on quality, closer machining tolerances and workpiece inspection, dictate that environmental concern be controlled. This cleanliness applies equally to the shop environment and the workpiece.

Cleaning is accomplished by one of several methods: 1) abrasive, 2) chemical, 3) electro-chemical and, 4) thermal. Abrasive can include blasting, deburring and polishing. Chemical is by far the most widely used cleaning method and includes solvent, alkaline and acidic cleaners. Some parts require a rinse after chemical cleaning to remove the chemical residue. Two effective cleaning processes in wide use today are vapor degreasing and ultrasonic cleaning. These methods reduce the part exposure to harsh chemicals and are environmentally easier to handle. They also adapt to a wide range of workpiece materials. The environmental concerns regarding chemicals in the manufacturing environment must be carefully considered when evaluating cleaning systems.
6.4 Manufacturing Systems

Over the last 20 years, manufacturing processes and philosophies have undergone what some observers believe to be a revolution. While some manufacturers have already made the transition to new manufacturing philosophies, others are either in the midst of transition or yet to begin. Basically, manufacturing is changing from a skilled craft to a disciplined science.

All too often, the sales engineer can become focused on the equipment they are selling and ignore the big picture at a customer’s facility. It is imperative that sales professionals have a working knowledge of this manufacturing transition and understand how it affects the way equipment is purchased and utilized. The sales engineer who can link the benefits of their equipment to the customer’s manufacturing philosophy and agenda will have the selling advantage.

This chapter will discuss two basic manufacturing philosophies: 1) Traditional Batch Manufacturing and 2) Lean Manufacturing. Newer, Lean manufacturing operations are quickly replacing older Traditional Batch manufacturing practices.

A partial list of Traditional Batch Manufacturing practices is shown below.

- Maintaining production volume is the priority.
- Reduction of direct labor.
- Increase production by working harder, smarter
- Minimum partpiece cycle time.
- Make it first, measure it when complete.
- Tolerance for some scrap and rework.
- Use of excess inventory to compensate for production and quality problems.

Equipment suppliers have learned to focus on: 1) reducing partpiece cycle time, 2) increasing machine speed, 3) reducing direct labor and 4) promoting price and features when selling in the Traditional environment.

In contrast, the Lean Manufacturing process moves away from many of the traditional practices and values and establishes a new set of performance measurables and operational disciplines. Selling into the Lean environment will require a complete shift on selling strategy. Here are some of the Lean opportunities and challenges:

- Major emphasis on: 1) part quality, 2) total process cost and 3) part delivery.
- Flexibility to handle part families and small batches.
- Machine reliability (uptime).
- Machine operators running multiple machines and processes.
- Emphasis on Takt time instead of cycle time.
- Ease of operation including error proofing.
- Minimal or zero setup time.
- Minimal equipment footprint (floor space).
- Statistical process control.
- Equipment suitability to cell integration.
- Visible machine signage and operational status (andes).
- Low life-cycle cost.
- Justification using Activity Based Costing.
- On-time equipment delivery.
- Maintenance and operational training.
- Formal machine installation and runoff schedule and task list.
- Easy access to machine maintenance areas.
- After-sale maintenance support and contracts.
- Less vendors - Partnerships with several key vendors
- Team buying.
- High degree of communication and openness by vendors.
- Electronic data exchange between vendor and customer.
- Continuous improvement in supplier performance.
- Customer satisfaction measurement by suppliers.
- Suppliers with formal problem solving skills.

Learning to sell in a Lean environment will require new selling strategies and skills. Suppliers must sell an entire package of equipment and value-added services. More selling strategy can be found at the end of the “Lean Manufacturing” section.

**TRADITIONAL BATCH MANUFACTURING SYSTEMS**

Manufacturing systems have traditionally been designed to process workpieces in low, medium or high volumes. The exact quantities for low, medium and high volumes are not well defined but depend on variables unique to the product being produced.

**High Volume** - Automotive parts manufacturing using special-purpose, multi-function transfer machines, typify high-volume operations. They offer the ultimate in automation, speed and material handling for large or continuous lot production.

There is still a great demand for traditional high-volume production, but even industries, such as automotive and appliance, are changing. Poor quality, high inventory and consistent production levels are no longer acceptable in today’s global marketplace. No longer is Batch Production determined by “Economic Order Quantity” (EOQ), which had been the determining factor.
Low to Medium Volume – These operations have traditionally been characterized by machines and equipment departmentalized by function (e.g. snagging, milling, drilling, boring, grinding, inspection, cleaning, painting, storing and shipping). Parts are released in lot sizes (batches) based on an Economic Order Quantity (EOQ). These batch sizes took into account extra parts needed for stock and expected scrap. Parts traveled in batches from department to department based on a work order generated by the processing department. The constant management challenge with the batch manufacturing system is to balance the workload in each department and keep the batches moving. This system is sometimes called "push" production as management devotes its efforts to keep the parts on schedule.

Push Production
A Push system permits production of partpieces to continue based on a preset timing schedule. Orders are put into the manufacturing system based on a scheduled period and assume that they will come out the end of the process at the end of the designated throughput times. Even the best closed-loop, push systems are much less responsive to in-process variation, and therefore much less effective for controlling production and work-in-process than pull systems. In many respects, Push systems are the opposite of the pull system.

Batch Production
This is a manufacturing process organized by groups of functions in given departments such as; snagging, grinding, milling, boring, turning, inspection, cleaning, painting and storage. A batch of gears could be in several departments for weeks or months before being used in assembly. Therefore, design changes, poor quality, and extra production quantities (for accidental scrap) all add to cost. Finally, work order releases have to be balanced to keep batches moving on a fixed schedule. Newer competitive pressures dictate changing from “Batch Production’ to “Lean manufacturing” methods.

Computer Numerical Control (CNC)
Originally, machine tools were stand-alone, manual machines that performed single functions such as drilling, milling, boring and turning. Productivity has increased with machines that are multi-functional, thus reducing departmental moves and setups.

CNC has had its greatest impact by improving productivity in low to medium volume operations. While the majority of CNC machines are still operating as stand-alone machine tools there is a growing trend to utilize CNC machine tools in higher-production applications. They can be arranged in manufacturing cells or integrated as a station in a high-production transfer line. These configurations are aimed at adding flexibility more than increasing production volumes. Where partpieces are produced in high-volume, with little or no change, a custom (non-CNC) automated machine is usually employed. Statistics still indicate that the majority of manufacturing time is spent with parts in move and queue, and efforts are being directed towards eliminating any expense or action that does not add value to the product (e.g. move and queue).
LEAN MANUFACTURING

Lean manufacturing is a manufacturing philosophy as well as a definitive system. It is a set of operating principles to eliminate waste, while maximizing quality and flexibility. Lean Production maximizes the efficient use of resources. A basic principle is involving people to: eliminate waste, standardize work, produce zero defects, and institute one-piece flow. It also includes material movement triggered by downstream operations (pull and inventory reductions).

Based on this definition, Lean Manufacturing affects every aspect of manufacturing including: 1) workplace culture, 2) work standards and 3) work flow. There are many pieces to the Lean Manufacturing puzzle. Some of the defined principles and processes are listed below. Lean manufacturing is a comprehensive subject and the Sales Engineer should read extensively on this topic. The more common issues are briefly discussed in this chapter.

**Workplace Culture**
- Leadership
- Standardized work
- Employee involvement
- Customer satisfaction
- Visual control
- Continuous improvement
- Kaizen

**Work Standards**
- Standardized process
- Total Productive Maintenance
- Problem solving and 6 sigma
- 5S Visual factory
- Error proofing
- Takt time

**Work Flow**
- Pull production
- Kanban
- Just-in-time
- Quick changeover
- Setup reduction
- Cellular manufacturing
- Flexibility
- Supplier involvement
- Value stream mapping

All of the Lean principles and processes listed above focus on three fundamental manufacturing targets: 1) Quality, 2) Cost and 3) Delivery.

“**Lean Manufacturing** – A production system that makes extensive use of teamwork, communication, efficient use of resources, effective application of machinery and equipment, the elimination of waste and continuous improvement. Compared to mass production, lean manufacturing utilizes about half the human effort in the factory, about half the manufacturing space and about half the investment in tooling, engineering hours and time to develop new products.”

Ford Motor Company – Guidebook for Effective Measurables
LEAN – WORKPLACE CULTURE

Waste & Value
Fundamental to Lean manufacturing is the total dedication to the elimination of waste. This is because it is the opposite of value. As a partpiece flows through the manufacturing process, it is either in a: 1) value-added mode or 2) waste mode.

While each organization has their own definition of waste, here are the most common types:
- Over-production.
- Inventory.
- Transportation.
- Waiting.
- Motion.
- Over-processing.
- Correction & rework.
- Underutilization of human talent and resources.

Identifying the causes of waste is an ongoing process in the Lean facility. The more recognized causes of waste are:
- Inefficient layout (distance).
- Long setup times.
- Inadequate processes.
- Poor maintenance.
- Poor work methods.
- Insufficient training.
- Poor product design.

Examples of Waste & Value-Added

![Diagram showing examples of waste and value-added activities](Fig. 2 – Waste & Value-Added (Courtesy Decision Technology, Inc.))
- Lack of performance measures.
- Ineffective production planning and scheduling.
- Poor equipment design and selection.
- Bad workplace organization.
- Inconsistent supplier quality and reliability.

**Customer Satisfaction**
Customer satisfaction is a driving force in a Lean company and satisfaction levels are measured and statistically trended. When key areas of dissatisfaction are identified, real change is demanded along the entire value added stream – from pre-sale activities through after-warranty service. The goal is to retain existing customers rather than incurring the high expense of finding new customers. This has a major impact on profitability and business stability.

In the Lean philosophy, the customer is the one who defines “quality”, not the supplier. Recent studies indicate that customers will defect even if they are satisfied with a product. Therefore, the goal of the Lean system is to not only meet, but also exceed customer expectations. Customers’ needs are addressed at the following levels:
- Quality, cost and delivery.
- Reliability and features.

Customer satisfaction encompasses both external customers as well as internal customers. All internal processes must meet the needs of the next customer in the process. A growing practice is to base management income and or bonus rewards, in some part, on customer satisfaction (external & internal) ratings.

**Leadership & Employee Involvement**
The Lean Manufacturing philosophy is very dependent on the leadership and involvement of employees. Unless management is totally committed to the process chances of failure are very high because corporate culture and values must change to implement Lean. A high degree of openness with employees is essential. Production statistics as well as key financial numbers are open for employee review.

Employees must also be committed and to do so they need to feel secure and operate in an environment of openness. Their suggestions must be treated with full consideration and respect. The Lean system depends on trusting and empowering employees to do their job with a sense of value-added contribution. Some companies are now adding more contract workers during peak economic cycles so that their own employees, the core group, will remain unaffected during periods of layoff.
Teamwork is an important part of the Lean system. Many employers will invest training time teaching teamwork principles. When people do not work as a team, human resource creative power as well as time is wasted. Teamwork addresses this waste factor.

**Communication**
In a lean organization, communication is everywhere. Information is shared freely with all participants up and down the value chain. Even machine operators have the necessary information to make improvements in their area of influence.

**Problem Solving - Root Cause Analysis – 5 Whys**
A common problem-solving tool in manufacturing is Root Cause Analysis. All too often addressing the symptom solves a surface problem. Later, the problem reoccurs. The goal is to track down problems to the root cause and make the fix at this level.

The “5 Why” problem-solving method is attributed to Taiichi Ohno. The question "why" is asked and answered until the root cause of a problem is identified. Corrections are then put in place. Here is an example:

1. Why is the part out of print tolerance? **Answer:** Operator error.
2. Why did the operator error? **Answer:** He didn’t change the tools?
3. Why didn’t he change the tools? **Answer:** New tools weren’t available.
4. Why weren’t new tools available? **Answer:** The shipment arrived one week late.
5. Why did the shipment arrive late? **Answer:** Purchasing miscalculated the business forecasts.

Lean manufacturing employs other problem solving techniques in addition to those discussed above. The Sales Engineer should inquire of customers which problem solving methods they employ. This will add to the Sales Engineer’s understanding of how the customer will handle problems that arise with vendors.

**Visual Factory**
As stated earlier, communication is a critical aspect of Lean. The traditional manufacturing plant is managed with a combination of computer reports and on-floor expediting. In the Lean plant, a different operational philosophy prevails. It is based on allowing information to flow and be interpreted at a rapid rate. Much of the visual factory is based on the use of 1) work cells (easy to observe all operations), 2) production control boards, 3) shadow boards (tools & tables), 4) color-coded bins, 5) horns, whistles, lights and 6) inventory control cards.
The characteristics of the visual factory are simple and practical:

- Workflow is designed so that it can be seen visually by workers as well as supervision from a single point. This is typical of a U-shaped work cell or in-line cell.
- Areas of possible abnormalities are highlighted.
- Workstations are clearly identified.
- Containers and part racks are labeled and easy to store and retrieve.
- Lines and boxes are drawn on the floor to identify isles, material drop areas and Kanban areas.
- Signage is used to clarify and direct emergency and work procedures.
- Packaging is color coded with respect to intended purpose.
- Indicator lights (andons) show equipment status.
- TPM charts detail maintenance schedule of the machinery.
- Machinery operating procedures are posted near the machine.
- Statistical process control charts with control limits are posted at each station.
- Process control boards at each station.
- Operating standards and process maps located at each station.

**LEAN – WORK STANDARDS**

**5S**

The five S’s focus on eliminating waste through workplace organization. The original 5S’s were Japanese words. Here are the Japanese words with their English translations: Seiri (organization), Seiton (neatness), Seiso (cleaning), Seiketsu (standardization) and Shitsuke (discipline). In order to keep the 5S nomenclature, the Western world has adopted our own matching 5S’s: Sort, Straighten, Sweep, Standardize and Sustain. These vary slightly from manufacturer to manufacturer. The goal is to organize a work area to maximize productivity, comfort, safety and cleanliness.

Most believe that the 5S system is the starting point for all Lean processes that follow. Without work area organization and discipline, other Lean activities will have severe difficulty. A great deal of worker time is wasted looking for lost of hard-to-find items.

- **Sort** – Determine a proper place for everything in the plant. Keep only those items necessary for current production in the work area.
- **Straighten** – Make sure that the plant is orderly. Mark and label all items for easy storage and retrieval. All components, fixtures, tools and storage areas are visually labeled for fast identification.
- **Sweep** – Keep the plant clean. This includes sweeping, dusting, wiping and painting.
- **Schedule** – Develop a schedule for regular and repetitive sorting, straightening and sweeping.
• **Sustain** – Maintain the above procedures until they become the habitual behavior of all employees.

The benefits of implementing 5S are many. Here are a few:
- Reduced search time.
- Lower inventory costs.
- More useable floor space.
- Better working conditions.
- Improved worker morale.
- Fewer accidents.
- Faster cycle times.
- Improved delivery times.
- Higher profits.

**Continuous Improvement (Kaizen)**
Continuous improvement is defined as the ongoing improvement of products, processes, and/or services. The gains made through continuous improvement activities are generally incremental, small-step improvements, as contrasted with more dramatic and sweeping improvements typically associated with initiatives such as policy deployment. In Japan, the continuous improvement process is often called kaizen.

This process is very people-oriented. Once all the other Lean methods are in place, Kaizen provides for the continual advancement and improvement necessary to achieve world-class benchmark performance. A cultural change is necessary for Continuous Improvement to function properly.

Typical Kaizen targets are:
- Unnecessary motion
- Unnecessary material handling
- Waiting time
- Rework & scrap
- Unnecessary part processing
- Excess inventories
- Over production

**Error Proofing (Poka-Yoke)**
Error proofing is an improvement approach that is focused on eliminating defects, errors, and equipment abnormalities in production processes before they occur. Error Proofing generally takes place at the workstation. Using Error Proofing techniques to stabilize equipment impacts Lean manufacturing results positively. For instance, Error Proofing reduces scrap, reruns, retests, and returns. Error Proofing has a major impact on customer satisfaction and being able to make the part right the first time through the system. Occasionally, you may hear the term Poka-Yoke, which is the Japanese term for error proofing.
Error proofing is based on a unique premise. Errors and mistakes are seldom blamed on the worker or machine operator; they are seen as a deficiency in the operational system.

The basic steps to error proofing are:
1) Identify and describe the defect.
2) Determine where the defect is made.
3) Review the current standard procedure.
4) Identify weaknesses or deficiencies from standard.
6) Specify the kind of Error Proofing device needed to prevent the error or defect.
7) Create device(s) and test(s) for effectiveness.

Error proofing devices are simple methods used to prevent errors about to occur, or detect errors that have already occurred. Some examples of Error Proofing devices are: guide or reference rod, template, limit or microswitch, counter, odd-part-out method, sequence restriction, standardization, critical condition detector, delivery chute, stopper/gate, assembly tangs and sensors. For instance, a tang or protrusion might be machined on a part that matches a reverse tang or protrusion on the matching part. This would only allow one way (the correct way) to assemble the two parts.

**Total Productive Maintenance (TPM)**

Many people confuse Total Productive Maintenance (TPM) with Preventative Maintenance (PM). TPM is far more comprehensive and people intensive.

TPM works to improve product quality and delivery through improved equipment up-time, reliability and optimization. TPM can be a major contributor to productivity and customer satisfaction. The following chart demonstrates the comparison between TPM and traditional manufacturing systems.

<table>
<thead>
<tr>
<th>Source</th>
<th>Traditional Manufacturing Plant</th>
<th>TPM Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value-Added time</td>
<td>39%</td>
<td>87%</td>
</tr>
<tr>
<td>Breaks, lunches, 5S, team meetings</td>
<td>11%</td>
<td>11%</td>
</tr>
<tr>
<td>Unplanned equipment breakdowns, scrap, rework, stoppages, etc</td>
<td>50%</td>
<td>0%</td>
</tr>
<tr>
<td>Operator preventative maintenance</td>
<td>0%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Implementing World Class Manufacturing, 1998, Rubrich & Watson
Lean Measurables
Each Lean implementation may use slightly different measurables and/or terms depending on their production characteristics. Here are the more common measurables.

- Dock to Dock time
- Overall Equipment Effectiveness
- First Time Through
- Total Cost
- Value-Add Time to Non-Value Add time ratio
- Manufacturing Cycle Time
- Square Footage
- Changeover Time
- Downtime
- Travel Distance
- Work in Process Inventory

Six Sigma
This is a statistical methodology used to track, analyze and control the variability of a process. More information is available in Chapter 12 – Machine Tool Accuracy.

Group Technology
Group technology is the use of a coding and classification system to group products or processes into families with similar attributes. Parts in a family may have similar setup times, cycle times, tool and fixture requirements or machining operations. Group technology directly affects cell manufacturing.

When logical part families are determined, a cell of machines is arranged to accommodate machining operations. Different part types are made in the cell, but all types go through the same machines. Simplified methods of grouping part families can be 1) visual part inspection or, 2) inspecting routing sheets. Another more sophisticated method involves part classification and coding. Part designs or manufacturing attributes are classified and integrated into a part code number that can be used at almost every level of planning and production.

Takt Time
Takt is a German word that means “pace” or “rhythm”. It is a calculation of “Available Time” divided by the “Customer Production Requirements” which varies considerably from “Cycle Time”. Calculating the Takt time helps prevent overproduction and identify waste.

Without balancing production to customer needs, production levels stabilize and inventory (waste) becomes the buffer between how much is made in a specific time and how much the customer needs. Stabilizing production tends to create
larger shock waves of increased and decreased production. Below is a sample calculation.

\[
\begin{align*}
\text{Takt Time} &= \frac{\text{Available Time}}{\text{Customer Requirements}} \\
\text{Takt Time} &= \frac{480\text{min (1 shift)} - 30\text{min (breaks)}}{500 \text{ Parts per shift}} \\
\text{Takt Time} &= \frac{450\text{min x 60sec/min}}{500 \text{ Parts per shift}} \\
\text{Takt Time} &= \frac{27,000 \text{ seconds/shift}}{500 \text{ Parts per shift}} \\
\text{Takt Time} &= \frac{54 \text{ seconds per part}}{}
\end{align*}
\]

Things that prevent obtaining Takt time and add costs to the system are:
- Breakdowns (major downtime).
- Changeover.
- Interruptions (minor downtime).
- Late starts.
- Scrap or rework.

**LEAN – WORK FLOW**

**Pull Production**

Pull production is a system of supervising the factory floor that minimizes work-in-process and dramatically improves throughput time by eliminating waiting (lines or queues) between operations. A pull-system requires two things: a pull signal and a fixed upper volume limit. Operators must stop producing parts (fixed upper volume limit) whenever they have not received their (pull signal) authorization to produce more parts. The pull signals are sometimes called Kanban.

The heart of any Pull Production or Kanban system is near zero set-up time to provide the means for fast changeover of key machine tools and production equipment to meet changing workloads. A second factor is a standardized product or products. When customized versions of standard products are produced while using Pull Production systems, careful attention must be given to engineering designs that can be readily adapted to shop production.

**Kanban**

This is a Japanese manufacturing term (pronounced "Kahn-bahn) whose literal translation to English is "card", "visible record" or "visible plate."

A Kanban production system is one that uses an order card, delivery card or visible signal to move material through a manufacturing plant. Kanban systems are associated with "pull" rather than "push" or "batch" type production systems.
Batch systems also may use order cards and routing sheets for ordering new parts, however the actual production control philosophy is completely different.

Kanban systems are always associated with Just in Time (JIT) manufacturing and are not practical when used in a non-JIT environment. Kanban systems work best in production plants needing parts on a daily basis with accurate forecasts of sales and shipments. However, Kanban systems are also used successfully in most plants making finished products assembled from units or sub-assemblies.

**Just in Time (JIT)**
The term "Just in Time" is often assumed to define an inventory or production control system. In reality, JIT combines pull production with other waste elimination (e.g. setup time reduction) to better connect production to actual customer consumption. Probably the biggest area of waste is stored or in-process inventory, which does not contribute to the value of the end product. In manufacturing, all inventory, queue time, and labor that are not required are targeted for reduction. JIT causes work to move through manufacturing faster, arriving at final assembly just in time for use. A major benefit of the JIT philosophy is that it allows increased productivity while reducing lot sizes - in some cases a lot size of one (1) is economically possible. A manufacturer now has the flexibility to tailor lot sizes to match the rate of incoming orders while keeping costs and inventory down.

**Setup Reduction & Quick Changeover**
In simple terms, a setup is defined as each time the partpiece is relocated in a machine tool. During the manufacturing process, a new workpiece setup occurs under the following conditions:

- The partpiece is reoriented in the machine (or moved to another machine) to expose additional work surfaces or features that were previously not reachable (e.g. blocked by fixturing).
- Each time you want to manufacture a different partpiece (e.g. different design than the previous partpiece).

Setup or changeover time is the time between the last good piece off one production run and the first good piece off the next run. Setup time does not add value to the partpiece and is therefore classified as waste. The goal should be: 1) reduce the number of setups (to zero if possible) and 2) reduce the length of setup time.

Required batch sizes and Economic Order Quantity (EOQ) requirements will determine the frequency of setup change over. Setup reduction will reduce delivery times and improve overall capacity.
Manufacturing Cells

A cell is a group of machines or equipment, with a defined flow, in a grouping composed to complete an entire operation or major production step. Cells combine different types of equipment and processes, thereby breaking down functional groupings of like machines. If setup times are reduced to make smaller batches, the cell reduces wait, thereby moving and handling waste, enabling faster response.

The most recognized form is a “U” shaped cell. It allows the staffing of multiple machines with one or two people. Other common types are the “In-line” and “S” shaped cells.

The key element of a flexible Cellular System is the ability to perform similar, and in some cases dissimilar, operations on a high number of part piece families, with almost zero set up time, with a limited amount of manual labor, and with six sigma on-line control of quality.

The challenge in forming cells is grouping and balancing the right types of equipment to enable material flow under a variety of product mixes and volumes.

Manufacturing cells of the type described above are in place in hundreds of manufacturing facilities today and provide products in “Just In Time” fashion not previously available. In some cases such Cellular manufacturing installations are fed by subcontractors or an in-plant Machining Cell containing groups of CNC palletized machine or near zero set up machine tool.
These manufacturing and assembly cells have the following benefits when employed in a Lean environment:

- Eliminate non-value added operations.
- Near zero set up time. (In terms of minutes, not hours)
- Faster inventory turnover. (15 to 30 times per year as opposed to 2 to 4 times per year in the past)
- Reduced WIP (Work In Process)
- Short direct, production flow with little if any in-process part storage requirements.
- High quality standards with improved Cpk values.
- Reduced scrap rates.
- More efficient use of labor and lower supervision requirements.
- A happier, more involved work force performing less tedious work.

**Supplier Involvement**

In a Lean production environment, suppliers play a more important role than ever before. Since there is waste in the external supply chain, it has become a target for manufacturers. Lean customers will reduce the total number of vendors to save on transaction costs. They will also look for strategic partners who understand the Lean philosophy and assist with its implementation and success.

One characteristic of these strategic partnerships will be open and integrated communication. Both supplier and customer will have access to key computer data on a real-time basis. Also, financial information may be more open for discussion and negotiation. In some cases, supplier employees will be located within the customer’s facility to handle a variety of tasks. It may be hard, in the more integrated cases, to tell where the line divides between supplier and customer.

Vendors who supply components will find the following changes when supplying to Lean customers:

1. Material picked ups and deliveries will coincide within predefined window times.
2. Shipments will be made in smaller, more frequent deliveries.
3. Shipping containers and racks (returnable) will be processed like production parts.
4. Key suppliers may actually be managing the logistics process.
SELLING IN A LEAN ENVIRONMENT

The sales engineer should take a proactive role in encouraging and supporting customers in their transition to Lean manufacturing. First, the sales engineer must be familiar with Lean terminology and concepts. Instead of seeing the micro picture of a single machine sale, they need to adopt a macro picture of the entire manufacturing process. Machinery and tooling requirements change in a Lean environment and if not prepared, the sales engineer’s agenda may be at odds with the customer’s goals.

Below are several major issues that must be considered when selling into a Lean system.

**Increasing Production**

There are five ways to increase production. Examine the following chart to understand the benefits of Lean manufacturing.

<table>
<thead>
<tr>
<th></th>
<th>Quality</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work Longer</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Work Harder</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Add People</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Add Equipment</td>
<td>↑(?)</td>
<td>↑</td>
</tr>
<tr>
<td>Eliminate Waste</td>
<td>↑</td>
<td>↓</td>
</tr>
</tbody>
</table>

The ramifications for manufacturing equipment suppliers are significant. Purchasing new equipment may no longer be a preferred solution for increasing production.

**Defects**

When defective parts are created in a Lean production process, the process is normally stopped and problems corrected before more defective parts are made. Defective parts (either scrap or rework) are an obvious form of waste. The application of new machine tools can improve the accuracy and repeatability of the process and keeping well within the control limits. This directly affects the quality of the end product.

**Direct Labor**

When selling in the traditional manufacturing setting, the focus is on reducing the operator’s direct labor hours. In the Lean system, the emphasis changes. Direct labor employees work in teams to find ways to reduce overall labor hours. Each area of production is addressed in view of the total picture. Having influence in maximizing the production process improves employee moral and motivation.
Support Labor
The elimination of waste in areas such as material movement, inventory tracking, expediting, paperwork processing and scheduling significantly reduces support labor hours. This also makes managing the production process easier.

Capital Equipment
Utilization levels of capital equipment have always been problematic. Typically, it is not fully utilized. The Lean model strives to match equipment utilization to market demand. Instead of increasing production to increase utilization (and wind up with excess inventory), Lean seeks to base utilization on the changing demand from customers. Flexible machine tools will be favored in this environment.

Space
Excess or empty space is like a magnet, attracting excess inventory or clutter. Therefore, less space is a good measurable in Lean. It reduces workflow distances and prevents buildup of inventory or tooling. If everything is stored in designated areas, they will be easier and faster to find. Equipment with a smaller footprint will be favored. This includes the base machinery as well as all peripheral support equipment. Some machines require more space for servicing and access, which will prompt a low rating.

Inventory
In the traditional production system, inventory can mask a lot of underlying problems. For instance, the assembly department might stock up on a certain part that has high failure rates. This prevents interrupt production and late delivery. One of the best ways to identify manufacturing constraints is to slowly reduce inventory levels – the problems will be revealed. In addition to masking problems, inventory is costly, incurring interest and capital charges.

When inventory is reduced: 1) parts must be produced in lower batch sizes, 2) vendors must deliver smaller batches in a specified time window, 3) part quality must be increased to prevent scrap or rework and 4) setup times must be reduced to accommodate more frequent, smaller batch runs.

The lean concept of inventory is not to buy it before you need it. The sales engineer should keep in mind that this also includes the purchase of manufacturing equipment.

At the beginning of this chapter, a list of Lean opportunities and challenges were presented. The list is repeated here with the intent that sales professionals study each item and brainstorm how their organizational and equipment benefits can help customers reach their Lean manufacturing goals.

- Major emphasis on: 1) part quality, 2) total process cost and 3) part delivery.
- Flexibility to handle part families and small batches.
- Machine reliability (uptime).
- Machine operators running multiple machines and processes.
Emphasis on Takt time instead of cycle time.
Ease of operation including error proofing.
Minimal or zero setup time.
Minimal equipment footprint (floor space).
Statistical process control.
Equipment suitability to cell integration.
Visible machine signage and operational status (andons).
Low life-cycle cost.
Justification using Activity Based Costing.
On-time equipment delivery.
Maintenance and operational training.
Formal machine installation and runoff schedule and task list.
Easy access to machine maintenance areas.
After-sale maintenance support and contracts.
Less vendors - Partnerships with several key vendors
Team buying.
High degree of communication and openness by vendors.
Electronic data exchange between vendor and customer.
Continuous improvement in supplier performance.
Customer satisfaction measurement by suppliers.
Suppliers with formal problem solving skills.

Learning to sell in a Lean environment will require new selling strategies and skills. Suppliers must sell an entire package of equipment and value-added services. More selling strategy can be found at the end of the “Lean Manufacturing” section.

Sales professionals who understand the Lean process will find many opportunities. Study each aspect of the Lean system and look for ways to help Lean customers reach their goals.

Further study is encouraged. Refer to the "Reference Books & Suggested Reading" at the end of Volume II.

**COMPUTER-INTEGRATED MANUFACTURING (CIM)**

Computer-Integrated Manufacturing is the integration of all information (engineering, business, and process control) involved in the total spectrum of manufacturing activity. It includes all components involved in converting raw materials into finished products and getting the products to the market. CIM goes a step beyond automation, in that it integrates these "Islands of Information" into a computer-based control and monitoring system. These "Islands of Information" may include but not be limited to:

- Manufacturing and human resource management
- Marketing
- Finance
- Product/process design and planning
- Strategic planning
- Factory automation

The role of CIM is to tie together, in a closed loop system, the information from the machine, station, cell, shop, facility and enterprise level. This means that CIM can control or track a part from initial design (CAD) through projected marketing forecasts, purchase of raw materials, production scheduling and shipping to the customer. It is a comprehensive, computer-based management control, planning, monitoring and reporting tool. CIM represents a major investment for a manufacturing facility.
6.5 Manufacturing Software

Increasing productivity in today’s manufacturing plant is a challenge that goes beyond the proper selection and application of machine tools. Management systems that plan, schedule, manufacture, track and ship products must be implemented at every level. As manufacturing evolves from a craft to a science it will continually seek computer-based solutions to assist with management strategy and tasks. Therefore, the implementation of manufacturing software is on a rapid growth curve. Two things are apparent:

- New generation software is not a miracle cure for managing the manufacturing environment. First, manufacturers must be committed to improving their entire business process.
- Manufacturers have outgrown systems used in the past. These were either manual systems or those based on older MRP (Material Resource Planning) systems. These systems simply lack the power, flexibility and functionality required by today’s world-class manufacturer.
- Small and mid-sized companies now need the benefits of factory-wide software systems once reserved for the large manufacturer.

Trends
The current growth trends in the manufacturing software business are as follows:

- The advent of Java, Sun Microsystems’ platform-independent programming language. This will make factory-floor application development faster and easier.
- ERP (Enterprise Resource Planning) solutions for mid-sized manufacturers.
- Internet-enabled electronic commerce.
- Supply-chain management.

Software System Types
The sales engineer may not sell manufacturing software; however, they need to understand how these systems impact the utilization of machine tools in a factory-wide setting. The brief descriptions of the terms and systems below will allow the sales engineer to obtain a “big picture” of the manufacturing management environment based on the application of key software systems. A brief familiarity only is the goal of the following material. In-depth, knowledge is not required for the CMTSE exam.

CAD/CAM/CAE
Computer-aided design and computer-aided manufacturing constitute the application known as CAD/CAM. In CAD engineers use specialized computer software to create geometric models that are redesigned as needed. CAM engineers can study varying designs to plan manufacturing processes, control-
manufacturing operations, test finished parts, and manage plants. CAD is linked with CAM through a database shared by design and manufacturing engineers.

**CMMS**

Computerized maintenance management systems maintain electronic documentation of plant equipment for the automated scheduling of repair and maintenance. Asset management, as it is also coming to be called, extends this automated documentation to the enterprise level and manages the life cycle of plant equipment as a capital asset in conjunction with the company’s finance and purchasing.

**EDI Communications**

Electronic data interchange is a standard for the automated exchange of business documents. Using EDI, purchasers and suppliers can exchange purchase orders, invoices and other business documents, and perform electronic funds transfers. The use of EDI, which originated among automakers and their suppliers, is a vital component of the supply chain.

**Relational Database Management Systems**

Relational database management systems store and organize corporate data such as sales figures, part numbers and geographical distribution in tables, rows, and columns in a multi-user system. This data can be accessed through ad hoc queries, or specialized data warehouses for analysis and decision making. RDBMSs give users a consistent method of entering, retrieving and updating data in the system and prevent duplication and unauthorized access to stored information.

**Forecast Management**

Forecasting is increasingly a short-term capability that can be met with specialized supply-chain management software. These systems, often called demand-planning software, can determine the optimum production schedule, manufacturing capacity, and available-to-promise on a global basis.

**Inventory Control/Financial Management**

Inventory control is the practice of maintaining stock in warehouses or distribution centers based on manufacturing production and/or supply-chain demand. Coupled with warehouse automation, software to manage replenishment of goods to ship or receive for manufacturing is increasingly considered a vital element in a supply-chain management solution. Financial management tracks where money is being spent within the realms of the entire manufacturing operation.

**MES**

Manufacturing execution systems are plant floor management systems that perform a variety of simulation, monitoring, and batch workorder functions under one umbrella system. An MES makes decisions on current plant floor information and dynamically adjusts resource allocation and other variables to
correct problems before they occur. An MES maintains a model of the manufacturing process to ensure that the right operators with the right training and qualifications carry out the right operations in the right order, at the right workstations. An MES also tracks and logs all process information in a database.

**MMI**
Man-machine interface is the graphical view of a plant floor and its operating conditions shown on a computer or terminal screen. This allows real-time monitoring, control, and information management, such as alarms and historical trending.

**MRP, MRP II & ERP**
This is computer-based software normally used with traditional batch lot production. The complete application software package contains modules including forecasting, order entry, master production scheduling, capacity planning, material requirements planning, procurement, shop floor control, and cost accounting. MRP II packages contain integrated accounting and financial reporting functions as well.

Manufacturing resource planning/enterprise resource planning (MRP II/ERP) is the practice of using computerized planning and scheduling of manufacturing resources such as materials, capacity, costs and labor. MRP II produces bills of materials and helps to produce master production schedules. ERP expands on MRP II to include distribution, project management, financials, and multisite manufacturing planning and scheduling, inventory management and in some systems, product definition and configuration.

**Network Integration/Internet**
This denotes the network of networks that comprises the Internet, of which the World Wide Web is one easily accessible part. On the plant floor, many device networks, linking sensors, machines, material handling systems, programmable controllers, and other systems, may have to be integrated to create a seamless flow of information.

**Advanced Planning & Scheduling**
Production planning is the computerized generation of process plans and distribution of work instructions for manufacturing discrete parts efficiently and economically to meet desired delivery dates. This includes scheduling of workers, materials, machines, lead times, time standards and workloads. Coupled with group technology, which analyzes relationships between parts, this process helps facilitate design-for-assembly.

**Process Optimization**
As opposed to process control, which fundamentally is concerned with managing and monitoring manufacturing processes, process optimization uses algorithms, rules, and integration with plant floor systems to create the optimum environment in which to manufacture. This includes such factors as tool management, time
and labor, energy management, and maintenance. In discrete manufacturing, it includes just-in-time (JIT) and flow manufacturing techniques.

Remote Support Capability
In networking terms, remote support capability is the ability to monitor, diagnose, and control information systems from different locations, either within the same facility or from a long distance.

Sales Force Automation
Sales force automation puts mobile communications in the hands of traveling sales engineers who can dial into manufacturing operations and check the status of orders or availability of products. In some cases, on-line engineering configuration of a new order can be done at a customer’s site, with prices and delivery dates. SFA can also be integrated into some ERP systems’ MRP II and financial applications.

Shop Floor Control
Shop floor control is a system for utilizing data from the shop floor as well as data processing files to communicate status information on shop orders and workcenters. Major subfunctions of SFC include assigning priority to each shop order status information record for executive decision-making, and providing actual output data for capacity control purposes.

Simulation
Simulation is the use of programming techniques to duplicate production processes and physical, thermal, or kinematic characteristics of a part being designed. Simulation can be used to exercise the electrical properties of a circuit, or perform finite element analysis on a surface. It can also be used to model a production facility for optimum throughput. Within MRP II, simulation programming utilizes a mathematical model to try out production configurations.
6.6 Review Questions

These review questions are provided for study purposes only and are not on the CMTSE certification exam. Correctly answering these questions does not guarantee a passing exam grade.

1. In a traditional batch manufacturing system, which statement is true?
   1. Parts spend less than 10% of the time being machined
   2. Parts are always released in batch sizes of 10 or less
   3. Batch processing is also called "Pull production"
   4. CNC machines are not well suited to batch manufacturing

2. What type of part(s) would be best suited to a CNC lathe with “live” rotary tooling capability?
   1. Low-volume simple parts
   2. Parts with secondary milling and drilling operations
   3. High-volume complex turning
   4. High-speed turning applications

3. The term "Kanban" refers to:
   1. the transfer of electronic data in a Flexible Manufacturing Cell.
   2. the length of time workpieces wait between machining operations.
   3. weight lifting restrictions on machine operators.
   4. the visible labeling and tracking system of parts in a factory.

4. Which is generally not a basic component of an FMS?
   1. CNC machine tools
   2. Conveyance network
   3. CMM
   4. System controller

5. The acronym TQC stands for:
   1. Total Quantity Calculation.
   2. Taguchi Quality Center.
   3. Times and Quota Capacity.
   4. Total Quality Control.

6. Which of the following does not describe JIT manufacturing?
   1. Little or no inventory is maintained
   2. Significant production flexibility
   3. Slow response to engineering changes
   4. Use of production and quality control charts
7. A kanban system makes use of:
   1. a visual part tracking system.
   2. a push production system.
   3. continuous flow manufacturing.
   4. cellular manufacturing.

8. The acronym AGVS refers to:
   1. Automatically Grounded Voltage System.

9. The application of FMS technology to manufacturing will usually result in:
   1. longer lead times.
   2. increased work in progress.
   3. faster response to changing production requirements.
   4. low-level machine control.

10. When used to aid in programming, CAM software is:
    1. better suited than CNC controls for complicated geometric shapes.
    2. a major reason that the use of manual programming is on the increase.
    3. better suited than CNC controls for situations in which there is a low degree of complexity.
    4. a major reason that CAD systems are shrinking in popularity.

11. Lean manufacturing is based primarily on:
    1. reducing setup time.
    2. elimination of waste.
    3. increasing production rates.
    4. improving quality.

12. Which of the following is used to balance available production time with customer usage?
    1. Inventory reduction
    2. Kaizen
    3. Kanban
    4. Takt time
ANSWERS TO REVIEW QUESTIONS

1. (1)
2. (2)
3. (4)
4. (3)
5. (4)
6. (3)
7. (1)
8. (4)
9. (3)
10. (1)
11. (2)
12. (4)