1 INTRODUCTION AND OVERVIEW OF MANUFACTURING

Review Questions

1.1 Define manufacturing.

Answer. The text defines manufacturing in two ways: technologically and economically. Technologically, manufacturing is the application of physical and chemical processes to alter the geometry, properties, and/or appearance of a given starting material to make parts or products; manufacturing also includes assembly of multiple parts to make products. Economically, manufacturing is the transformation of materials into items of greater value by means of one or more processing and/or assembly operations. The key point is that manufacturing adds value to the material by changing its shape or properties, or by combining it with other materials.

1.2 What are the differences between primary, secondary, and tertiary industries? Give an example of each category.

Answer. A primary industry is one that cultivates and exploits natural resources, such as agriculture or mining. A secondary industry takes the outputs of primary industries and converts them to consumer and capital goods. Examples of secondary industries are textiles and electronics. A tertiary industry is in the service sector of the economy. Examples of tertiary industries are banking and education.

1.3 What is the difference between consumer goods and a capital goods? Give some examples in each category.

Answer. Consumer goods are products purchased directly by consumers, such as cars, personal computers, TVs, tires, and tennis rackets. Capital goods are those purchased by companies to produce goods and/or provide services. Examples of capital goods include aircraft, computers, communication equipment, medical apparatus, trucks and buses, railroad locomotives, machine tools, and construction equipment.

1.4 What is the difference between soft product variety and hard product variety, as these terms are defined in the text?

Answer. Soft product variety is when there are only small differences among products, such as the differences among car models made on the same production line. In an assembled product, soft variety is characterized by a high proportion of common parts among the models. Hard product variety is when the products differ substantially, and there are few common parts, if any. The difference between a car and a truck exemplifies hard variety.

1.5 How are product variety and production quantity related when comparing typical factories?

Answer. In general, production quantity is inversely related to product variety. A factory that produces a large variety of products will produce a smaller quantity of each. A company that produces a single product will produce a large quantity.

1.6 One of the dimensions of manufacturing capability is technological processing capability. Define technological processing capability.

Answer. The technological processing capability of a plant (or company) is its available set of manufacturing processes. Certain plants perform machining operations, others roll steel billets into sheet stock, and others build automobiles. The underlying feature that distinguishes these plants is the processes they can perform. Technological processing capability includes not only the physical processes, but also the expertise possessed by plant personnel in these processing technologies.

1.7 What are the four categories of engineering materials used in manufacturing?

Answer. The four categories of engineering materials are (1) metals, (2) ceramics, (3) polymers, and (4) composite materials, which consist of non-homogeneous mixtures of the other three types.

1.8 What is the definition of steel?

Answer. Steel can be defined as an iron–carbon alloy containing 0.02% to 2.11% carbon. Its composition often includes other alloying elements as well, such as manganese, chromium, nickel, and molybdenum, to enhance the properties of the metal.

1.9 What are some of the typical applications of steel?

Answer. Applications of steel include construction (e.g., bridges, I-beams, and nails), transportation (trucks, rails, and rolling stock for railroads), and consumer products (automobiles and appliances).

1.10 What is the difference between a thermoplastic polymer and a thermosetting polymer?

Answer. Thermoplastic polymers can be subjected to multiple heating and cooling cycles without substantially altering the molecular structure of the polymer. Thermosetting polymers chemically transform (cure) into a rigid structure on cooling from a heated plastic condition.

1.11 Manufacturing processes are usually accomplished as unit operations. Define unit operation.

Answer. A unit operation is a single step in the sequence of steps required to transform the starting material into a final product. A unit operation is generally performed on a single piece of equipment that runs independently of other operations in the plant.

1.12 In manufacturing processes, what is the difference between a processing operation and an assembly operation?

Answer. A processing operation transforms a work material from one state of completion to a more advanced state that is closer to the final desired product. It changes the geometry, properties, or appearance of the starting material. In general, processing operations are performed on discrete work parts, but certain processing operations are also applicable to assembled items (e.g., painting a spot-welded car body). An assembly operation joins two or more components to create a new entity, called an assembly, subassembly, or some other term that refers to the joining process (e.g., a welded assembly is called a weldment).

1.13 One of the three general types of processing operations is shaping operations, which are used to create or alter the geometry of the work part. What are the four categories of shaping operations?

Answer. The four categories of shaping operations are (1) solidification processes, in which the starting material is a heated liquid or semifluid that cools and solidifies to form the part geometry; (2) particulate processing, in which the starting material is a powder, and the powders are formed and heated into the desired geometry; (3) deformation processes, in which the starting material is a ductile solid (commonly metal) that is deformed to shape the part; and (4) material removal processes, in which the starting material is a solid (ductile or brittle), from which material is removed so that the resulting part has the desired geometry.

1.14 What is the difference between net shape processes and near net shape processes?

Answer. Net shape processes are manufacturing processes that transform nearly all of the starting material into product and require no subsequent machining to achieve final part geometry. Near net shape processes are ones that require minimum machining to produce the final shape.

1.15 Identify the four types of permanent joining processes used in assembly.

Answer. The four types are welding, brazing, soldering, and adhesive bonding.

1.16 What is a machine tool?

Answer. The term developed during the Industrial Revolution, when it referred to power-driven machines used to operate cutting tools previously operated by hand. Modern machine tools are described by the same basic definition, except that the power is electrical rather than water or steam, and the level of precision and automation is much greater today.

1.17 What is the difference between special purpose and general purpose production equipment?

Answer. General-purpose equipment is more flexible and adaptable to a variety of jobs. It is commercially available for any manufacturing company to invest in. Special-purpose equipment is usually designed to produce a specific part or product in very large quantities. Another reason may be because the process is unique and commercial equipment is not available. Some companies with unique processing requirements develop their own special purpose equipment.

1.18 Define batch production and describe why it is often used for medium-quantity production.

Answer. Batch production is where groups, lots, or batches of materials or parts are processed together through the manufacturing operations. All units in the batch are processed at a given station before the group proceeds to the next station. In a medium or low quantity production situation, the same machines are used to produce many types of products. Whenever a machine switches from one product to another, a changeover occurs. The changeover requires the machine setup to be torn down and set up for the new product. Batch production allows the changeover time to be distributed across a larger number of parts and hence reduce the average operation time per part.

1.19 What is the difference between a process layout and a product layout in a production facility?

Answer. A process layout is one where the machinery in a plant is arranged based on the type of process it performs. To produce a product it must visit the departments in the order of the operations that must be performed. This often includes large travel distances within the plant. A process layout is often used when the product variety is large and the operation sequences of products are dissimilar. A product layout is one where the machinery is arranged based on the general flow of the products that will be produced. Travel distance is reduced because products will generally flow to the next machine in the sequence. A product layout works well when all products tend to follow the same sequence of production operations.

1.20 Name two departments that are typically classified as manufacturing support departments.

Answer. A common organizational structure includes the following three manufacturing support departments: (1) manufacturing engineering, (2) production planning and control, and (3) quality control.

1.21 What are overhead costs in a manufacturing company?

Answer. Overhead costs consist of all of the expenses of operating the company other than material, direct labor, and equipment.

1.22 Name and define the two categories of overhead costs in a manufacturing company.

Answer. The two categories are (1) factory overhead and (2) corporate overhead. Factory overhead consists of the costs of running the factory excluding materials, direct labor, and equipment. This overhead category includes plant supervision, maintenance, insurance, heat and light, and so forth. Corporate overhead consists of company expenses not related to the factory, such as sales, marketing, accounting, legal, engineering, research and development, office space, utilities, and health benefits.

1.23 What is the difference between fixed costs and variable costs?

Answer. A fixed cost remains constant for any level of production output, whereas variable costs are paid for as they are used. The cost of the factory and equipment are fixed costs. Direct labor and materials that are used to produce the product are variable costs.

1.24 What is meant by the term *availability*?

Answer. Availability is a reliability term which is simply the proportion uptime of the equipment.

Problems

Answers to problems labeled **(A)** are listed in an Appendix at the back of the book.

Manufacturing Economics

1.1 **(A)** A company invests $750,000 in a piece of production equipment. The cost to install the equipment in the plant = $25,000. The anticipated life of the machine = 12 years. The machine will be used eight hours per shift, five shifts per week, 50 weeks per year. Applicable overhead rate = 18%. Assume availability = 100%. Determine the equipment cost rate if (a) the plant operates one shift per day and (b) the plant operates three shifts per day.

Solution: (a) For a one-shift operation, hours of operation per year H = 50(1)(5)(8) = 2000 hr/yr. Using Eq. (1.8),
C_{eq} = (750,000 + 25,000)(1.18)/(60 × 12 × 2000) = **\$0.635/min = \$38.10/hr**

(b) For a three-shift operation, hours of operation per year H = 50(3)(5)(8) = 6000 hr/yr.
C_{eq} = (750,000 + 25,000)(1.18)/(60 × 12 × 6000) = **\$0.212/min** = **\$12.70/hr**
Note the significant advantage the company has if it runs three shifts per day rather than one shift.

1.2 A production machine was purchased six years ago for an installed price of \$530,000. At that time it was anticipated that the machine would last 10 years and be used 4000 hours per year. However, it is now in need of major repairs that will cost \$125,000. If these repairs are made, the machine will last four more years, operating 4000 hours per year. Applicable overhead rate = 30%. Assume availability = 100%. Determine the equipment cost rate for this machine.

Solution: The cost rate under the original conditions was the following:
C_{eq} = 530,000(1.30)/(60 × 10 × 4000) = \$0.287/min = \$17.23/hr
The repairs will add to that cost rate as follows:
C_{eq} = 125,000(1.30)/(60 × 4 × 4000) = \$0.169/min = \$10.16/hr
The repaired machine has a cost rate C_{eq} = 0.287 + 0.169 = **\$0.456/min = \$27.36/hr**

1.3 Instead of repairing the machine in Problem 1.2, a proposal has been made to purchase a new machine and scrap the current machine at a zero salvage value. The new machine will have a production rate that is 20% faster than the current equipment, whose production rate = 12 parts per hour. Each part has a starting material cost = \$1.33 and a selling price = \$6.40. All parts produced during the next four years on either machine can be sold at this price. At the end of the four years, the current machine will be scrapped, but the new machine would still be productive for another six years. The new machine costs \$700,000 installed, has an anticipated life of 10 years, and an applicable overhead rate of 30%. It will be used 4000 hours per year, same as the current machine. The labor rate for either alternative = \$24.00/hr which includes applicable overhead costs. Assume availability = 100% and scrap rate = 0. Which alternative is more economical using total profit over four years as the criterion, (a) repairing the current machine or (b) purchasing the new machine?

Solution: (a) The first alternative is to repair the current machine. The cost rate was determined in the solution to Problem 1.2. Repeating here, the original cost rate is calculated as follows:
C_{eq} = 530,000(1.30)/(60 × 10 × 4000) = \$0.287/min = \$17.23/hr
The repairs will add to that cost rate as follows:
C_{eq} = 125,000(1.30)/(60 × 4 × 4000) = \$0.169/min = \$10.16/hr
The repaired machine has a cost rate C_{eq} = 0.287 + 0.169 = \$0.456/min = \$27.36/hr
Labor cost = \$24.00/hr (given)
Given that annual hours of operation = 4000, total cost of production on this machine is calculated as follows: TC = 4000(24.00 + 27.36) = \$205,440/yr
At a production rate of 12 pc/hr and operating 4000 hr/yr, annual output = 4000(12) = 48,000 pc/yr
Total revenue = 48,000(6.40 – 1.33) = \$243,360/yr.
Total profit over four years = 4(243,360 – 205,440) = \$151,680

(b) The second machine has an equipment cost rate determined as follows:
C_{eq} = 700,000(1.30)/(60 × 10 × 4000) = \$0.379/min = \$22.75/hr
Labor cost = \$24.00/hr (given)
Given that annual hours of operation = 4000, total annual cost of production on this machine is
TC = 4000(24.00 + 22.75) = \$187,000/yr
Production rate on the new machine is 20% faster, so production rate = 12(1.20) = 14.4 pc/hr
At 14.4 pc/hr and operating 4000 hr/yr, annual output = 4000(14.4) = 57,600 pc/yr
Total revenue = 57,600(6.40 – 1.33) = \$292,032/yr.
Total profit over four years = 4(292,032 – 187,000) = \$420,128

Conclusion: The new machine should be purchased and the old machine scrapped.

1.4 **(A)** A machine tool is used to machine parts in batches. In one batch of interest, the starting piece is a casting that costs = \$5.00 each. Batch quantity = 40. The actual machining time in the operation = 6.86 min. Time to load and unload each workpiece = 2.0 min. Cost of the cutting tool = \$3.00, and each tool must be changed every 10 pieces. Tool change time = 1.5 min. Setup time for the batch = 1.75 hr. Hourly wage rate of the operator = \$16.00/hr, and the applicable labor overhead rate = 50%. Hourly equipment cost rate = \$22.00/hr, which includes overhead. Assume availability = 100% and scrap rate = 0. Determine (a) the cycle time for the piece, (b) average hourly production rate when setup time is figured in, and (c) cost per piece.

Solution: (a) Processing time T_o = 6.86 min, part handling time T_h = 2.00 min, and tool handling time T_t = 1.50 min/10 = 0.15 min. T_c = 6.86 + 2.00 + 0.15 = **9.01 min**

(b) Average production time per piece including setup time T_p = 1.75(60)/40 + 9.01 = 11.64 min. Average hourly production rate R_p = 60/11.64 = **5.16 pc/hr**

(c) Equipment cost rate C_{eq} = \$22.00/60 = \$0.367/min.
Labor cost rate C_L = 16.00(1.50) = \$24.00/hr = \$0.40/min
Cost of tooling C_t = 3.00/10 = \$0.30/pc
Finally, cost per piece C_{pc} = 5.00 + (0.40 + 0.367)(11.64) + 0.30 = **\$14.23/pc**

1.5 A plastic molding machine produces a product whose annual demand is in the millions. The machine is automated and used full time just for the production of this product. The molding cycle time = 45 sec. No tooling is required other than the mold, which cost \$100,000 and is expected to produce 1,000,000 moldings (products). The plastic molding compound costs \$1.20/lb. Each molding weighs 0.88 lb. The only labor required is for a worker to periodically retrieve the moldings. Labor rate of the worker = \$18.00/hr including overhead. However, the worker also tends other machines and only spends 20% of his time on this machine. Setup can be ignored because of the long production run. The molding machine was purchased for \$500,000 installed, its anticipated life = 10 years, and it operates 6,000 hours per year. Equipment overhead rate = 30%. Availability = 100% and scrap rate = 0. Determine (a) the hourly production rate of the machine, (b) annual quantity of product molded, and (c) cost per piece.

Solution: (a) With a cycle time T_c = 45 sec = 0.75 min, R_p = 60/0.75 = 80 pc/hr
Factoring in the 98% proportion uptime, R_p = 0.98(80) = **78.4 pc/hr**

Annual quantity of product = 6,000(78.4) = **470,400 pc/yr**

(b) Equipment cost rate C_{eq} = 500,000(1.30)/(60 × 10 × 6000) = \$0.1806/min
Mold cost per piece C_t = 100,000/1,000,000 = \$0.10/pc
Labor cost rate C_L = 18.00(0.20) = \$3.60/hr = \$0.06/min
Finally, cost per piece C_{pc} = 1.20(0.88) + (0.06 + 0.1806)(0.75) + 0.10 = **\$1.34/pc**

1.6 A stamping press produces sheet-metal stampings in batches. The press is operated by a worker whose labor rate = \$15.00/hr and applicable labor overhead rate = 42%. Cost rate of the press = \$22.50/hr and applicable equipment overhead rate = 20%. In one job of interest, batch size = 400 stampings, and the time to set up the die in the press takes 75 min. The die cost \$40,000 and is expected to last for 200,000 stampings. Each cycle in the operation, the starting blanks of sheet metal are manually loaded into the press, which takes 42 sec. The actual press stroke takes only 8 sec. Unloading the stamping from the press takes 13 sec. Cost of the starting blanks = \$0.23/pc. The press operates 250 days per year, 7.5 hours per day, but the operator is paid for 8 hours per day. Assume availability = 100% and scrap rate = 0. Determine (a) cycle time, (b) average production rate with and without setup time included, and (c) cost per stamping produced.

Solution: (a) Cycle time T_c = 42 + 8 + 13 = 63 sec = **1.05 min**

(b) Including setup time, T_p = 75/400 + 1.05 = 1.2375 min
R_p = 60/1.2375 = **48.485 pc/hr**
Excluding setup time, R_c = 60/1.05 = **57.143 pc/hr**

(c) Equipment cost rate C_{eq} = 22.50(1.20)/60 = \$0.45/min
Die cost per piece C_t = 40,000/200,000 = \$0.20/pc
Labor cost rate C_L = 15.00(1.42)/60 = \$0.355/min
This labor cost should be adjusted for the fact that although the press operates 7.5 hr/day, the operator is paid for 8 hr. C_L = 0.355(8/7.5) = \$0.379
Finally, cost per stamping C_{pc} = 0.23 + (0.379 + 0.45)(1.2375) + 0.20 = **\$1.456/pc**

1.7 A production machine operates in a semi-automatic cycle but a worker must tend the machine 100% of the time to load parts. Unloading is accomplished automatically. The worker's cost rate = \$27/hr including applicable labor overhead rate. The equipment cost rate of the machine = \$18.00/hr including applicable overhead costs. Cost of the starting parts = \$0.15/pc. The job runs several months so the effect of setup can be ignored. Each cycle, the actual process time = 24 sec, and time to load the part = 6 sec. Automatic unloading takes 3 sec. A proposal has been made to install an automatic parts-loading device on the machine. The device would cost \$36,000 and would reduce the part loading time to 3 sec each cycle. Its expected life = 4 years. The device would also relieve the worker from full-time attention to the machine. Instead, the worker could tend four machines, effectively reducing the labor cost to 25% of its current rate for each machine. The operation runs 250 days per year, eight hours per day. Assume availability = 100% and scrap rate = 0. Determine the cost per part produced (a) without the parts loading device and (b) with the parts loading device installed. (c) How many days of production are required to pay for the automatic loading device? In other words find the breakeven point.

Solution: (a) Equipment cost rate C_{eq} = 18/60 = \$0.30/min

Labor cost rate C_L = 27/60 = \$0.45/min
Without the loading device, C_{pc} = 0.15 + (0.45 + 0.30)(24 + 6 + 3)/60 = **\$0.563/pc**

(b) Cost rate of the device = 36,000/(60×4×2000) = \$0.075/min = \$4.50/hr
With the loading device, C_{pc} = 0.15 + (0.45/4 + 0.30 + 0.075)(24 + 3 + 3)/60 = **\$0.394/pc**

(c) Without the device, T_c = 24 + 6 + 3 = 33 sec = 0.55 min and C_{pc} = 0.563/pc
R_p = R_c = 60/0.55 = 109.1 pc/hr = 872 pc/day
With the device, T_c = 24 + 3 + 3 = 33 sec = 0.50 min and C_{pc} = 0.394/pc
At 100% reliability and no setup time, R_p = R_c = 60/0.50 = 120.0 pc/hr = 960 pc/day
Let D = number of days of production at which the two alternatives are equivalent.
872(0.563)D = 36,000 + 960(0.394)D
490.9D = 36,000 + 378.2D
(490.9 – 378.2)D = 112.7D = 36,000 D = 319.5 round to **320 days**

1.8 **(A)** In a long-running high-production operation, the starting work part cost = \$0.45 each, and cycle time = 0.75 min. Equipment cost rate = \$28.00/hr, and labor cost rate = \$21.00/hr. Both rates include overhead costs. Tooling cost = \$0.05/pc. Availability of the production machine = 96%, and the scrap rate = 3%. Determine (a) production rate and (b) finished part cost.

Solution: (a) Production rate, including effect of availability (60/0.75)(0.96) = 76.8 pc/hr
However, because of the 3% scrap rate, the production rate of acceptable parts is
R_p = 76.8(1 – 0.03) = **74.5 pc/hr**

(b) Factoring in availability and scrap rate, part cost is
C_{pc} = 0.45/0.97 + ((21 + 28)/60)(0.75/(0.97 × 0.96)) + 0.05 = **\$1.172/pc**

1.9 The starting work part costs \$2.00 in a batch production operation. Batch quantity = 100 parts. Each cycle, part handling time = 0.40 min, and operation time = 1.52 min. Setup time = 50 min. Equipment cost rate = \$30.00/hr, and labor cost rate = \$18.00/hr, including overhead costs. There is no tool change or tool cost in the operation. The machine tool is 100% reliable, and scrap rate = 2%. Determine (a) production rate, (b) finished part cost, and (c) number of hours required to complete the batch.

Solution: (a) T_c = 1.52 + 0.40 = 1.92 min/pc
Given q = 2%, the starting quantity of parts Q_o = 100/0.98 = 102.04 rounded to 102 pc
Determine batch time, including setup time.
T_b = 50 + 102(1.92) = 50 + 195.84 = 245.84 min/batch = 4.097 hr
Average production rate of parts R_p = 100/4.097 = 24.41 pc/hr
Average production rate of acceptable parts R_p = 24.41(1 – 0.02) = **23.92 pc/hr**

(b) Now determine batch cost, including setup time.
C_b = 102(2.00) + ((18 + 30)(4.097) = 204.00 + 196.66 = \$400.66/batch
C_{pc} = 400.66/100 = **\$4.007/pc**
Alternative calculation of C_{pc}:
C_{pc} = 2.00/0.98 + ((18 + 30)/60)(50/100) + ((18 + 30)/60)(1.92/0.98)
C_{pc} = 2.041 + 0.40 + 1.567= \$4.008/pc

(c) Time to complete the batch was computed in part (a) as T_b = **245.84 min = 4.097 hr**

1.10 In a batch-production machining operation, the starting work part is a casting that costs \$4.50 each. Batch quantity = 65 parts. Part handling time each cycle = 2.5 min, and machining time per part = 3.44 min. It takes 75 min to set up the machine for production. Equipment cost rate = \$25.00/hr, and labor cost rate = \$20.00/hr. Both rates include overhead costs. The cutting tool in the operation costs = \$5.75/pc and it must be changed every 18 parts. Tool change time = 3.0 min. Availability of the machine tool = 98%, and the scrap rate = 0. Determine (a) production rate and (b) finished part cost. (c) How many hours are required to complete the batch?

Solution: (a) T_c = 3.44 + 2.5 + 3/18 = 6.11 min/pc
Given q = 0, the starting quantity of parts Q_o = 65 pc
Now determine batch time, including setup time and availability, assuming that the availability factor does not apply during setup because the machine is not running.
T_b = 75 + 65(6.11)/0.98 = 75 + 405.26 = 480.26 min/batch = 8.004 hr
Average production rate of parts R_p = 65/8.004 = **8.121 pc/hr**

(b) Now determine batch cost, including setup time and availability, assuming that the availability factor does not apply during setup because the machine is not running. The number of cutting tools required = 68/18 = 3.78 rounded up to 4 tools at \$5.75 each = \$23.00.
C_{batch} = 65(4.50) + ((20 + 25)(8.004) + 4(5.75) = 292.50 + 360.18 + 23.00 = \$675.68/batch
C_{pc} = 675.68/65 = **\$10.39/pc**
Alternative calculation of C_{pc}:
C_{pc} = 4.50 + ((20 + 25)/60)(75/65) + ((20 + 25)/60)(6.11/0.98) + 23.00/65
C_{pc} = 4.50 +0.865 + 4.676 + 0.354 = \$10.395/pc (Close enough!)

(c) Time to complete the batch was computed in part (a) as T_b = **480.26 min = 8.004 hr**

1.11 **(A)** During a particular 40-hour week of an automated production operation, 336 acceptable (non-defective) parts and 22 defective parts were produced. The operation cycle consists of a processing time of 5.73 min, and a part handling time of 0.38 min. Every 60 parts, a tool change is performed, and this takes 7.2 min. The machine experienced several breakdowns during the week. Determine (a) hourly production rate of acceptable parts, (b) scrap rate, and (c) availability (proportion uptime) of the machine during this week.

Solution: (a) Production rate of acceptable parts R_p = 336/40 = **8.40 pc/hr**

(b) Total parts processed during the week Q_o = 336 + 22 = 358 pc
Scrap rate q = 22/358 = 0.0615 = **6.15%**

(c) Cycle time of the unit operation T_c = 5.73 + 0.38 + 7.2/60 = 6.23 min
Total uptime during the week = 358(6.23) = 2230.34 min = 37.17 hr
Proportion uptime A = 37.17/40 = 0.929 = **92.9%**

1.12 A high-production operation was studied during an 80-hr period. During that time, a total of seven equipment breakdowns occurred for a total lost production time of 3.8 hr, and the operation produced 38 defective products. No setups were performed during the period. The operation cycle consists of a processing time of 2.14 min, a part handling time of 0.65 min, and a tool change is required every 25 parts, which takes 1.50 min. Determine (a) hourly production rate of acceptable parts and (b) scrap rate during the period.

Solution: (a) Cycle time of the unit operation T_c = 2.14 + 0.65 + 1.50/25 = 2.85 min

Hours of production during 80 hours = 80 – 3.8 = 76.2 hr
Total number of parts produced = 76.2(60)/2.85 = 1604 pc
Number of acceptable parts produced = 1604 – 38 = 1566 pc
Production rate of acceptable parts R_p = 1566/80 = **19.58 pc/hr**

(b) Scrap rate q = 38/1566 = 0.0243 = **2.43%**