

## OBJECTIVE 6

Demonstrate the first-in, first-out (FIFO) method of process costing

The **first-in, first-out (FIFO) process-costing method** assigns the cost of the earliest equivalent units available (starting with the equivalent units in beginning work-in-process inventory) to units completed and transferred out, and the cost of the most recent equivalent units worked on during the period to ending work-in-process inventory. This method assumes that the earliest equivalent units in Work in Process—Assembly account are completed first.

Exhibit 17-8 presents step 4—summarizing total costs to account for, and assigning costs to units completed and to ending work in process—using the FIFO method. The total costs columns in Panel A of Exhibit 17-8 summarize the total costs to be accounted for in March 19\_7 of \$62,280 as described in the Example data (p. 619).

Panel B of Exhibit 17-8 describes the assignment of costs under FIFO. The FIFO method assigns the costs of the beginning work-in-process inventory to the first units completed and transferred out. The costs of work done in the current period are first assigned to the additional work done to complete the beginning work in process, then to the work done on units started and completed during the current period, and finally to the ending work in process. Follow these computations in Panel B of Exhibit 17-8. For example, consider conversion costs. The costs of the 135 equivalent units of beginning inventory at \$60 per unit are assigned to the first units completed and transferred out. The costs of the 315 equivalent units of work done in March 19\_7 at \$52 per unit are assigned as follows: (1) The first 90 units to the work done to complete the beginning work in process, (2) the next 175 units to the work done on units started and completed during the current period, and (3) the final 50 units to ending work in process.

Under FIFO, the ending work-in-process inventory comes from units that were started but not fully completed during the current period. The total cost of the 100 partially assembled physical units in ending work in process consists of

Direct materials: 100 equivalent units × cost per equivalent unit in March, \$72	\$7,200
Conversion costs: 50 equivalent units × cost per equivalent unit in March, \$52	<u>2,600</u>
Total costs of work in process on March 31	<u>\$9,800</u>

Note that the total costs accounted for in Panel B of Exhibit 17-8, \$62,280, equal the total costs to account for in Panel A.

*Before proceeding, please pause and review Exhibit 17-8 carefully to check your understanding of the FIFO method.* The journal entries and flow of costs through the T-accounts under the FIFO method parallel the journal entries and flow of costs under the weighted-average method and are not repeated here.

The average cost of units transferred out is  $\$52,480 \div 400 \text{ units} = \$131.20$  per DG-19 unit. The Assembly Department uses FIFO to distinguish between monthly batches of production. The succeeding department, Testing, however, costs these units at one average unit cost (\$131.20 in this illustration). If this averaging were not done, the attempt to track costs on a pure FIFO basis throughout a series of processes would be unduly cumbersome.

Only rarely is an application of pure FIFO ever encountered in process costing. It should really be called a *modified* or *departmental* FIFO method. Why? Because FIFO is applied within a department to compile the cost of units transferred *out*, but the units transferred *in* during a given period usually are carried at a single average unit cost as a matter of convenience.

## COMPARISON OF WEIGHTED-AVERAGE AND FIFO METHODS

The following table summarizes the costs assigned to units completed and those still in process under the weighted-average and FIFO process-costing methods for our example:



## EXHIBIT 17-8

Step 4: Summarize Total Costs to Account for, and Assign These Costs to Units Completed and to Units in Ending Work in Process Using the FIFO Method, Assembly Department of Global Defense, Inc., for March 19\_7

	Direct Materials			Conversion Costs			Total Prod. Costs
	Equiv. Units (1)	Cost per Equiv. Unit (2)	Total Costs (3) = (1) × (2)	Equiv. Units (4)	Cost per Equiv. Unit (5)	Total Costs (6) = (4) × (5)	(7) = (3) + (6)
<b>PANEL A:</b>							
<b>TOTAL COSTS TO ACCOUNT FOR</b>							
Work in process, beginning (from Exhibit 17-6)	225	\$80	\$18,000	135	\$60	\$ 8,100	\$26,100
Work done in current period only (from Exhibit 17-6)	275	\$72	19,800	315	\$52	16,380	36,180
To account for	<u>500</u>		<u>\$37,800</u>	<u>450</u>		<u>\$24,480</u>	<u>\$62,280</u>
<b>PANEL B:</b>							
<b>ASSIGNMENT OF COSTS</b>							
Completed and transferred out (400 physical units)							
Work in process, beginning (225 physical units)	225	\$80	\$18,000	135	\$60	\$ 8,100	\$26,100
Work done in current period to complete beginning work in process	0*	\$72	0	90 <sup>†</sup>	\$52	4,680	4,680
Total from beginning inventory	225		18,000	225		12,780	30,780
Started and completed (175 physical units)	175 <sup>‡</sup>	\$72	12,600	175 <sup>‡</sup>	\$52	9,100	21,700
Total completed and transferred out (400 physical units)	400		30,600	400		21,880	52,480
Work in process, ending (100 physical units)	100 <sup>§</sup>	\$72	7,200	50 <sup>§</sup>	\$52	2,600	9,800
Accounted for	<u>500</u>		<u>\$37,800</u>	<u>450</u>		<u>\$24,480</u>	<u>\$62,280</u>

\*Beginning work in process is 100% complete as to direct materials so zero equivalent units of direct materials need to be added to complete beginning work in process.

<sup>†</sup>Beginning work in process is 60% complete, which equals 135 equivalent units of conversion costs. To complete the 225 physical units of beginning work in process, 90 (225 - 135) equivalent units of conversion costs need to be added.

<sup>‡</sup>400 total equivalent units completed and transferred out (Exhibit 17-5) minus 225 equivalent units completed and transferred from beginning inventory equals 175 equivalent units.

<sup>§</sup>From Exhibit 17-5.



	Weighted Average (from Exhibit 17-7)	FIFO (from Exhibit 17-8)	Difference
Cost of units completed and transferred out	\$52,000	\$52,480	+\$480
Work in process, ending	10,280	9,800	-\$480
Total costs accounted for	<u>\$62,280</u>	<u>\$62,280</u>	

The weighted-average ending inventory is higher than the FIFO ending inventory by \$480, or 4.9% ( $\$480 \div \$9,800$ ). This is a significant difference when aggregated over the many thousands of components that Global Defense makes. The weighted-average method in our example also results in lower cost of goods sold and hence higher operating income and higher tax payments than the FIFO method. Differences in equivalent unit costs of beginning inventory and work done during the current period account for the differences in weighted-average and FIFO costs. Recall from Exhibit 17-6 that the cost per equivalent unit of beginning work in process was greater than the cost per equivalent unit of work done during the period.

For the Assembly Department, FIFO assumes that all the higher-cost prior-period units in beginning work in process are the first to be completed and transferred out while ending work in process consists of only the lower-cost current-period units. The weighted-average method, however, smoothes out cost per equivalent unit by assuming that more of the lower-cost units are completed and transferred out, while some of the higher-cost units are placed in ending work in process. Hence, in this example, the weighted-average method results in a lower cost of units completed and transferred out and a higher ending work-in-process inventory relative to FIFO.

Unit costs can differ materially between the weighted-average and FIFO methods when (1) the direct materials or conversion costs per unit vary from period to period, and (2) the physical inventory levels of work in process are large in relation to the total number of units transferred out.

Managers need feedback about their most recent performance (March in this illustration) in order to plan and improve their future performance. A major advantage of FIFO is that it gives managers information from which they can judge their performance in the current period independently from that in the preceding period. Work done during the current period is vital information for these planning and control purposes.

## STANDARD COSTS AND PROCESS COSTING

*This section assumes that you have already studied Chapters 7 and 8. If you have not, proceed to the next major section, Transferred-in Costs in Process Costing (p. 629).*

As we have mentioned, companies that use process-costing systems produce numerous like or similar units of output. Setting standard quantities for inputs is often relatively straightforward in such companies. Standard costs per input unit may then be assigned to the physical standards to develop standard costs.

Weighted-average and FIFO methods become very complicated when used in industries that produce a variety of products. For example, a steel-rolling mill uses various steel alloys and produces sheets of various sizes and of various finishes. The items of direct materials are not numerous; neither are the operations performed. But used in various combinations, they yield too great a variety of products that inaccurate costs for each product result if the broad averaging procedure of historical process costing is used. Similarly complex conditions are frequently found, for example, in plants that manufacture rubber products, textiles, ceramics, paints, and packaged food products. As we shall see, standard costing is especially useful in these situations. The intricacies of weighted-average and FIFO historical costing methods and the conflicts between them are also eliminated by using standard costs.

### OBJECTIVE 7

Show how standard costs simplify process costing



## Computations under Standard Costing

We again use the Assembly Department of Global Defense, Inc., as an example, except this time we assign standard costs to the process. The same standard costs apply in February and March of 19\_7:

Direct materials	\$ 74 per unit
Conversion costs	<u>54 per unit</u>
Total standard manufacturing costs	<u>\$128 per unit</u>

Data for the Assembly Department are

### Physical Units for March 19\_7

Work in process, beginning inventory (March 1)	225 units
Direct materials (100% complete)	
Conversion costs (60% complete)	
Started during March	275 units
Completed and transferred out during March	400 units
Work in process, ending inventory (March 31)	100 units
Direct materials (100% complete)	
Conversion costs (50% complete)	

### Total Costs for March 19\_7

Work in process, beginning inventory at standard costs		
Direct materials: 225 equivalent units × \$74 per unit	\$16,650	
Conversion costs: 135 equivalent units × \$54 per unit	<u>7,290</u>	\$23,940
Actual direct materials costs added during March		19,800
Actual conversion costs added during March		16,380

We follow the four steps introduced earlier in Case 2. Steps 1 and 2 for standard costing are identical to the steps described for the weighted-average and FIFO methods in Exhibit 17-5. Steps 1 and 2 are the same as before because they measure the same physical and equivalent unit quantities of work done in March. Work done in the current period equals direct materials, 275 equivalent units, and conversion costs, 315 equivalent units.

Step 3 is easier under standard costing than under the weighted-average and FIFO methods. Why? Because the cost per equivalent unit does not have to be computed, as was done for the weighted-average and FIFO methods. Instead, the costs per equivalent unit are the standard costs: direct materials, \$74, and conversion costs, \$54. Using standard costs simplifies the computations for assigning total costs to account for, costs completed and transferred out, and ending work-in-process inventory. Exhibit 17-9 describes step 4.

Panel A of Exhibit 17-9 summarizes the total costs to account for—that is, the total debits in Work in Process. The debits differ from the debits to Work in Process—Assembly under the actual cost-based weighted-average and FIFO methods explained earlier in the chapter. Why? Because *in standard costing systems* (see Chapters 7 and 8) the debits to the Work in Process account are at standard costs rather than actual costs. These standard costs total \$61,300.

Panel B of Exhibit 17-9 assigns total costs to units completed and to units in ending work-in-process inventory. All equivalent units are costed at standard costs. Note how the total costs accounted for in Panel B of Exhibit 17-9, \$61,300, equal the total costs to account for in Panel A. If standard costs had changed between February and March 19\_7, these costs would be assigned to units completed and to ending work-in-process inventory using the FIFO method described in Exhibit 17-8.

## Accounting for Variances

Process-costing systems using standard costs usually accumulate actual costs separately from the inventory accounts. The following is an example. The actual data are recorded in the first two entries. Recall that Global Defense purchases direct



**EXHIBIT 17-9**

Step 4: Summarize Total Costs to Account for and Assign These Costs to Units Completed and to Units in Ending Work in Process Using Standard Costs, Assembly Department of Global Defense, Inc., for March 19\_7

	Direct Materials			Conversion Costs			Total Prod. Costs
	Equiv. Units (Exh. 17-5) (1)	Cost per Equiv. Unit (2)	Total Costs (3) = (1) × (2)	Equiv. Units (Exh. 17-5) (4)	Cost per Equiv. Unit (5)	Total Costs (6) = (4) × (5)	(7) = (3) + (6)
<b>PANEL A:</b>							
<b>TOTAL COSTS TO ACCOUNT FOR</b>							
Work in process, beginning	225	\$74	\$16,650	135	\$54	\$ 7,290	\$23,940
Work done in current period only	275	\$74	20,350	315	\$54	17,010	37,360
To account for	<u>500</u>		<u>\$37,000</u>	<u>450</u>		<u>\$24,300</u>	<u>\$61,300</u>
<b>PANEL B:</b>							
<b>ASSIGNMENT OF COSTS</b>							
Completed and transferred out (400 physical units)	→ 400	\$74	\$29,600	→ 400	\$54	\$21,600	\$51,200
Work in process, ending (100 physical units)	→ <u>100</u>	\$74	<u>7,400</u>	→ <u>50</u>	\$54	<u>2,700</u>	<u>10,100</u>
Accounted for	<u>500</u>		<u>\$37,000</u>	<u>450</u>		<u>\$24,300</u>	<u>\$61,300</u>

standard costs:

materials as needed and that these materials are delivered directly to the Assembly Department. The total variances are recorded in the next two entries. The final entry transfers out the completed goods at standard costs.

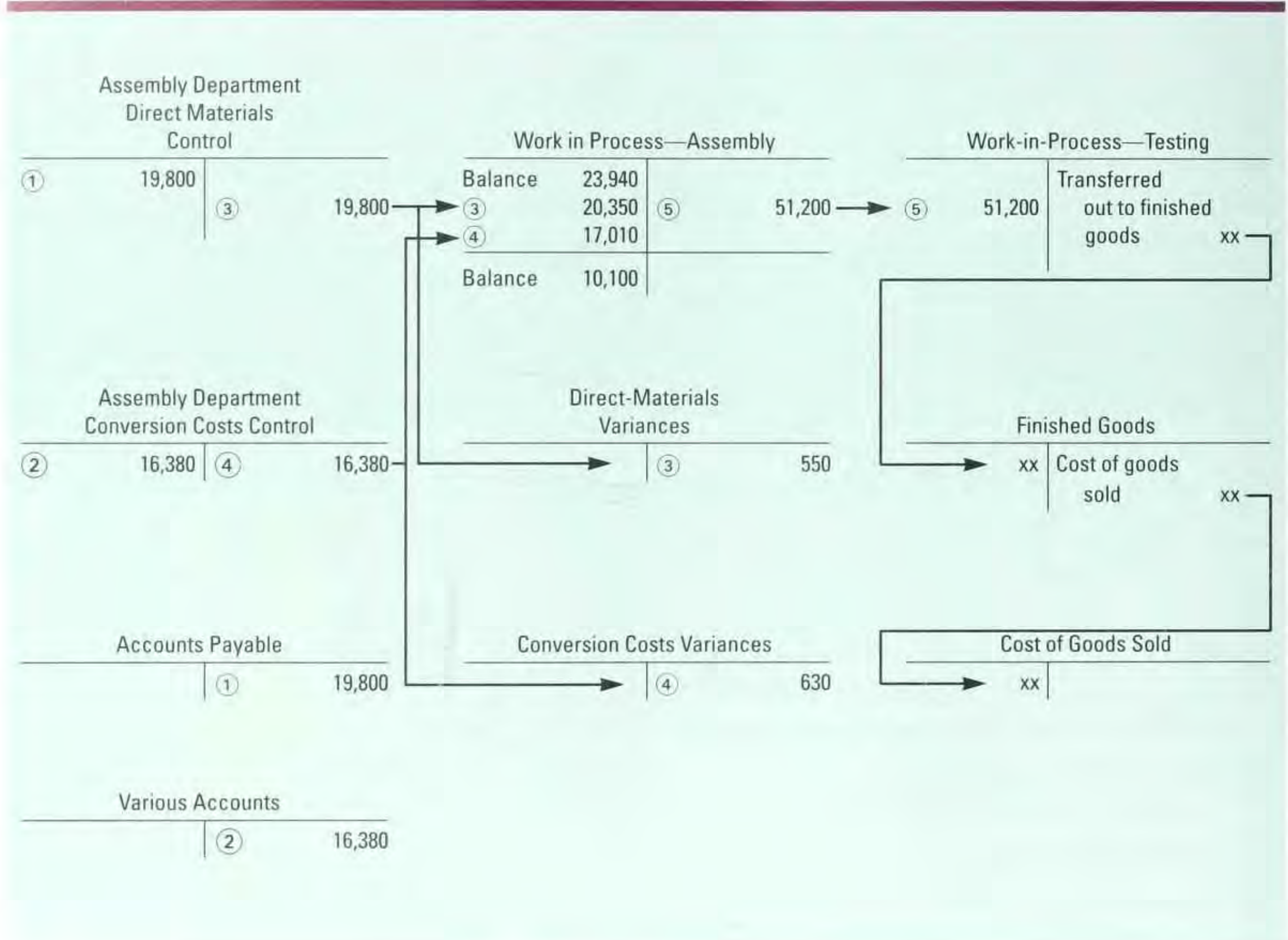
- Assembly Department Direct Materials Control (at actual) 19,800  
Accounts Payable 19,800  
To record direct materials purchased and used in production during March. This cost control account is debited with actual costs and credited later with standard costs assigned to the units worked on.
- Assembly Department Conversion Costs Control (at actual) 16,380  
Various accounts 16,380  
To record Assembly Department conversion costs for March.
- (Entries 3, 4, and 5 use standard cost dollar amounts from Exhibit 17-9.)  
3. Work in Process—Assembly (at standard costs) 20,350  
Direct Materials Variances 550  
Assembly Department Direct Materials Control 19,800  
To record actual direct materials used and total direct materials variances.
4. Work in Process—Assembly (at standard costs) 17,010  
Conversion Costs Variances 630  
Assembly Department Conversion Costs Control 16,380  
To record actual conversion costs and total conversion costs variances.
5. Work in Process—Testing (at standard costs) 51,200  
Work in Process—Assembly (at standard costs) 51,200  
To record cost of units completed and transferred at standard cost from Assembly to Testing.



Variances arise under the standard costing method, as in entries 3 and 4 above, because the standard costs assigned to products on the basis of work done in the current period do not usually equal the actual costs incurred in the current period. Variances can be measured and analyzed in little or great detail for feedback, control, and decision-making purposes, in the same manner as described in Chapters 7 and 8. Exhibit 17-10 shows how the costs flow through the accounts.

#### EXHIBIT 17-10

Flow of Standard Costs in a Process-Costing System, Assembly Department of Global Defense, Inc., for March 19\_7



We conclude by explaining the comment we made at the beginning of this section—that standard costs are particularly helpful when a process produces a variety of products. In these situations, historical-cost FIFO and weighted-average methods calculate a *single* average cost for all products produced resulting in inaccurate product costs. Under standard costing, teams of design and process engineers, operations personnel and cost accountants, determine *separate* standard or equivalent unit costs on the basis of the different technical processing specifications for each product. Identifying standard costs for each product overcomes the disadvantage of costing all products at a single average amount as in historical-cost methods.



## TRANSFERRED-IN COSTS IN PROCESS COSTING

Many process-costing systems have two or more departments or processes in the production cycle. Ordinarily, as units move from department to department, related costs are also transferred by monthly journal entries. If standard costs are used, the accounting for such transfers is relatively simple. However, if weighted average or FIFO is used, the accounting can become more complex. We now extend our Global Defense, Inc., example to encompass the Testing Department. The Assembly Department of Global Defense transfers DG-19 units to its Testing Department. Here the units receive additional direct materials, such as crating and other packing materials, to prepare the units for shipment, at the end of the process. Conversion costs are added evenly during the Testing Department's process. As the process in Assembly is completed, units are immediately transferred to Testing; as units are completed in Testing, they are immediately transferred to Finished Goods.

Data for the Testing Department for the month of March 19\_7 are

### Physical Units for March 19\_7

Work in process, beginning inventory (March 1)	240 units
Transferred-in costs (100% complete)	
Direct materials (0% complete)	
Conversion costs ( $\frac{5}{8}$ or 62.5% complete)	
Transferred-in during March	400 units
Completed during March	440 units
Work in process, ending inventory (March 31)	200 units
Transferred-in costs (100% complete)	
Direct materials (0% complete)	
Conversion costs (80% complete)	

### Costs of Testing Department for March 19\_7

Work in process, beginning inventory <sup>1</sup>		
Transferred-in costs	\$33,600	
Direct materials	0	
Conversion costs	18,000	\$51,600
Transferred-in during March		
Weighted average (from Exhibit 17-7)		52,000
FIFO (from Exhibit 17-8)		52,480
Direct materials costs added during March		13,200
Conversion costs added during March		48,600

**Transferred-in costs** (or **previous department costs**) are costs incurred in a previous department that are carried forward as part of the product's cost as it moves to a subsequent department for processing. That is, as the units move from one department to the next, their costs move with them. Thus, computations of Testing costs must include transferred-in costs, as well as any additional direct materials costs and conversion costs added in Testing.

We use the four-step procedure described earlier (p. 615) to account for the costs of a subsequent department that has transferred-in costs. Exhibit 17-11 shows steps 1 and 2 for Testing: summarize output in physical units and compute equivalent units. Units are fully completed as to transferred-in costs because these costs are just carried forward from the previous process. Direct materials costs, however, have a zero degree of completion in both beginning and ending work-in-process inventories, because in Testing, direct materials are introduced at the end of the process.

<sup>1</sup>The work-in-process beginning inventory is the same under both the weighted-average and FIFO inventory methods because we assumed costs per equivalent unit to be the same in both January and February. If the cost per equivalent unit had been different in February compared to January, the work-in-process inventory at the end of February (beginning of March) would be costed differently under the weighted-average and FIFO methods. If this were the case, the basic approach to process costing with transferred-in costs would still be the same as what we describe in this section. Only the beginning balances of work in process would be different.



Note that the numbers in steps 3 and 4 will differ between the weighted-average and FIFO methods with transferred-in costs. Why? Because differences in transferred-in costs under the two methods result in different debits to Work in Process.

### Transferred-in Costs and the Weighted-Average Method

#### OBJECTIVE 8

Explain weighted-average process-costing with transferred-in costs

Exhibit 17-12 describes step 3, the computation of equivalent unit costs. Exhibit 17-13 presents step 4. Panel A of Exhibit 17-13 summarizes the total costs to account for—that is, the total debits to Work in Process under the weighted-average method. These costs total \$165,400. Panel B of Exhibit 17-13 shows how these costs are assigned to units completed and to units in ending work-in-process inventory. Note how beginning work in process and work done in the current period are totaled and merged together for purposes of computing weighted-average costs.

#### EXHIBIT 17-11

Steps 1 and 2: Summarize Output in Physical Units and Compute Equivalent Units, Testing Department of Global Defense, Inc., for March 19\_7

Flow of Production	(Step 1) Physical Units	(Step 2) Equivalent Units		
		Transferred- in Costs	Direct Materials	Conversion Costs
Completed and transferred out during current period	440	440	440	440
Add work in process, ending* (200 × 100%; 200 × 0%; 200 × 80%)	200	200	0	160
Total accounted for	640	640	440	600
Deduct work in process, beginning† (240 × 100%; 240 × 0%; 240 × 62.5%)	240	240	0	150
Transferred in during current period	400			
Work done in current period only		400	440	450

\*Degree of completion in this department: transferred-in costs, 100%; direct materials, 0%; conversion costs, 80%.

†Degree of completion in this department: transferred-in costs, 100%; direct materials, 0%; conversion costs, 62.5%.

#### EXHIBIT 17-12

Step 3: Compute Equivalent Unit Costs under the Weighted-Average Method, Testing Department of Global Defense, Inc., for March 19\_7

	Transferred- in Costs	Direct Materials	Conversion Costs
<i>Equivalent unit costs of beginning work in process</i>			
Work in process, beginning (given, p. 630)	\$33,600	—	\$18,000
Divide by equivalent units of beginning work in process (from Exhibit 17-11)	÷ 240	—	÷ 150
Cost per equivalent unit of beginning work in process	\$ 140	—	\$ 120
<i>Equivalent unit costs of work done in current period only</i>			
Costs added in current period (given, p. 630)	\$52,000	\$13,200	\$48,600
Divide by equivalent units of work done in current period (from Exhibit 17-11)	÷ 400	÷ 440	÷ 450
Cost per equivalent unit of work done in current period only	\$ 130	\$ 30	\$ 108



EXHIBIT 17-13

Step 4: Summarize Total Costs to Account for, and Assign These Costs to Units Completed and to Units in Ending Work in Process Using the Weighted-Average Method, Testing Department of Global Defense, Inc., for March 19\_7

	Transferred-in Costs			Direct Materials			Conversion costs			Total Production Costs
	Equivalent Units (1)	Cost per Equivalent Unit (2)	Total Costs (3) = (1) × (2)	Equivalent Units (4)	Cost per Equivalent Unit (5)	Total Costs (6) = (4) × (5)	Equivalent Units (7)	Cost per Equivalent Unit (8)	Total Costs (9) = (7) × (8)	(10) = (3) + (6) + (9)
<b>PANEL A:</b>										
<b>TOTAL COSTS TO ACCOUNT FOR</b>										
Work in process, beginning (from Exhibit 17-12)	240	\$140.00	\$33,600	0	—	\$ 0	150	\$120	\$18,000	\$ 51,600
Work done in current period only (from Exhibit 17-12)	<u>400</u>	\$130.00	<u>52,000</u>	<u>440</u>	\$30	<u>13,200</u>	<u>450</u>	\$108	<u>48,600</u>	<u>113,800</u>
To account for	<u>640</u>	\$133.75*	<u>\$85,600</u>	<u>440</u>	\$30†	<u>\$13,200</u>	<u>600</u>	\$111‡	<u>\$66,600</u>	<u>\$165,400</u>
<b>PANEL B:</b>										
<b>ASSIGNMENT OF COSTS</b>										
Completed and transferred out (440 physical units)	440 <sup>§</sup>	→ \$133.75	\$58,850	440 <sup>§</sup>	→ \$30	\$13,200	440 <sup>§</sup>	→ \$111	\$48,840	\$120,890
Work in process, ending (200 physical units)	<u>200<sup>§</sup></u>	→ \$133.75	<u>26,750</u>	<u>0<sup>§</sup></u>	—	<u>0</u>	<u>160<sup>§</sup></u>	→ \$111	<u>17,760</u>	<u>44,510</u>
Accounted for	<u>640</u>		<u>\$85,600</u>	<u>440</u>		<u>\$13,200</u>	<u>600</u>		<u>\$66,600</u>	<u>\$165,400</u>

\*Weighted-average cost per equivalent unit of transferred-in costs = Total transferred-in costs divided by total equivalent units of transferred-in costs =  $\$85,600 \div 640 = \$133.75$ .

†Weighted-average costs per equivalent unit of direct materials = Total direct materials costs divided by total equivalent units of direct materials =  $\$13,200 \div 440 = \$30$ .

‡Weighted-average cost per equivalent unit of conversion costs = Total conversion costs divided by total equivalent units of conversion costs =  $\$66,600 \div 600 = \$111$ .

§From Exhibit 17-11.



Using the dollar amount from Exhibit 17-13 (column 10), the journal entry for the transfer out of Testing to finished goods inventory is

Finished Goods	120,890	
Work in Process—Testing		120,890
To transfer units to finished goods.		

Entries to the key T-account, Work in Process—Testing follow (from Exhibit 17-13).

Work in Process—Testing			
Beginning inventory, March 1	51,600	Transferred out	120,890
Transferred-in-costs	52,000		
Direct materials	13,200		
Conversion costs	48,600		
Ending inventory, March 31	44,510		

A company may split the Work in Process account into Work in Process—Testing, Transferred-in Costs, Work in Process—Testing, Direct Materials, and Work in Process—Testing, Conversion Costs. The journal entries would contain this detail, though the underlying reasoning and techniques would be unaffected.

### Transferred-in Costs and the FIFO Method

#### OBJECTIVE 9

Explain FIFO process-costing with transferred-in costs

Exhibit 17-14 (p. 634) describes Step 3, the computation of equivalent unit costs. The costs transferred-in from the Assembly Department are different when the weighted-average rather than the FIFO method is used. Exhibit 17-15 (p. 635) presents Step 4. Panel A of Exhibit 17-15 summarizes the total costs to account for, consisting of the beginning inventory plus costs added during the current period, under the FIFO method. These costs totaling \$165,880 differ from the total debits to Work in Process under the weighted-average method of \$165,400 because of the different costs of completed units transferred-in from the Assembly Department under the weighted-average and FIFO methods. Panel B of Exhibit 17-15 shows how these costs are assigned to units completed and to units in ending work in process inventory. When assigning costs, the FIFO method keeps the beginning inventory separate and distinct from the work done during the current period.

#### EXHIBIT 17-14

Step 3: Compute Equivalent Unit Costs under the FIFO Method, Testing Department of Global Defense, Inc., for March 19\_7

	Transferred-in Costs	Direct Materials	Conversion Costs
<i>Equivalent unit costs of beginning work in process</i>			
Work in process, beginning (given, p. 630)	\$33,600	—	\$18,000
Divide by equivalent units of beginning work in process (from Exhibit 17-11)	÷ 240	—	÷ 150
Cost per equivalent unit of beginning work in process	<u>\$ 140</u>	—	<u>\$ 120</u>
<i>Equivalent unit costs of work done in current period only</i>			
Costs added in current period (given, p. 630)	\$52,480	\$13,200	\$48,600
Divide by equivalent units of work done in current period (from Exhibit 17-11)	÷ 400	÷ 440	÷ 450
Cost per equivalent unit of work done in current period only	<u>\$131.20</u>	<u>\$ 30</u>	<u>\$ 108</u>



EXHIBIT 17-15 Step 4: Summarize Total Costs to Account for and Assign These Costs to Units Completed and to Units in Ending Work in Process Using the FIFO Method, Testing Department of Global Defense, Inc., for March 19\_7

	Transferred-in Costs			Direct Materials			Conversion Costs			Total Production Costs
	Equivalent Units (1)	Cost per Equivalent Unit (2)	Total Costs (3) = (1) × (2)	Equivalent Units (4)	Cost per Equivalent Unit (5)	Total Costs (6) = (4) × (5)	Equivalent Units (7)	Cost per Equivalent Unit (8)	Total Costs (9) = (7) × (8)	(10) = (3) + (6) + (9)
<b>PANEL A:</b>										
<b>TOTAL COSTS TO ACCOUNT FOR</b>										
Work in process, beginning (from Exhibit 17-14)	240	\$140.00	\$33,600	0	—	\$ 0	150	\$120	\$ 18,000	\$ 51,600
Work done in current period only (from Exhibit 17-14)	400	\$131.20	52,480	440	\$30	13,200	450	\$108	48,600	114,280
To account for	640		\$86,080	440		\$13,200	600		\$66,600	\$165,880
<b>PANEL B:</b>										
<b>ASSIGNMENT OF COSTS</b>										
Completed and transferred out (440 physical units)										
Work in process, beginning (240 physical units)	240	\$140.00	\$33,600	0	—	\$ 0	150	\$120	\$ 18,000	\$ 51,600
Work done in current period to complete beginning work in process	→ 0*		0	→ 240†	\$30	7,200	→ 90‡	\$108	9,720	16,920
Total from beginning inventory	240		33,600	240		7,200	240		27,720	68,520
Started and completed (200 physical units)	→ 200§	\$131.20	26,240	→ 200§	\$30	6,000	→ 200§	\$108	21,600	53,840
Total completed and transferred out (440 physical units)	440**		59,840	440**		13,200	440**		49,320	122,360
Work in process, ending (200 physical units)	→ 200**	\$131.20	26,240	→ 0**		0	→ 160**	\$108	17,280	43,520
Accounted for	640		\$86,080	440		\$13,200	600		\$66,600	\$165,880

\*Beginning work in process is 100% complete as to transferred-in costs so zero equivalent units of transferred-in costs need to be added to complete beginning work in process. †Beginning work in process is 0% complete, which equals zero equivalent units of direct materials. To complete the 240 physical units of beginning work in process, 240 equivalent units of direct materials need to be added. ‡Beginning work in process is 62.5% complete, which equals 150 equivalent units of conversion costs. To complete the 240 physical units of beginning work in process, 90 (240 – 150) equivalent units of conversion costs need to be added. §440 total equivalent units completed and transferred out (Exhibit 17-11) minus 240 equivalent units completed and transferred from beginning inventory equals 200 equivalent units. \*\*From Exhibit 17-11.



Using the dollar amount from Exhibit 17-15 (column 10) the journal entry for the transfer out to finished goods inventory is

Finished Goods	122,360	
Work in Process—Testing		122,360
To transfer units to finished goods.		

Entries to the key T-account, Work in Process—Testing follow, using information from Exhibit 17-15.

Work in Process—Testing			
Beginning inventory, March 1	51,600	Transferred out	122,360
Transferred-in costs	52,480		
Direct materials	13,200		
Conversion costs	48,600		
Ending inventory, March 31	43,520		

Remember that in a series of interdepartmental transfers, each department is regarded as being separate and distinct for accounting purposes. All costs transferred in during a given accounting period are carried at one unit cost figure, as described when discussing modified FIFO (p. 623), regardless of whether previous departments used the weighted-average or the FIFO method.

### Common Mistakes with Transferred-in Costs

Here are some common pitfalls to avoid when accounting for transferred-in costs:

1. Remember to include transferred-in costs from previous departments in your calculations. Such costs should be treated as if they were another kind of direct material added at the beginning of the process. In other words, when successive departments are involved, transferred units from one department become all or a part of the direct materials of the next department; however, they are called transferred-in costs, not direct materials costs.
2. In calculating costs to be transferred on a FIFO basis, do not overlook the costs assigned at the beginning of the period to units that were in process but are now included in the units transferred. For example, do not overlook the \$51,600 in Exhibit 17-15.
3. Unit costs may fluctuate between periods. Therefore, transferred units may contain batches accumulated at different unit costs. For example, the 400 units transferred in at \$52,480 in Exhibit 17-15 using the FIFO method consist of units that have different unit costs for direct materials and conversion costs when these units were worked on in the Assembly Department (see Exhibit 17-8). Remember, however, that when these units are transferred in to the Testing Department, they are costed at *one* average unit cost of \$131.20 ( $\$52,480 \div 400$ ) as in Exhibit 17-15.
4. Units may be measured in different terms in different departments. Consider each department separately. Unit costs could be based on kilograms in the first department and liters in the second, so as units are received by the second department, their measurements must be converted to liters.



## Process Costing in the Ceramics Industry

Ceramics, Inc., produces ceramic products (such as, multilayer packages for integrated circuits) in a batch flow manufacturing process. Forming and finishing are the two major production stages.

- ◆ **Forming.** Ceramic material is mixed, forced through an extruder, and sent to a dryer.
- ◆ **Finishing.** The products are fired in a kiln, cut, ground, and packaged.

For many years Ceramics, Inc., has manufactured like or similar products in large production runs for industrial customers (termed "original equipment manufacturers," or OEMs) such as computer companies and defense companies.

Ceramics, Inc., costs individual products using standard costs in a process-costing system. Cost data are accumulated and tracked for the forming and finishing operations. Conversion costs are allocated to departments using standard (scheduled) hours of production time in each department. Depreciation on plant and equipment is included in this conversion cost. The controller at Ceramics believes that this system "accurately measures the cost of manufacturing OEM products." These products are manufactured in large batches in a highly standardized way.

Ceramics, Inc., recently added a "custom production line" at its plant. This line manufactures ceramic products that vary greatly in production volume and frequently are tailored to each individual customer's needs. For example, custom-designed nozzles used for pollution control are being manufactured for one customer who needs to rid its flue gas of sulfur.

The controller is skeptical about the accuracy of product costs for these custom products based on the existing process-costing system. She believes that the costs of these products are driven by more variables than standard hours in production at each department. For example, many custom jobs require specialized finishing steps that are undertaken in a job shop adjoining the main production area. Currently she is keeping a separate, largely manual job-costing system that uses some data from the main system and some separately maintained cost data.

The controller is now exploring ways to adapt the formal process-costing system to incorporate some elements of a job-costing system. Her point is that custom jobs put different demands on the resources of Ceramics, Inc., than does the average large production run job. For these custom jobs, a hybrid costing system with elements of both process costing and job costing may be appropriate.



Source: Adapted from U. Karmarkar, P. Lederer, and J. Zimmerman, "Choosing Manufacturing Production Control and Cost Accounting Systems," in R. Kaplan, *Measures For Manufacturing Excellence* (Boston, Mass.: Harvard Business School Press, 1990). Ceramics, Inc., is a fictitious name for the actual company.



## PROBLEM FOR SELF-STUDY

### PROBLEM

Allied Chemicals operates a thermoassembly process as the second of three processes at its plastics plant. Direct materials in thermoassembly are added at the end of the process. The following data pertain to the Thermoassembly Department for June 19\_7:

Work in process, beginning inventory	50,000 units
Transferred-in costs (100% complete)	
Direct materials (0% complete)	
Conversion costs (80% complete)	
Transferred in during current period	200,000 units
Completed and transferred out during current period	210,000 units
Work in process, ending inventory	40,000 units
Transferred-in costs (100% complete)	
Direct materials (0% complete)	
Conversion costs (40% complete)	

### REQUIRED

Compute the equivalent units for work done in the current period.

### SOLUTION

Flow of Production	(Step 1) Physical Units	(Step 2) Equivalent Units		
		Transferred- in Costs	Direct Materials	Conversion Costs
Completed and transferred out during current period	210,000	210,000	210,000	210,000
Add work in process, ending* (40,000 × 100%; 40,000 × 0%; 40,000 × 40%)	40,000	40,000	0	16,000
Total accounted for	250,000			
Deduct work in process, beginning† (50,000 × 100%; 50,000 × 0%; 50,000 × 80%)	50,000	50,000	0	40,000
Transferred in during current period	200,000			
Work done in current period only		200,000	210,000	186,000

\*Degree of completion in this department: transferred-in costs, 100%; direct materials, 0%; conversion costs, 40%.

†Degree of completion in this department: transferred-in costs, 100%; direct materials, 0%; conversion costs, 80%.

## SUMMARY

The following points are linked to the chapter's learning objectives.

1. Process-costing systems are used in industries like chemical processing, oil refining, and breakfast cereals to cost like or similar products or services. The key feature of process costing is the averaging of costs over a quantity (often large) of these like or similar units.
2. The four key steps in a process-costing system using equivalent units are (a) summarize flow of physical units of output, (b) compute output in terms of equivalent units, (c) compute equivalent unit costs, and (d) summarize total costs to account for, and assign these costs to units completed and to units in ending work in process.



3. An equivalent unit measures output in terms of the physical quantities of inputs necessary to produce one fully complete unit of the product or service. Equivalent unit calculations are necessary when all physical units of output are not uniformly completed.
4. Journal entries in a process-costing system are similar to entries in a job-costing system. The main difference is that in a process-costing system, there is a separate work-in-process account for each department rather than for each job.
5. The weighted-average method of process costing computes unit costs by focusing on the total costs and the total equivalent units completed to date and assigns this average cost to units completed and to units in ending work-in-process inventory.
6. The first-in, first-out (FIFO) method of process costing assigns unit costs of the earliest equivalent units available to units completed, and the unit costs of the most recent equivalent units worked on during the period to ending work-in-process inventory.
7. The use of standard costs simplifies process costing because standard costs directly serve as the costs per equivalent unit when assigning costs to units completed and to units in ending work-in-process inventory.
8. The weighted-average process-costing system for transferred-in costs computes weighted-average costs for transferred-in costs by merging beginning work in process and work done in the current period.
9. The FIFO process-costing system for transferred-in costs assigns transferred-in costs in beginning work in process to units completed, and the costs transferred in during the current period to ending work-in-process inventory.

## TERMS TO LEARN

This chapter and the Glossary at the end of this book contain definitions of the following important terms:

equivalent units (p. 615)	transferred-in costs (630)
first-in, first-out (FIFO) process-costing method (623)	weighted-average process-costing method (620)
previous department costs (630)	

## ASSIGNMENT MATERIAL

### QUESTIONS

- 17-1 Give three examples of industries that often use process-costing systems.
- 17-2 In process costing, why are costs often divided into two main classifications?
- 17-3 Explain equivalent units. Why are equivalent-unit calculations necessary for process costing?
- 17-4 What problems might arise in estimating the degree of completion of an aircraft blade in a machining shop?
- 17-5 Name the four key steps in process costing when equivalent units are computed.
- 17-6 Name the three inventory methods commonly associated with process costing.
- 17-7 Describe the distinctive characteristic of weighted-average computations in assigning costs to units completed and ending work in process.
- 17-8 Describe the distinctive characteristic of FIFO computations in assigning costs to units completed and ending work in process.



- 17-9 Why should the FIFO method be called a modified or departmental FIFO method?
- 17-10 Identify a major advantage of the FIFO method for purposes of planning and control.
- 17-11 Identify the main difference between journal entries in process costing and the ones in job costing.
- 17-12 "Standard cost procedures are particularly applicable to process-costing situations." Do you agree? Why?
- 17-13 Why should the accountant distinguish between transferred-in costs and additional direct materials costs for a particular department?
- 17-14 "Previous department costs are those incurred in the preceding accounting period." Do you agree? Explain.
- 17-15 "There's no reason for me to get excited about the choice between the weighted-average and FIFO methods in my process-costing system. I have long-term contracts with my materials suppliers at fixed prices." State the conditions under which you would (a) agree and (b) disagree with this statement, made by a plant controller. Explain.

## EXERCISES

- 17-16 **No beginning inventory.** International Electronics manufactures microchips in large quantities. Each microchip undergoes assembly and testing. The total assembly costs during January 19\_7 were

Direct materials used	\$ 720,000
Conversion costs	760,000
Total manufacturing costs	<u>\$1,480,000</u>

### REQUIRED

- Assume there was no beginning inventory on January 1, 19\_7. During January, 10,000 microchips were placed into production and all 10,000 microchips were fully completed at the end of January. What is the unit cost of an assembled microchip in January 19\_7?
  - Assume that during February 10,000 microchips were placed into production. Further assume the same total assembly costs for January are also incurred in February 19\_7, but only 9,000 microchips are fully completed at the end of February. All direct materials had been added to the remaining 1,000 microchips. However, on average, these remaining 1,000 microchips were only 50% complete as to conversion costs. (a) What are the equivalent units for direct materials and conversion costs and their respective equivalent unit costs for February? (b) What is the unit cost of an assembled microchip in February 19\_7?
  - Explain the difference in your answers to requirements 1 and 2.
- 17-17 **Journal entries (continuation of 17-16).** Refer to requirement 2 of Exercise 17-16.

### REQUIRED

Prepare summary journal entries for the use of direct materials and conversion costs. Also prepare a journal entry to transfer out the cost of goods completed. Show the postings to the Work in Process account.

- 17-18 **No beginning inventory, materials introduced in middle of process.** Vaasa Chemicals has a mixing department and a refining department. Its process-costing system in the mixing department has two direct materials cost categories (chemical P and chemical Q) and one conversion costs pool. The following data pertain to the mixing department for July 19\_7:

Units	
Work in process, July 1	0
Units started	50,000
Completed and transferred to refining department	35,000



Costs	
Chemical P	\$250,000
Chemical Q	70,000
Conversion costs	135,000

Chemical P is introduced at the start of operations in the mixing department, and chemical Q is added when the product is three-fourths completed in the mixing department. Conversion costs are added uniformly during the process. The ending work in process in the mixing department is two-thirds completed.

#### REQUIRED

1. Compute the equivalent units in the mixing department for July 19\_7 for each cost element.
2. Compute (a) the cost of goods completed and transferred to the refining department during July, and (b) the cost of work in process as of July 31, 19\_7.

**17-19 Journal entries (continuation of 17-18).** Refer to requirement 2 of Exercise 17-18.

#### REQUIRED

Prepare journal entries. Assume that the completed goods are transferred to the refining department.

**17-20 Equivalent units and equivalent unit costs.** Consider the following data for the satellite assembly division of Aerospatiale:

	Physical Units (Satellites)	Direct Materials	Conversion Costs
Beginning work in process, (May 1)*	8	\$ 4,968,000	\$ 928,000
Started in May 19_7	50		
Completed during May 19_7	46		
Ending work in process (May 31) <sup>†</sup>	12		
Costs added during May 19_7		\$32,200,000	\$13,920,000

\*Degree of completion: direct materials, 90%; conversion costs, 40%.

<sup>†</sup>Degree of completion: direct materials, 60%; conversion costs, 30%.

#### REQUIRED

1. Compute equivalent units of work done in the current period for direct materials and conversion costs. Show physical units in the first column.
2. Calculate cost per equivalent unit of beginning work in process and of work done in the current period for direct materials and conversion costs.

**17-21 Weighted-average method.** The Chatham Company makes chemical compounds in a single processing department. The following information about equivalent units and actual costs for July 19\_7 is available.

	Direct Materials		Conversion Costs	
	Equivalent Units	Total Costs	Equivalent Units	Total Costs
Work in process, July 1*	20,000	\$120,000	14,000	\$140,000
Work done during July 19_7	30,000	210,000	28,000	301,000
To account for	50,000	\$330,000	42,000	\$441,000
Completed during July 19_7	34,000	?	34,000	?
Work in process, July 31 <sup>†</sup>	16,000	?	8,000	?

\*Degree of completion: direct materials, 100%; conversion costs, 70%.

<sup>†</sup>Degree of completion: direct materials, 100%; conversion costs, 50%.



**REQUIRED**

Summarize total costs to account for, and assign these costs to units completed (and transferred out) and to units in ending work in process using the weighted-average method.

- 17-22 **FIFO method.** Refer to the information in Exercise 17-21.

**REQUIRED**

Do Exercise 17-21 using the FIFO method.

- 17-23 **Standard costing method.** Refer to the information in Exercise 17-21. Suppose Chatham determines standard costs of \$6.10 per (equivalent) unit for direct materials and \$10.20 per (equivalent) unit for conversion costs for both beginning work in process and work done in the current period.

**REQUIRED**

1. Do Exercise 17-21 using the standard costing method.
2. Provide journal entries for the total direct materials and conversion costs variances for July 19\_7.

- 17-24 **Transferred-in costs, equivalent unit costs, working backwards.**

Bangkok Plastics has two processes—extrusion and thermoassembly. Consider the June 19\_7 data for physical units in the thermoassembly process of Bangkok Plastics: beginning work in process, 15,000 units; transferred in from the Extruding Department during September, 9,000; ending work in process, 5,000. Direct materials are added when the process in the Thermoassembly Department is 80% complete. Conversion costs are added evenly during the process. Bangkok Plastics uses the weighted-average process-costing method. The following information is available.

	Transferred-in Costs	Direct Materials	Conversion Costs
Beginning work-in-process cost	\$90,000	—	\$45,000
Cost per equivalent unit of beginning work in process	\$ 6	—	\$ 5
Costs added in current period	\$58,500	\$57,000	\$57,200
Cost per equivalent unit of work done in current period	\$ 6.50	\$ 3	\$ 5.20

**REQUIRED**

1. For each cost element, compute equivalent units of (a) beginning work in process, and (b) work done in the current period.
2. For each cost element, compute the equivalent units in ending work in process.
3. (a) For each cost element, calculate the percentage of completion of beginning work-in-process inventory, and (b) for each cost element, calculate the percentage of completion of ending work-in-process inventory.

- 17-25 **Transferred-in costs, weighted-average method.** Hideo Chemicals manufactures an industrial solvent in two departments—mixing and cooking. This question focuses on the Cooking Department. During June 19\_7, 90 tons of solvent were completed and transferred out from the Cooking Department. Direct materials are added at one point in time during the process. Conversion costs are added uniformly during the process. Hideo Chemicals uses the weighted-average process-costing method. The following information about the actual costs for June 19\_7 is available.

	Transferred-in Costs		Direct Materials		Conversion Costs	
	Equivalent Tons	Total Costs	Equivalent Tons	Total Costs	Equivalent Tons	Total Costs
Work in process, June 1	40	\$40,000	0	\$ 0	30	\$18,000
Work done in June 19_7	80	\$87,200	90	\$36,000	75	\$49,725
Completed in June 19_7	?	?	?	?	?	?
Work in process, June 30	?	?	?	?	?	?



### REQUIRED

1. Calculate the equivalent tons of solvent completed and transferred out, and in ending work in process for each cost element.
2. Compute cost per equivalent unit for beginning work in process and work done in current period.
3. Summarize total costs to account for, and assign these costs to units completed (and transferred out) and to units in ending work in process using the weighted-average method.

**17-26 Transferred-in costs, FIFO method.** Refer to the information in Exercise 17-25. Suppose that Hideo uses the FIFO method instead of the weighted-average method in all its departments. The only changes under the FIFO method are that the total transferred-in cost of beginning work in process is \$39,200 and that the cost of work done in the current period is \$85,600.

### REQUIRED

Do Exercise 17-25 using the FIFO method.

**17-27 Transferred-in costs, standard costing method.** Refer to the information in Exercise 17-25. Suppose Hideo determines standard costs of \$1,050 per (equivalent) ton of transferred-in costs, \$390 per (equivalent) ton of direct materials, and \$640 per (equivalent) ton of conversion costs for both beginning work in process and work done in the current period.

### REQUIRED

Do Exercise 17-25 using the standard costing method.

## PROBLEMS

**H 17-28 Weighted-average method.** Global Defense, Inc., is a manufacturer of military equipment. Its Santa Fe plant manufactures the Interceptor missile under contract to the U.S. government and friendly countries. All Interceptors go through an identical manufacturing process. Every effort is made to ensure that all Interceptors are identical and meet many demanding performance specifications. The product-costing system at the Santa Fe plant has a single direct-cost category (direct materials) and a single indirect-cost category (conversion costs). Each Interceptor passes through two departments—the Assembly Department and the Testing Department. Direct materials are added at the beginning of the process in Assembly. Conversion costs are added evenly throughout the two departments. When the Assembly Department finishes work on each Interceptor, it is immediately transferred to Testing.

Global Defense uses the weighted-average method of process costing. Data for the Assembly Department for October 19\_7 are

	Physical Units (Missiles)	Direct Materials	Conversion Costs
Work in process, October 1*	20	\$ 460,000	\$120,000
Started during October 19_7	80		
Completed during October 19_7	90		
Work in process, October 31†	10		
Costs added during October 19_7		\$2,000,000	\$935,000

\*Degree of completion: direct materials, 70%; conversion costs, 60%.

†Degree of completion: direct materials, 70%; conversion costs, 70%.

### REQUIRED

1. For each cost element, compute equivalent units of work done in October 19\_7 in the Assembly Department. Show physical units in the first column.
2. For each cost element, calculate cost per equivalent unit of beginning work in process and of work done in October 19\_7.



- Summarize the total Assembly Department costs for October 19\_7, and assign these costs to units completed (and transferred out) and to units in ending work in process using the weighted-average method.

**17-29 Journal entries (continuation of 17-28).**

**REQUIRED**

Prepare a set of summarized journal entries for all October 19\_7 transactions affecting Work in Process—Assembly. Set up a T-account for Work in Process—Assembly, and post the entries to it.

**H 17-30 FIFO method (continuation of 17-28 and 17-29).**

**REQUIRED**

Do Problem 17-28 using the FIFO method of process costing. Explain any difference between the cost of work completed and transferred out and cost of ending work in process in the Assembly Department under the weighted-average method and the FIFO method.

**✓ 17-31 Transferred-in costs, weighted average (related to 17-28 to 17-30).**

Global Defense, Inc., as you know, manufactures the Interceptor missile at its Santa Fe plant. It has two departments—Assembly Department and Testing Department. This problem focuses on the Testing Department. (Problems 17-28 to 17-30 focused on the Assembly Department.) Direct materials are added at the end of the Testing Department. Conversion costs are added evenly during the Testing Department's process. As work in Assembly is completed, each unit is immediately transferred to Testing. As each unit is completed in Testing, it is immediately transferred to Finished Goods.

Global Defense uses the weighted-average method of process costing. Data for the Testing Department for October 19\_7 are

	Physical Units (Missiles)	Transferred-in Costs	Direct Materials	Conversion Costs
Work in process, October 1*	30	\$ 985,800	\$ 0	\$ 331,800
Transferred-in during October 19_7	290			
Completed during October 19_7	105			
Work in process, October 31†	15			
Costs added during October 19_7		\$3,192,866	\$3,885,000	\$1,581,000

\*Degree of completion: transferred-in costs, 70%; direct materials, 0%; conversion costs, 70%.

†Degree of completion: transferred-in costs, 70%; direct materials, 0%; conversion costs, 60%.

**REQUIRED**

- What is the percentage of completion for (a) transferred-in costs and direct materials in beginning work-in-process inventory, and (b) transferred-in costs and direct materials in ending work-in-process inventory?
- For each cost element, compute equivalent units of work done in October 19\_7 in the Testing Department. Show physical units in the first column.
- For each cost element, calculate the cost per equivalent unit of beginning work in process and of work done in October 19\_7.
- Summarize total Testing Department costs for October 19\_7, and assign these costs to units completed (and transferred out) and to units in ending work in process using the weighted-average method.
- Prepare journal entries for October transfers from the Assembly Department to the Testing Department and from Testing to Finished Goods.

**17-32 Transferred-in costs, FIFO costing (continuation of 17-31).**

**REQUIRED**

Using the FIFO process-costing method, do the requirements of Problem 17-31. The transferred-in costs from the Assembly Department for the beginning work in process on October 1 are \$980,060. During October, costs



transferred in to the Testing Department are \$3,188,000. All other data are unchanged.

**17-33 Weighted-average method.** Star Toys manufactures one type of wooden toy figure. It buys wood as its direct material for the Forming Department of its Madison plant. The toys are transferred to the Finishing Department, where they are hand shaped and metal is added to them.

Star Toys uses the weighted-average method of process costing. Consider the following data for the Forming Department in April 19\_7:

	Physical Units (Toys)	Direct Materials	Conversion Costs
Work in process, April 1*	300	\$ 7,500	\$ 2,125
Started during April 19_7	2,200		
Completed during April 19_7	2,000		
Work in process, April 30†	500		
Costs added during April 19_7		\$70,000	\$42,500

\*Degree of completion: direct materials, 100%; conversion costs, 40%.

†Degree of completion: direct materials, 100%; conversion costs, 25%.

#### REQUIRED

Summarize the total Forming Department costs for April 19\_7, and assign these costs to units completed (and transferred out) and to units in ending work in process using the weighted-average method.

**17-34 Journal entries (continuation of 17-33).**

#### REQUIRED

Prepare a set of summarized journal entries for all April transactions affecting Work in Process—Forming. Set up a T-account for Work in Process—Forming, and post the entries to it.

**17-35 FIFO computations (continuation of 17-33 and 17-34).**

#### REQUIRED

Do Problem 17-33, using FIFO and four decimal places for unit costs. Explain any difference between the cost of work completed and transferred out and cost of ending work in process in the Forming Department under the weighted-average method and the FIFO method.

**17-36 Transferred-in costs, weighted-average (related to 17-33 through 17-35).** Star Toys manufactures wooden toy figures at its Madison plant. It has two departments—the Forming Department and the Finishing Department. (Problems 17-33 to 17-35 focused on the Forming Department.) Consider now the Finishing Department, which processes the formed toys through hand shaping and the addition of metal. For simplicity here, suppose all additional direct materials are added at the end of the process. Conversion costs are added evenly during Finishing operations.

Star Toys uses the weighted-average method of process costing. The following is a summary of the April 19\_7 operations in the Finishing Department:

	Physical Units (Toys)	Transferred-in Costs	Direct Materials	Conversion Costs
Work in process, April 1*	500	\$ 17,750	\$ 0	\$ 7,250
Transferred-in during April 19_7	2,000			
Completed during April 19_7	2,100			
Work in process, April 30†	400			
Costs added during April 19_7		\$104,000	\$23,100	\$38,400

\*Degree of completion: transferred-in costs, 100%; direct materials, 0%; conversion costs, 60%.

†Degree of completion: transferred-in costs, 100%; direct materials, 0%; conversion costs, 30%.



**REQUIRED**

1. Summarize the total Finishing Department costs for April 19\_7, and assign these costs to units completed (and transferred out) and to units in ending work in process using the weighted-average method.
2. Prepare journal entries for April transfers from the Forming Department to the Finishing Department and from the Finishing Department to Finished Goods.

**17-37 Transferred-in costs, FIFO costing (continuation of 17-36).****REQUIRED**

1. Using the FIFO process-costing method, do the requirements of Problem 17-36. The transferred-in costs from the Forming Department for the April beginning work in process are \$17,520. During April, the costs transferred in are \$103,566. All other data are unchanged.
2. Explain any difference between the cost of work completed and transferred out and cost of ending work in process in the Finishing Department under the weighted-average method and the FIFO method.

- 17-38 Transferred-in costs, weighted-average and FIFO.** Frito-Lay, Inc., manufactures convenience foods, including potato chips and corn chips. Production of corn chips occurs in four departments: cleaning, mixing, cooking, and drying and packaging. Consider the Drying and Packaging Department, where direct materials (packaging) is added at the end of the process. Conversion costs are added evenly during the process. Suppose the accounting records of a Frito-Lay plant provided the following information for corn chips in its Drying and Packaging Department during a weekly period (week 37):

	Physical Units (Cases)	Transferred-in Costs	Direct Materials	Conversion Costs
Beginning work in process, week 37*	1,250	\$29,000	\$ 0	\$ 9,060
Transferred-in during week 37 from Cooking Department	5,000			
Completed during week 37	5,250			
Ending work in process, week 37†	1,000			
Costs added during week 37		\$96,000	\$25,200	\$38,400

\*Degree of completion: transferred-in costs, 100%; direct materials, 0%; conversion costs, 80%.

†Degree of completion: transferred-in costs, 0%; direct materials, 0%; conversion costs, 40%.

**REQUIRED**

1. For each cost element, compute equivalent units of work done in week 37 in the Drying and Packaging Department. Show physical units in the first column.
2. Summarize the total Drying and Packaging Department costs for week 37, and assign these costs to units completed (and transferred out) and to units in ending work in process using the weighted-average method.
3. Assume that the FIFO method is used for the Drying and Packaging Department. The transferred-in costs for work-in-process beginning inventory are \$28,920. The transferred-in costs during the week from the Cooking Department are \$94,000. All other data are unchanged. Summarize the total Drying and Packaging Department costs for week 37 and assign these costs to units completed (and transferred out) and to units in ending work in process using the FIFO method.

- 17-39 Standard costing with beginning and ending work in process.** The Victoria Corporation uses a standard costing system for its manufacturing oper-



ations. Standard costs for the cooking process are \$6 per unit for direct materials and \$3 per unit for conversion costs. All direct materials are introduced at the beginning of the process, but conversion costs are added uniformly during the process. The operating summary for May 19\_7 included the following data for the cooking process:

Work-in-process inventories

May 1: 3,000 units\*

(direct materials \$18,000; conversion costs \$5,400)

May 31: 5,000 units†

Units started in May: 20,000

Units completed and transferred out of cooking in May: 18,000

Additional actual costs incurred for cooking during May

Direct materials: \$125,000

Conversion cost: \$57,000

\*Degree of completion: direct materials, 100%; conversion costs, 60%.

†Degree of completion: direct materials, 100%; conversion costs, 50%.

### REQUIRED

1. Compute the total standard costs of units transferred out in May and the total standard costs of the May 31 inventory of work in process.
2. Compute the total May variances for direct materials and conversion costs.

**17-40 Equivalent unit computations, benchmarking, ethics.** Margaret Major is the corporate controller of Leisure Suits. Leisure Suits has 20 plants worldwide that manufacture basic suits for retail stores. Each plant uses a process-costing system. At the end of each month, each plant manager submits a production report and a production-cost report. The production report includes the plant manager's estimate of the percentage of completion of the ending work in process as to direct materials and conversion costs. Major uses these estimates to compute the equivalent units of work done in each plant and the cost per equivalent unit of work done for both direct materials and conversion costs in each month. Plants are ranked from 1 to 20 in terms of (a) cost per equivalent unit of direct materials, and (b) cost per equivalent unit of conversion costs. Each month Major publishes a report that she calls "Benchmarking for Efficiency Gains at Leisure Suits." The top three ranked plants on each category receive a bonus and are written up as the best in their class in the company newsletter.

Major has been pleased with the success of her benchmarking program. However, she has heard some disturbing news. She has received some unsigned letters stating that two plant managers have been manipulating their monthly estimates of percentage of completion in an attempt to obtain best in class status.

### REQUIRED

1. How and why might plant managers "manipulate" their monthly estimates of percentage of completion?
2. Major's first reaction is to contact each plant controller and discuss the problem raised by the unsigned letters. Is that a good idea?
3. Assume that the plant controller's primary reporting responsibility is to the plant manager and that each plant controller receives the phone call from Major mentioned in requirement 2. What is the ethical responsibility of each plant controller (a) to Margaret Major, and (b) to Leisure Suits in relation to the equivalent unit information each plant provides for the "Benchmarking for Efficiency" report?



4. How might Major gain some insight into whether the equivalent unit figures provided by particular plants are being manipulated?

### COLLABORATIVE LEARNING PROBLEM

**17-41 Weighted-average, FIFO, standard costs methods, working backwards.** “I am astounded that we cannot find the cost records for the month of July 19\_7,” said Greg Andrews, plant manager of Detroit Component Works (DCW). “I have a division meeting to attend where I will be asked about the plant’s July performance compared to June. All I have now are the weighted-average cost figures, but those numbers are hardly helpful in answering the question of whether we have improved our performance this month compared to the previous months. I think we have improved the efficiency of our operations, and direct materials prices have also been lower, so I was expecting to report some good news at the division meeting. I need those July numbers and I need them now.” DCW makes complex aircraft engine components in two operations—machining and assembly. The following is a summary of the Assembly operations in July 19\_7.

	Physical Units	Transferred-in Costs	Direct Materials	Conversion Costs
Work in process, July 1*	120	\$16,800	\$ 0	\$9,000
Transferred-in during July 19_7	200			
Completed during July 19_7	220			
Work in process, July 31†	100			
Costs added during July		?	?	?
Weighted-average cost per equivalent unit		\$ 131.25	\$20	\$ 114

\*Degree of completion: transferred-in costs, 100%; direct materials, 0%; conversion costs, 5/8 or 62.5%.

†Degree of completion: transferred-in costs, 100%; direct materials, 0%; conversion costs, 80%.

### INSTRUCTIONS

Form groups of two or three students. Compute the missing numbers. Then discuss requirements 4, 5, and 6 among yourselves to prepare for class discussion.

### REQUIRED

- For each cost element, compute the equivalent units of work done in the current period.
- For each cost element, calculate the cost per equivalent unit of beginning work in process.
- Calculate the total Assembly Department costs to account for in July 19\_7 for each cost element.
- For each cost element, calculate the cost per equivalent unit of work performed in the current period. These are the numbers that Greg Andrews wants for the division meeting. Prepare a brief report comparing and commenting on the cost per equivalent unit of work done in the current period with the cost per equivalent unit of beginning inventory.
- Without doing any further calculations, do you think the cost of units completed and transferred out in July 19\_7 would have been lower or higher if DCW had used the FIFO rather than the weighted-average method? Why? Explain briefly.



6. DCW is looking to add more variations of the components it currently manufactures to its product line. Gina Davis, the plant controller, believes that if it does so, DCW should consider implementing a standard costing system. The assistant controller, Tom Rogers, however, feels that a job-costing system might be more appropriate. What do you think DCW should do—maintain its current system, adopt a standard costing system, or switch to a job-costing system?

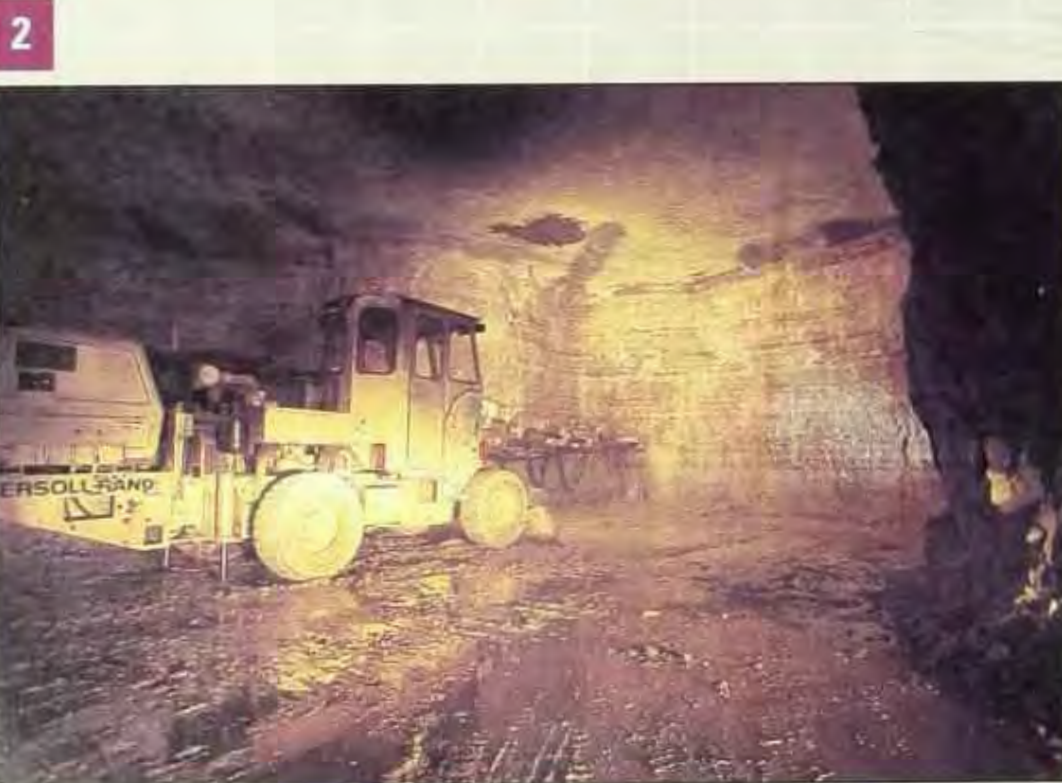


# A WALK THROUGH . . .

## Nally & Gibson Georgetown, Inc.

When Nally & Gibson Georgetown, Inc., was founded in 1955, business was, so to speak, rocky—and it has stayed that way ever since. Why? Because Nally & Gibson mines and supplies limestone rock from its 200-acre quarry. **1** Having fully mined the quality limestone from the surface, Nally & Gibson's mining operations take place 350 feet underneath their quarry. **2** The underground rock must first be loosened by carefully placed dynamite charges. **3** It is then loaded into trucks and transported to the surface, where it is taken to a rock crushing plant. Here the limestone is broken into smaller pieces. **4** These pieces are then carried by a conveyor belt to a second crushing plant. **5** By using filtering screens, rocks in the

second crusher are separated by size. Because size is the main and sometimes only difference among Nally & Gibson's different rock products, the second crushing plant is considered the split-off point for many of those products.





6



7



8



9



10



**6** Once the rocks are separated by size, each grouping leaves the second crushing unit on its own conveyer belt. These conveyers transport the rocks to various stockpiles, **7** from which they can be loaded onto trucks for customers **8** or moved to storage piles farther away from the crushing plants. Although the company sells rocks of all different sizes, certain sizes are more popular and, therefore, command higher prices. **9** Rocks that are either too large or too small to sell are used to fill reclaimed land on the quarry's surface. Because its products come from the same source, are processed in the same way, and vary only in size, Nally & Gibson uses a process costing system. **10** One of the biggest costs this system must track is the depreciation on equipment such as the rock crushers and company trucks. By appropriately tracking and allocating this and all other costs, Nally & Gibson's cost accounting system helps keep the company rock solid.



# VIDEO CASE 4

## NALLY & GIBSON GEORGETOWN, INC. Cost Allocation and Process Costing

**Y**ou drive on it, walk on it, wear it, and even brush your teeth with it. For 3 cents, you can buy 10 pounds of it. What is it? Limestone. It's a versatile natural resource found in asphalt highways, concrete sidewalks, cosmetics, and toothpaste, to name a few. Nally & Gibson Georgetown, Inc., in central Kentucky, has been a primary supplier of quality limestone products since 1955. Over the years, the company has seen many changes as its business and its local economy have matured. Its rock quarry operations are a good example of the role cost accounting can play in a process-based business.

Considered a commodity, limestone rock is extracted from Nally & Gibson's underground mine located 350 feet below the original 200-acre surface of the quarry. Limestone used to be mined on the surface, but the supply of quality surface rock has been exhausted. Engineers estimate that close to 40 million tons of good quality limestone rock still remain to be mined underground. The production process involves three primary stages. First, the rock is blasted with dynamite charges to loosen it. The large limestone rocks are loaded into 35-ton capacity trucks for transport to one of two rock-crushing plants located at the quarry. Next, the rock is dumped into a crusher, which breaks the rocks into smaller pieces. These pieces then travel by conveyor to a second crusher, where the split-off point for various sizes of rock occurs. Finally, the rocks are separated into different sizes. Filtering screens are used to separate the pieces into their respective size groupings. The different sizes of rock are

carried by multiple conveyers to various stockpiles, where they can be loaded onto trucks for customers or moved to a storage pile away from the crushing plant. Nally & Gibson uses process costing to determine the cost per ton of limestone rock processed. All rock is processed in a relatively homogeneous way, and all costs are placed into a single cost pool. By this use of a single cost pool, the company can calculate an equivalent cost per ton of limestone rock.

Pricing of the quarry's thirty-six different sizes of rock is largely driven by market conditions and competitive forces. The most popular rock sizes are those with diameters of 1/4 to 3/8 inch, and they command a higher per-ton price. While the rock-crushing process produces varying sizes of rock, nothing goes to waste. Rocks that are too large to be crushed and the fine sand produced in crushing are used to fill in reclaimed surface land at the quarry. Byproducts, such as unpopular rock sizes that are unavoidable in the crushing process, are sold at lower prices as dictated by the market.

Within a 25-mile radius of Nally & Gibson are six other quarries that offer the same products. Because pricing is so competitive, managers at Nally & Gibson keep a close eye on costs to ensure operations remain profitable. Major costs for the business include depreciation on \$5 million worth of equipment; labor, repair, and maintenance; fuel; transportation; and safety and environmental protection costs. The results of operations are reviewed weekly by the company's management team. The cost data have been particularly useful for identifying whether certain expenditures are within expected ranges and have given managers better information with which to maximize the quarry's profitability. ♦

### QUESTIONS

1. Which costing system would you suggest Nally & Gibson use to determine product costs?
2. Because the mining of limestone rock has an effect on the surrounding environment, what costs would you expect Nally & Gibson to incur related to maintaining and preserving the environment?
3. What quality issues might be associated with the mining and production of different rock sizes? How are costs and prices affected by these issues?
4. If Nally & Gibson called the processing plant a joint cost area, how would it use an estimated net realizable value joint costing method?
5. How might Nally & Gibson use a revenue mix variance analysis to examine profitability changes over time?



# 18

## CHAPTER

# SPOILAGE, REWORKED UNITS, AND SCRAP



Reducing spoilage, reworked units, and scrap is an important aspect of cost management. Motorola monitors both financial and nonfinancial variables in its efforts to minimize reworked units and scrap, and to improve quality. Motorola estimates that these initiatives have resulted in billions of dollars of cost savings.

## LEARNING OBJECTIVES

After studying this chapter, you should be able to

1. Distinguish among spoilage, reworked units, and scrap
2. Describe the general accounting procedures for normal and abnormal spoilage
3. Account for spoilage in process costing using the weighted-average method
4. Account for spoilage in process costing using the first-in, first-out method
5. Account for spoilage in process costing using the standard costs method
6. Account for spoilage in job costing
7. Account for reworked units
8. Account for scrap



## OBJECTIVE 1

Distinguish among spoilage, reworked units and scrap

The emphasis on quality, and the high costs of spoilage, reworked units, and scrap, has resulted in managers paying close attention to these costs. **Spoilage** refers to unacceptable units of production that are discarded or are sold for net disposal proceeds. Partially completed or fully completed units of output may be spoiled. Examples are defective shirts, jeans, shoes and carpets sold as “seconds,” and defective aluminum cans sold to aluminum manufacturers for remelting and production of aluminum foils. **Reworked units** are unacceptable units of production that are subsequently reworked and sold as acceptable finished goods. For example, defective units of products such as pagers, computer disk drives, computers, and telephones can sometimes be repaired and sold as good products. Scrap is material left over when making a main or joint product. *Scrap* is defined in Chapter 15 as a product that has minimal (frequently zero) sales value compared with the sales value of the main or joint product(s). Examples are shavings and short lengths from woodworking operations, steel edges left over from stamping operations, and frayed cloth and end cuts from suit-making operations.

Recording and identifying the costs of spoilage, rework, and scrap helps managers make more informed decisions, especially concerning production systems. For example, major reductions in these costs might help managers justify investments in cutting-edge production systems such as just-in-time (JIT) and computer-integrated manufacturing (CIM). This chapter concentrates on how spoilage, rework, and scrap are recorded in management accounting systems.

## MANAGEMENT EFFORT AND CONTROL

Some amount of spoilage, rework, or scrap appears to be an inherent part of many production processes. One example is semiconductor manufacturing, where the products are so complex and delicate that some spoiled units are invariably produced. In this case, the spoiled units cannot be reworked. An example involving spoilage and rework occurs in the manufacture of high-precision machine tools that must be built to very demanding tolerances. In this case, spoiled units can be reworked to meet standards but only at a considerable cost. And in the mining industry, companies process ore that contains varying amounts of valuable metals and rock. Some amount of rock, which is scrap, is inevitable, but its volume can often be decreased. Managers in all industries must strive to reduce costly spoilage, rework, and scrap. For example, managers can take steps to improve quality and reduce costs by designing better products and processes, training and motivating workers, and properly maintaining machines.

In many cases, growing competition in the global market place has forced managers to focus on improving quality. Executives have learned that a rate of defects regarded as normal in the past is no longer tolerable. Consider these words from a speech by George Fisher, the former chief executive officer of Motorola, an electronics manufacturer:

We want to improve our quality in everything we do by ten times in two years, by a hundred times in four years, and in six years . . . three and a half defects for every million operations, whether typing, manufacturing, or serving a customer.

## SPOILAGE IN GENERAL

### OBJECTIVE 2

Describe the general accounting procedures for normal and abnormal spoilage

Two key objectives when accounting for spoilage are determining the magnitude of the costs of spoilage and distinguishing between the costs of normal and abnormal spoilage. Managers use this information both to cost products and to control and reduce costs by improving the quality of the product and process.

There is an unmistakable trend in manufacturing to increase quality. Why? Because managers at companies, such as AT&T, IBM, and Milliken Corporation have found that improved quality and intolerance for high spoilage have lowered overall costs and increased sales. The accounting procedures in this section highlight



spoilage costs so that they are not ignored or buried as an unidentified part of the costs of good units manufactured.<sup>1</sup>

## Normal Spoilage

**Normal spoilage** is spoilage that arises under efficient operating conditions; it is an inherent result of the particular production process. For a given production process, management must decide the rate of spoilage it is willing to accept as normal. Costs of normal spoilage are typically viewed as a part of the costs of good units manufactured, when good units cannot be made without the simultaneous appearance of spoiled units.

Normal spoilage rates should be computed using the total good units completed as the base, not the total *actual* units started. Why? Because total actual units started also include any abnormal spoilage in addition to normal spoilage.

## Abnormal Spoilage

**Abnormal spoilage** is spoilage that is not expected to arise under efficient operating conditions; it is not an inherent part of the chosen production process. Most abnormal spoilage is usually regarded as avoidable and controllable. Line operators and other plant personnel can generally decrease abnormal spoilage by minimizing machine breakdowns, accidents, and the like. Abnormal spoilage costs are written off as losses of the accounting period in which detection of the spoiled units occurs. For the most informative feedback, the Loss from Abnormal Spoilage account should appear in a detailed income statement as a separate line item and not be buried as an indistinguishable part of the cost of goods manufactured.

Many companies such as the Toyota Motor Corporation adhere to a perfection standard as a part of their emphasis on total quality control. Their ideal goal is zero defects. Hence, all spoilage would be treated as abnormal.

## PROCESS COSTING AND SPOILAGE

### Count All Spoilage

Spoiled units can either be recognized (approach A) or not counted (approach B) when computing output units—actual or equivalent—in a process-costing system. Approach A makes visible the costs associated with spoilage. Approach B spreads the spoilage costs over good units, potentially resulting in less accurate product costs.

Spoilage is typically assumed to occur at the stage of completion where inspection takes place. Why? Because spoilage is not detected until that point.

**EXAMPLE 1** Chipmakers, Inc., manufactures computer chips for television sets. All direct materials are added at the beginning of the chipmaking process. To highlight issues that arise with spoilage, we assume no beginning inventory. In May 19\_7, \$270,000 in direct materials were introduced. Production data for May indicate that 10,000 units were started, 5,000 good units were completed, 1,000 units were spoiled (all normal spoilage). Ending work in process had 4,000 units (each 100% complete as to direct materials costs). Spoilage is detected upon completion of the process.

The direct materials unit costs are computed and assigned using approaches A and B as shown in Exhibit 18-1. Not counting the equivalent units for spoilage decreases equivalent units, resulting in a higher cost of each good unit. A \$30 equivalent unit cost (instead of a \$27 equivalent unit cost) is assigned to work in process that has not reached the inspection point. Simultaneously, the direct materials costs assigned to good units completed, which include the cost of normal spoilage, are too low (\$150,000 instead of \$162,000). Consequently, the 4,000 units in ending work in process contain costs of spoilage of \$12,000 (\$120,000 – \$108,000) that do not

<sup>1</sup>The helpful suggestions of Samuel Laimon, University of Saskatchewan, are gratefully acknowledged.



**EXHIBIT 18-1**

Effect of Recognizing Equivalent Units in Spoilage for Direct Materials Costs, Chipmakers, Inc., for May 19\_7

	<b>Approach A: Recognizing Spoiled Units • When Computing Output in Equivalent Units</b>	<b>Approach B: Not Counting Spoiled Units When Computing Output in Equivalent Units</b>
Costs to account for	\$270,000	\$270,000
Divide by equivalent units	÷ 10,000	÷ 9,000
Cost per equivalent unit	<u>\$ 27</u>	<u>\$ 30</u>
Assigned to		
Good units transferred out		
Good units completed:		
5,000 × \$27; 5,000 × \$30	\$135,000	\$150,000
Add normal spoilage: 1,000 × \$27	<u>27,000</u>	<u>0</u>
Good units transferred out	162,000	150,000
Work in process, ending:		
4,000 × \$27; 4,000 × \$30	<u>108,000</u>	<u>120,000</u>
Costs accounted for	<u>\$270,000</u>	<u>\$270,000</u>

pertain to those units and that, in fact, belong with the good units completed and transferred out. The 4,000 units in ending work in process undoubtedly include some units that will be detected as spoiled in the subsequent accounting period. In effect, under approach B, these units will bear two charges for spoilage. The ending work in process is being charged for spoilage in the current period, and it will be charged again when inspection occurs as the units are completed. Such cost distortions do not occur when spoiled units are recognized in the computation of equivalent units. Approach A has a further advantage. It highlights the cost of normal spoilage to management and thereby focuses management's attention on reducing spoilage. Therefore, we will use approach A to present process costing with spoilage.

**EXAMPLE 2** The Anzio Company manufactures a wooden recycling container in its Processing Department. Direct materials for this product are introduced at the beginning of the production cycle. At the start of production, all direct materials required to make one output unit are bundled together in a single kit. Conversion costs are added evenly during the cycle. Some units of this product are spoiled as a result of defects only detectable at inspection of finished units. Normally, the spoiled units are 10% of the good output. Summary data for July 19\_7 are

**Physical Units for July 19\_7**

Work in process, beginning inventory (July 1)	1,500 units
Direct materials (100% complete)	
Conversion costs (60% complete)	
Started during July	8,500 units
Completed and transferred out in July (good units)	7,000 units
Work in process, ending inventory (July 31)	2,000 units
Direct materials (100% complete)	
Conversion costs (50% complete)	



### Total Costs for July 19\_7

Work in process, beginning inventory		
Direct materials	\$12,000	
Conversion costs	<u>9,000</u>	\$ 21,000
Direct materials costs added during July		76,500
Conversion costs added during July		<u>89,100</u>
Total costs to account for		<u>\$186,600</u>

## Computing Spoiled Units

The number of total spoiled units is computed as follows:

$$\begin{aligned}\text{Total spoiled units} &= \left( \begin{array}{c} \text{Beginning} \\ \text{units} \end{array} + \begin{array}{c} \text{Units} \\ \text{started} \end{array} \right) - \left( \begin{array}{c} \text{Good units} \\ \text{transferred out} \end{array} + \begin{array}{c} \text{Ending} \\ \text{units} \end{array} \right) \\ &= (1,500 + 8,500) - (7,000 + 2,000) \\ &= 10,000 - 9,000 \\ &= 1,000 \text{ units}\end{aligned}$$

Normal spoilage at Anzio's Processing Department is 10% of the 7,000 units of good output, or 700 units. Thus,

$$\begin{aligned}\text{Abnormal spoilage} &= \text{Total spoilage} - \text{Normal spoilage} \\ &= 1,000 - 700 \\ &= 300 \text{ units}\end{aligned}$$

We now illustrate how the weighted-average, FIFO, and standard costing methods of process costing discussed in Chapter 17 can incorporate both normal and abnormal spoilage in their computations.

## Follow the Four-Step Approach

The basic four-step approach used in Chapter 17 needs only slight modification to accommodate spoilage. The following observations pertain to the weighted-average, FIFO, and standard costing methods:

**Step 1 Summarize the flow of physical units of output.** Identify both normal and abnormal spoilage.

**Step 2 Compute output in terms of equivalent units.** Compute equivalent units for spoilage in the same way as for good units. Because Anzio inspects at the completion point, the same amount of work will be done on each spoiled unit and each completed good unit.

**Step 3 Compute equivalent unit costs.** The details of this step do not differ from those in Chapter 17. We assume that spoiled units are included in the computation of output units.

**Step 4 Summarize total costs to account for, and assign these costs to units completed, spoiled units, and to units in ending work in process.** This step now includes computation of the cost of spoiled units and the cost of good units.

Exhibit 18-2 presents steps 1 and 2 and includes calculations of equivalent units of normal and abnormal spoilage. Exhibit 18-3 computes the equivalent unit costs for beginning work in process and work done in the current period (step 3).



# EXHIBIT 18-2

Steps 1 and 2: Summarize Output in Physical Units and Compute Equivalent Units, Processing Department of the Anzio Company for July 19\_7

Flow of Production	(Step 1) Physical Units	(Step 2) Equivalent Units	
		Direct Materials	Conversion Costs
Good units completed and transferred out during current period	7,000	7,000	7,000
✓ Normal spoilage* 700 × 100%; 700 × 100%	700	700	700
✓ Abnormal spoilage† 300 × 100%; 300 × 100%	300	300	300
Work in process, ending‡ 2,000 × 100%; 2,000 × 50%	2,000	2,000	1,000
Total Accounted For	10,000	10,000	9,000
Deduct work in process, beginning§ 1,500 × 100%; 1,500 × 60%	1,500	1,500	900
Started during current period	8,500		
Work done in current period only		8,500	8,100

\*Normal spoilage is 10% of good units transferred out: 10% × 7,000 = 700 units. Degree of completion of normal spoilage in this department: direct materials, 100%; conversion costs, 100%.

†Abnormal spoilage = Actual spoilage – Normal spoilage = 1,000 – 700 = 300 units. Degree of completion of abnormal spoilage in this department: direct materials, 100%; conversion costs, 100%.

‡Degree of completion in this department: direct materials, 100%; conversion costs, 50%.

§Degree of completion in this department: direct materials, 100%; conversion costs, 60%.

# EXHIBIT 18-3

Step 3: Compute Equivalent Unit Costs, Processing Department of the Anzio Company for July 19\_7

	Direct Materials	Conversion Costs
Equivalent unit costs of beginning work in process		
Work in process, beginning (given, p. 655)	\$12,000	\$ 9,000
Divide by equivalent units of beginning work in process (from Exhibit 18-2)	÷ 1,500	÷ 900
Cost per equivalent unit of beginning work in process	\$ 8	\$ 10
Equivalent unit costs of work done in current period only		
Costs added in current period (given, p. 655)	\$76,500	\$89,100
Divide by equivalent units of work done in current period (from Exhibit 18-2)	÷ 8,500	÷ 8,100
Cost per equivalent unit of work done in current period only	\$ 9	\$ 11

## OBJECTIVE 3

Account for spoilage in process costing using the weighted-average method

## Weighted-Average Method and Spoilage

Exhibit 18-4 presents step 4 using the weighted-average method. The total costs columns in Panel A of Exhibit 18-4 summarize the costs to account for. Note how, for each cost category, the costs of beginning work in process and costs of work done in the current period are totaled and divided by the sum of the equivalent units in beginning work in process and equivalent units of work done in the current period to calculate the weighted-average cost. The costs of abnormal spoilage of \$5,925 are



## EXHIBIT 18-4

Step 4: Summarize Total Costs to Account for, and Assign These Costs to Units Completed, Units Spoiled and Units in Ending Work in Process Using the Weighted-Average Method, Processing Department of Anzio Company for July 19\_7

	Direct Materials			Conversion Costs			Total Prod. Costs
	Equiv. Units (1)	Cost per Equiv. Unit (2)	Total Costs (3) = (1) × (2)	Equiv. Units (4)	Cost per Equiv. Unit (5)	Total Costs (6) = (4) × (5)	(7) = (3) + (6)

**PANEL A:****TOTAL COSTS TO ACCOUNT FOR**

Work in process, beginning (from Exhibit 18-3)	1,500	\$8.00	\$12,000	900	\$10.00	\$ 9,000	\$ 21,000
Work done in current period only (from Exhibit 18-3)	<u>8,500</u>	\$9.00	<u>76,500</u>	<u>8,100</u>	\$11.00	<u>89,100</u>	<u>165,600</u>
To account for	<u>10,000</u>	\$8.85*	<u>\$88,500</u>	<u>9,000</u>	\$10.90†	<u>\$98,100</u>	<u>\$186,600</u>

**PANEL B:****ASSIGNMENT OF COSTS**

Good units completed and transferred (out 7,000 units)							
Costs before adding normal spoilage							
	7,000‡	\$8.85	\$61,950	7,000‡	\$10.90	\$76,300	\$138,250
	700‡	\$8.85	<u>6,195</u>	700‡	\$10.90	<u>7,630</u>	<u>13,825</u>
(A)	Total costs of good units transferred out		68,145			83,930	<u>152,075</u>
(B)	Abnormal spoilage	300‡	\$8.85	300‡	\$10.90	3,270	5,925
(C)	Work in process, ending	<u>2,000‡</u>	<u>\$8.85</u>	<u>1,000‡</u>	<u>\$10.90</u>	<u>10,900</u>	<u>28,600</u>
(A) + (B) + (C)	Accounted for	<u>10,000</u>	<u>\$88,500</u>	<u>9,000</u>		<u>\$98,100</u>	<u>\$186,600</u>

\*Weighted-average cost per equivalent unit of direct materials = Total costs of direct materials divided by total equivalent units  
= \$88,500 ÷ 10,000 = \$8.85.

†Weighted-average cost per equivalent unit of conversion costs = Total conversion costs divided by total equivalent units  
= \$98,100 ÷ 9,000 = \$10.90.

‡From Exhibit 18-2.



assigned to the Loss from Abnormal Spoilage account. The costs of normal spoilage, \$13,825, are added to the costs of their related good units. Hence, the cost per good unit completed and transferred out equals the total costs transferred out (including the costs of normal spoilage) divided by the number of good units produced,  $\$152,075 \div 7,000 = \$21.725$ . It is not equal to \$19.75, the sum of the costs per equivalent unit of direct materials, \$8.85 and conversion costs, \$10.90. Why? Because the cost per good unit is equal to the total cost of an equivalent unit, \$19.75 *plus* a share of the normal spoilage, \$1.975 ( $\$13,825 \div 7,000$ ), or \$21.725.

This illustration assumes inspection upon completion. In contrast, inspection may take place at some other stage—say, at the halfway point in the production cycle. In such a case, normal spoilage costs would be added to completed goods and to the units in process that are at least 50% completed.

Having early and frequent inspections in production processes reduces the amount of material and conversion costs wasted on units that are already spoiled. Thus, in the Exhibit 18-4 example, suppose inspection can occur when units are 80% complete as to conversion costs and 100% complete as to direct materials, and spoilage occurs before this point. Then the company would avoid incurring the final 20% of conversion costs on the spoiled units.

#### OBJECTIVE 4

Account for spoilage in process costing using the first-in, first-out method

### FIFO Method and Spoilage

Exhibit 18-5 presents step 4 using the FIFO method. The total costs columns in Panel A of Exhibit 18-5 summarize the costs to account for. Note how the FIFO method keeps the costs of the beginning work-in-process inventory separate and distinct from the costs of work done in the current period when assigning costs. All spoilage costs are assumed to be related to units completed during this period, using the unit costs of the current period.<sup>2</sup> With the exception of accounting for spoilage, the FIFO method is the same as presented in Chapter 17.

### Journal Entries

The information in Exhibits 18-4 and 18-5 supports the following journal entries:

	Weighted Average	FIFO
1. Finished Goods	152,075	151,600
Work in Process—Processing	152,075	151,600
To transfer good units completed in July.		
2. Loss from Abnormal Spoilage	5,925	6,000
Work in Process—Processing	5,925	6,000
To recognize abnormal spoilage detected in July.		

#### OBJECTIVE 5

Account for spoilage in process costing using the standard costs method

### Standard Costs and Spoilage

*This section assumes you have studied Chapters 7 and 8 and the standard costs method in Chapter 17 (pp. 625–629). Otherwise, omit this section.*

Standard costing methods can also be used to account for normal and abnormal spoilage. We illustrate how much simpler the calculations become by continuing our Anzio Company example.

<sup>2</sup>If the FIFO method were used in its purest form, normal spoilage costs would be split between the goods started and completed during the current period and those completed from beginning work in process—using the appropriate unit costs of the period in which the units were worked on. The simpler, modified FIFO method, as illustrated in Exhibit 18-5, in effect uses the unit costs of the current period for assigning normal spoilage costs to the goods completed from beginning work in process. This modified FIFO method assumes that all normal spoilage traceable to the beginning work in process was started and completed during the current period, an obvious contradiction to the pure FIFO method.



## EXHIBIT 18-5

Step 4: Summarize Total Costs to Account for, and Assign These Costs to Units Completed, Units Spoiled and Units in Ending Work in Process Using the FIFO Method, Processing Department of Anzio Company for July 19\_7

			Direct Materials		Conversion Costs		Total Prod. Costs		
			Equiv. Units (1)	Cost per Equiv. Unit (2)	Total Costs (3) = (1) × (2)	Equiv. Units (4)	Cost per Equiv. Unit (5)	Total Costs (6) = (4) × (5)	(7) = (3) + (6)
PANEL A:									
TOTAL COSTS TO ACCOUNT FOR									
Work in process, beginning (from Exhibit 18-3)			1,500	\$8.00	\$12,000	900	\$10.00	\$ 9,000	\$ 21,000
Work done in current period only (from Exhibit 18-3)			8,500	\$9.00	76,500	8,100	\$11.00	89,100	165,600
To account for			10,000		\$88,500	9,000		\$98,100	\$186,600
PANEL B:									
ASSIGNMENT OF COSTS									
Good units completed and transferred out (7,000 physical units)									
Work in process, beginning(1,500 physical units)			1,500	\$8.00	\$12,000	900	\$10.00	\$ 9,000	\$ 21,000
Work done in current period to complete beginning work in process			→ 0*	\$9.00	→ 0	→ 600†	\$11.00	→ 6,600	→ 6,600
Total from beginning inventory before normal spoilage			1,500		12,000	1,500		15,600	27,600
Started and completed before normal spoilage (5,500 units)			→ 5,500‡	\$9.00	→ 49,500	→ 5,500‡	\$11.00	→ 60,500	→ 110,000
Normal spoilage (700 units)			→ 700§	\$9.00	→ 6,300	→ 700§	\$11.00	→ 7,700	→ 14,000
(A)	Total costs of good units transferred out				67,800			83,800	151,600
(B)	Abnormal spoilage (300 units)		→ 300§	\$9.00	→ 2,700	→ 300§	\$11.00	→ 3,300	→ 6,000
(C)	Work in process, ending (2,000 units)		→ 2,000§	\$9.00	→ 18,000	→ 1,000§	\$11.00	→ 11,000	→ 29,000
(A) + (B) + (C) Accounted for			10,000		\$88,500	9,000		\$98,100	\$186,600

\*Beginning work in process is 100% complete as to direct materials so zero equivalent units of direct materials need to be added to complete beginning work in process.

†Beginning work in process is 60% complete, which equals 900 equivalent units of conversion costs. To complete the 1,500 physical units of beginning work in process, 600 (1,500 – 900) equivalent units of conversion costs need to be added.

‡7,000 total equivalent units completed and transferred out (Exhibit 18-2) minus 1,500 equivalent units completed and transferred out from beginning inventory equal to 5,500 equivalent units.

§From Exhibit 18-2.



Suppose the Anzio Company develops standard costs for the Processing Department. Assume the same standard costs apply to the beginning inventory and to work done in July 19\_7.

Standard Costs for Processing Department for July 19\_7

Direct materials	\$ 8.50 per unit
Conversion costs	10.50 per unit
Total production costs	<u>\$19.00 per unit</u>

Steps 1 and 2 for standard costing are the same as for the weighted-average and FIFO methods described in Exhibit 18-2. Step 3, the cost per equivalent unit is simply the standard cost: direct materials \$8.50, and conversion costs, \$10.50. Standard costing makes calculating equivalent unit costs unnecessary and so simplifies process costing. Exhibit 18-6 presents step 4. The costs to account for in Panel A of Exhibit 18-6 are at *standard* costs and hence differ from the costs to account for under the weighted-average and FIFO methods, which are at *actual* costs. Step 4 uses standard costs to assign costs to units completed, to normal and abnormal spoilage, and to ending work-in-process inventory. Variances can be measured and analyzed in the manner described in Chapters 7 and 8.

### Assumptions for Allocating Normal Spoilage

Spoilage might actually occur at various points or stages of the production cycle, but spoilage is typically not detected until one or more specific points of inspection. The cost of spoiled units is assumed to be all costs incurred by spoiled units prior to inspection. When spoiled goods have a disposal value, the net cost of spoilage is computed by deducting disposal value from the costs of the spoiled goods accumulated to the point of inspection. The unit costs of abnormal and normal spoilage are the same when the two are detected simultaneously. However, situations might arise when abnormal spoilage is detected at a different point than normal spoilage. In such cases, the unit cost of abnormal spoilage would differ from the unit cost of normal spoilage.

Costs of abnormal spoilage are separately accounted for as losses for the period. Recall, however, that normal spoilage costs are added to costs of good units. Accounting for normal spoilage, therefore, raises an additional issue: Should normal spoilage costs be allocated between completed units and ending work-in-process inventory? One approach is to presume that normal spoilage occurs at the inspection point in the production cycle and to allocate its cost over all units that have passed that point. In the Anzio Company example, spoilage is assumed to occur when finished units are inspected, so no cost of normal spoilage is allocated to ending work in process.

*Whether the cost of normal spoilage is allocated to the units in ending work-in-process inventory, in addition to completed units, depends strictly on whether they have passed the point of inspection.* For example, if the inspection point is presumed to be the halfway stage of the production cycle, work in process that is more than 50% completed would be allocated a full measure of normal spoilage costs, calculated on the basis of all costs incurred prior to the point of inspection. But work in process that is under 50% completed would not be allocated any normal spoilage costs. The appendix to this chapter contains additional discussion concerning various assumptions about spoilage.

## SPOILAGE, REWORK, AND SCRAP IN JOB-COSTING SYSTEMS

The concepts of normal and abnormal spoilage also apply to job-costing systems. Abnormal spoilage is usually regarded as controllable by the manager. It is separately identified with the goal of eliminating it altogether. Costs of abnormal spoilage are not considered as product manufacturing costs and are written off as costs of the period in which detection occurs. Normal or planned spoilage in job-costing systems, however, are considered part of normal manufacturing costs, although increasingly, managements are tolerating only small amounts of spoilage as normal. The costs are



## EXHIBIT 18-6

Step 4: Summarize Total Costs to Account for and Assign These Costs to Units Completed, Units Spoiled and Units in Ending Work in Process Using Standard Costs, Processing Department of Anzio Company for July 19\_7

	Direct Materials			Conversion Costs			Total Prod. Costs
	Equiv. Units (Exh. 8-2) (1)	Cost per Equiv. Unit (2)	Total Costs (3) = (1) × (2)	Equiv. Units (Exh. 18-2) (4)	Cost per Equiv. Unit (5)	Total Costs (6) = (4) × (5)	(7) = (3) + (6)

## PANEL A:

## TOTAL COSTS TO ACCOUNT FOR

Work in process, beginning	1,500	\$8.50	\$12,750	900	\$10.50	\$ 9,450	\$ 22,200
Work done in current period only	<u>8,500</u>	\$8.50	<u>72,250</u>	<u>8,100</u>	\$10.50	<u>85,050</u>	<u>157,300</u>
To account for	<u>10,000</u>	\$8.50	<u>\$85,000</u>	<u>9,000</u>	\$10.50	<u>\$94,500</u>	<u>\$179,500</u>

## PANEL B:

## ASSIGNMENT OF COSTS

	Good units completed and transferred out (7,000 units)							
	Costs before adding normal spoilage	→ 7,000	\$8.50	\$59,500	→ 7,000	\$10.50	\$73,500	\$133,000
	Normal spoilage	→ 700	\$8.50	<u>5,950</u>	→ 700	\$10.50	<u>7,350</u>	<u>13,300</u>
(A)	Total costs of good units transferred out			65,450			80,850	146,300
(B)	Abnormal spoilage	→ 300	\$8.50	2,550	→ 300	\$10.50	3,150	5,700
(C)	Work in process, ending	→ <u>2,000</u>	\$8.50	<u>17,000</u>	→ <u>1,000</u>	\$10.50	<u>10,500</u>	<u>27,500</u>
(A) + (B) + (C)	Accounted for	<u>10,000</u>		<u>\$85,000</u>	<u>9,000</u>		<u>\$94,500</u>	<u>\$179,500</u>



then assigned to individually distinct jobs, a step unnecessary in process costing since masses of similar units are manufactured. When assigning costs, job-costing systems generally distinguish normal spoilage attributable to a specific job from normal spoilage common to all jobs.

We also use the job-costing context to illustrate the accounting for rework and scrap. For rework, we again distinguish (1) abnormal rework, (2) normal rework attributable to a specific job, and (3) normal rework common to all jobs. Scrap accounting follows the accounting for a by-product described in Chapter 15. No distinctions are made between normal and abnormal scrap, but scrap attributable to a specific job is distinguished from scrap common to all jobs.

## JOB COSTING AND SPOILAGE

### OBJECTIVE 6

Account for spoilage in job costing

We illustrate the accounting for spoilage in job costing using the following example.

**EXAMPLE 3** In the Hull Machine Shop, 5 aircraft parts out of a job lot of 50 aircraft parts are spoiled. Costs assigned up to the point of inspection are \$100 per unit. Hull calculates these costs on the basis of its inventory costing assumptions—weighted average, FIFO, or standard costs. We do not, however, emphasize cost-flow assumptions in our presentation here or in subsequent sections. The current disposal price of the spoiled parts is estimated to be \$30 per part. When the spoilage is detected, the spoiled goods are inventoried at \$30 per unit.

**Normal Spoilage Attributable to a Specific Job** When normal spoilage occurs because of the specifications of a specific job, that job bears the cost of the spoilage reduced by the current disposal value of that spoilage. The journal entry to recognize the disposal value of the salvage (items in parentheses indicate subsidiary postings) is as follows:

Materials Control (spoiled goods at current disposal value): $5 \times \$30$	150	
Work-in-Process Control (specific job): $5 \times \$30$		150

The effect of this accounting is that the net cost of the normal spoilage, \$350 (\$500 – \$150) becomes a direct cost of the 45 (50 – 5) good units produced.

**Normal Spoilage Common to All Jobs** In some cases, spoilage may be considered a normal characteristic of a given production cycle. The spoilage inherent in the process only coincidentally occurs when a specific job is being worked on. The spoilage then is not attributable, and hence is not charged, to the specific job. Instead, it is costed as manufacturing overhead. The budgeted manufacturing overhead allocation rate includes a provision for normal spoilage cost. Therefore, normal spoilage cost is spread, through overhead allocation, over all jobs rather than loaded on particular jobs only.<sup>3</sup>

Materials Control (spoiled goods at current disposal value): $5 \times \$30$	150	
Manufacturing Department Overhead Control (normal spoilage): $5 \times \$70$	350	
Work-in-Process Control (specific job): $5 \times \$100$		500

**Abnormal Spoilage** If the spoilage is abnormal, the net loss is highlighted to management by charging the loss to an abnormal loss account:

Materials Control (spoiled goods at current disposal value): $5 \times \$30$	150	
Loss from Abnormal Spoilage: $5 \times \$70$	350	
Work-in-Process Control (specific job): $5 \times \$100$		500

<sup>3</sup>Note that costs *already assigned to products* are being charged back to Manufacturing Department Overhead Control, which generally accumulates only *costs incurred*, not both costs incurred and costs assigned.



## REWORKED UNITS

Reworked units are unacceptable units of production that are subsequently reworked into good units and sold.

Consider the Hull Machine Shop data (Example 3). Assume that the five spoiled parts used in our Hull Machine Shop illustration are reworked. The journal entry for the \$500 of total costs (details of costs assumed) assigned to the five spoiled units before considering rework costs are as follows:

Work-in-Process Control	500
Materials Control	200
Wages Payable	200
Manufacturing Overhead Allocated	100

Assume that rework costs equal \$190 (direct materials, \$40; direct labor, \$100; manufacturing overhead, \$50).

**Normal Rework Attributable to a Specific Job** If the rework is normal but occurs because of the requirements of a specific job, the rework costs are charged to that job. The journal entry is as follows:

Work-in-Process Control (specific job)	190
Materials Control	40
Wages Payable	100
Manufacturing Overhead Allocated	50

**Normal Rework Common to All Jobs** When rework is normal and not attributable to any specific job, the costs of rework are charged to manufacturing overhead and spread, through overhead allocation, over all jobs.

Manufacturing Department Overhead Control (rework)	190
Materials Control	40
Wages Payable	100
Manufacturing Overhead Allocated	50

**Abnormal Rework** If the rework is abnormal, it is highlighted to management by charging abnormal rework to a separate loss account.

Loss from Abnormal Rework	190
Materials Control	40
Wages Payable	100
Manufacturing Overhead Allocated	50

Accounting for rework in process costing only requires abnormal rework to be distinguished from normal rework. Abnormal rework is accounted for as in job costing. Since masses of similar units are manufactured, accounting for normal rework follows the accounting described for normal rework common to all jobs.

Costing rework highlights the resources wasted on activities that would not have to be undertaken if the product were made correctly. It prompts management to seek ways to reduce rework, for example, by designing new products or processes, training workers, or investing in new machines. Calculating rework costs helps management perform cost-benefit analyses for various alternatives. To emphasize the importance of eliminating rework and to simplify the accounting, some companies expense all rework, including the costs of normal rework, as an expense of the current period.

### OBJECTIVE 7

Account for reworked units

### OBJECTIVE 8

Account for scrap

## ACCOUNTING FOR SCRAP

Scrap was defined in Chapter 15 in conjunction with the discussion of byproducts. Scrap is a product that has minimal (frequently zero) sales value compared with the sales value of the main or joint product(s).



There are two major aspects of accounting for scrap:

1. Planning and control, including physical tracking.
2. Inventory costing, including when and how to affect operating income.

Initial entries to scrap records are most often in physical or nonfinancial terms such as in pounds or units. In various industries, items such as stamped-out metal

## SURVEYS OF COMPANY PRACTICE

### Rejection in the Electronics Industry

From country to country and from industry to industry, the rates of rejected and reworked units vary tremendously. The data in the following table focus on different segments of the U.S. electronics industry. The data reported are median numbers drawn from companies that are members of the American Electronics Association. The reject rate is the rejects as a percentage of items checked by quality control. The rework rate is reworked items as a percentage of rejects and returns. The scrap rate reports scrap as a percentage of all materials and products purchased. Also reported is the operating income to net sales figure for each segment of the electronics industry.

Segment of Electronics Industry	Reject Rate (% rejects)	Rework Rate (% rework)	Scrap Rate (% scrap)	Operating Income to Net Sales
1. Computers and office equipment (includes mainframes, minicomputers, microcomputers, printers, and point-of-sale equipment)	2.55%	6.50%	0.62%	5.33%
2. Electronic components and accessories (includes printed circuit boards and semiconductors)	1.55	2.00	1.63	4.53
3. Specialized production equipment (includes semiconductor production equipment)	7.50	10.00	0.43	5.67
4. Telecommunications equipment (includes telephone, radio, and TV apparatus)	1.00	2.00	1.29	4.73
5. Aerospace, nautical, and military equipment (includes aircraft manufacture and guided missiles)	—	1.50	0.52	6.52
6. Laboratory and measurement devices (includes optical instruments and process control equipment)	4.90	3.30	0.66	3.89
7. Prepackaged software	1.00	0.80	0.06	4.02
8. Computer-related services (includes data processing and computer systems design)	5.00	N/A	N/A	7.78

The reject rate for specialized production equipment is five times as great as that for electronic components and semiconductors. Electronic components and semiconductors show a low percentage of rework (in part because rework is not always possible when defects arise). Scrap rates are reasonably small across all industry segments. The operating income to net sales ratio ranges from 3.89% for laboratory and measurement devices to 6.52% for aerospace, nautical, and military equipment. Given these profitability percentages, reductions in reject and rework rates can markedly increase the profitability of many companies in the electronics industry.

Source: Adapted from American Electronics Association, *Operating Ratios Survey*. Full citation is in Appendix A.



sheets are quantified by weighing, counting, or some other expedient means. Scrap records not only help measure efficiency, but also often focus on a tempting source for theft. Scrap reports are prepared as source documents for periodic summaries of the amount of actual scrap compared with budgeted norms or standards. Scrap is either sold or disposed of quickly, or stored in some routine way for later sale, disposal, or reuse.

The tracking of scrap often extends into the financial records. For example, in one survey, 60% of the companies maintained a distinct cost for scrap somewhere in their cost accounting system.<sup>4</sup> The issues here are similar to those discussed in Chapter 15 regarding the accounting for byproducts:

1. When should any value of scrap be recognized in the accounting records: at the time of production of scrap or at the time of sale of scrap?
2. How should revenue from scrap be accounted for?

To illustrate, we extend our Hull Machine Shop example by assuming that the manufacture of aircraft parts generates scrap. We further assume that the normal scrap from a job lot has a total sales value of \$45.

### Recognizing Scrap at the Time of Sale of Scrap

**Scrap Attributable to a Specific Job** Job-costing systems sometimes trace the sales of scrap to the jobs that yielded the scrap. This method is used only when the tracing can be done in an economically feasible way. For example, the Hull Machine Shop and particular customers, such as the U.S. Department of Defense, may reach an agreement that provides for charging specific jobs with all rework or spoilage costs and for crediting these jobs with all scrap sales that arise from them. The journal entry is

Scrap returned to storeroom:	No journal entry. [Memo of quantity received and related job is entered in the inventory record.]	
Sale of scrap:	Cash or Accounts Receivable	45
	Work in Process Control	45
	Posting made to specific job record.	

Unlike spoilage and rework, there is no cost attached to the scrap, and hence no normal or abnormal scrap. All scrap sales, whatever the amount, are credited to the specific job. Scrap sales reduce the materials' costs of the job.

**Scrap Common to All Jobs** The journal entry in this case is

Scrap returned to storeroom:	No journal entry. [Memo of quantity received and related job is entered in the inventory record.]	
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When scrap is sold, the simplest accounting is to regard scrap sales as a separate line item of other revenues. The journal entry is

Sale of scrap:	Cash or Accounts Receivable	45
	Sales of Scrap	45

However, many companies account for the sales as offsets against manufacturing overhead. The journal entry is

Sale of scrap:	Cash or Accounts Receivable	45
	Manufacturing Department Overhead Control	45
	Posting made to subsidiary record—"Sales of Scrap" column on department cost record.	

<sup>4</sup>Price Waterhouse, *Survey of the Cost Management Practices of Selected Midwest Manufacturers* (Cleveland: Price Waterhouse, 1989), p. 10.



## Managing Waste and Environmental Costs at the DuPont Corporation

The DuPont Corporation manufactures a wide range of chemicals and chemical products. DuPont classifies the spoilage and scrap it generates as waste. Besides the cost of lost materials, chemical waste is a particular problem because of its impact on the environment.

Strict environmental laws require that chemical waste be disposed of in an environmentally safe way, further adding to the cost of generating waste.

DuPont calculates the full cost of waste to include (1) the costs of materials lost in the chemical process minus their scrap value; (2) the full costs of semifinished and finished products spoiled; (3) the full cost of disposing of or treating the waste, such as site charges for hazardous waste, or costs of scrubbers and biotreatment plants to treat the waste; and (4) the cost of any solvents used to clean plant and equipment as a result of generating waste.

DuPont believes that calculating the total costs of waste helps businesses understand the operational and environmental costs of waste. This motivates individual plants to take actions such as redesigning products, reconfiguring processes, or investing in capital equipment to reduce these costs.

DuPont's acrylonitrile process at Beaumont, Texas, is a good example of how DuPont reduces waste costs. This plant generated more than 110 million pounds of ammonium sulfate waste, which was disposed of by injecting the waste in deep wells. While DuPont considered the disposal of the waste environmentally safe, the U.S. Environmental Protection Agency included ammonium sulfate in its figures of the toxic releases generated by DuPont. To improve its environmental performance and to reduce its waste costs, a team of DuPont engineers began modifying the reactor operating conditions for producing acrylonitrile. By changing the process, the team improved the yields of acrylonitrile and reduced ammonium sulfate waste by 70 million pounds. By altering its acrylonitrile process, DuPont saved a million dollars a year in lower waste and waste disposal costs.

Source: Adapted from 1990 Environmental Respect Awards, DuPont Corporation and based on discussions with Dale Martin, Manager, Environmental Effectiveness.



This method does not link scrap with any particular physical product. Instead, all products bear regular production costs without any credit for scrap sales except in an indirect manner: The sales of scrap are considered when setting budgeted manufacturing overhead rates. Thus, the budgeted overhead rate is lower than it would be if no credit for scrap sales were allowed in the overhead budget. This accounting for scrap is used in both process-costing and job-costing systems.

### Recognizing Scrap at the Time of Production of Scrap

Our preceding illustrations assume that scrap returned to the storeroom is sold or disposed of quickly and hence not assigned an inventory cost figure. Scrap, however, sometimes has a significant market value, and the time between storing it and selling or reusing it can be quite long. Under these conditions, the company is justified in inventorying scrap at a conservative estimate of net realizable value so that production costs and related scrap recovery may be recognized in the same accounting period. Some companies tend to delay sales of scrap until the market price is most attractive. Volatile price fluctuations are typical for scrap metal. If scrap inventory becomes significant, it should be inventoried at some "reasonable value"—a difficult task in the face of volatile market prices.



**Scrap Attributable to a Specific Job** The journal entry in the Hull Machine Shop example is

Scrap returned to storeroom:	Materials Control	45	
	Work in Process Control		45

**Scrap Common to All Jobs** The journal entry in this case is

Scrap returned to storeroom:	Materials Control	45	
	Manufacturing Department Overhead Control		45

Observe that Materials Control account is debited in place of Cash or Accounts Receivable.

When this scrap is sold, the journal entry is

Sale of scrap:	Cash or Accounts Receivable	45	
	Materials Control		45

Scrap is sometimes reused as direct materials rather than sold as scrap. Then it should be debited to Materials Control as a class of direct materials and carried at its estimated net realizable value. For example, the entries when the scrap generated is common to all jobs are

Scrap returned to storeroom:	Materials Control	45	
	Manufacturing Department Overhead Control		45
Reuse of scrap:	Work in Process Control	45	
	Materials Control		45

The accounting for scrap under process costing follows the accounting for jobs when scrap is common to all jobs since process costing is used to cost the mass manufacture of similar units. The high cost of scrap focuses management's attention on ways to reduce scrap and to use it more profitably. For example, General Motors has redesigned its plastic injection molding processes to reduce the scrap plastic that must be broken away from its molded products. General Motors also regrinds and reuses the plastic scrap as direct materials, saving substantial input costs.

## PROBLEM FOR SELF-STUDY

### PROBLEM

*Burlington Textiles has some spoiled goods that had an assigned cost of \$4,000 and zero net disposal value.*

### REQUIRED

Prepare a journal entry for each of the following conditions under both (a) process costing (Department A) and (b) job costing:

1. Abnormal spoilage of \$4,000.
2. Normal spoilage of \$4,000 related to general plant operations.
3. Normal spoilage of \$4,000 related to specifications of a particular job.

### SOLUTION

(a) Process Costing			(b) Job Costing		
1. Loss from Abnormal Spoilage	4,000		Loss from Abnormal Spoilage	4,000	
Work in Process—Dept. A		4,000	Work in Process Control (job)		4,000
2. No entry until units are transferred. Then the normal spoilage costs are transferred along with the other costs:			Manufacturing Dept. Overhead Control		
Work in Process—Dept. B	4,000		Work in Process Control (job)	4,000	
Work in Process—Dept. A		4,000			4,000
3. Not applicable			No entry. Spoilage cost remains in Work in Process Control (job)		



## SUMMARY

The following points are linked to the chapter's learning objectives.

1. Spoilage is unacceptable units of production that are discarded or are sold for net disposal proceeds. Reworked units are unacceptable units that are subsequently reworked and sold as acceptable finished goods. Scrap is a product that has minimal sales value compared with the sales value of the main or joint product(s).
2. Normal spoilage is spoilage that arises under efficient operating conditions. Abnormal spoilage is spoilage that is not expected to arise under efficient operating conditions. Many accounting systems explicitly recognize both forms of spoilage when computing output units. Normal spoilage is typically included in the cost of good output units, while abnormal spoilage is recorded as a loss for the period.
3. Under the weighted-average method of process costing, costs in beginning inventory are pooled with costs in the current period when determining the costs of good units (which includes a normal spoilage amount) and the costs of abnormal spoilage.
4. Under the FIFO method of process costing, costs in beginning inventory are kept separate from the costs in the current period when determining the cost of good units (which includes a normal spoilage amount). The cost of abnormal spoilage is kept separate from the cost of good units.
5. Under the standard costing method of process costing, standard costs are used to determine the cost of good units (which includes a normal spoilage amount) and the costs of abnormal spoilage.
6. With a job-costing system, companies can decide to assign spoilage to specific jobs. Alternatively, they can allocate spoilage to all jobs as part of manufacturing overhead. Loss from abnormal spoilage is recorded as a period cost.
7. Reworked units should be indistinguishable from nonreworked good units when completed, and hence the two are assigned the same costs. Normal rework can be assigned to a specific job, or if common, to all jobs as part of manufacturing overhead. Abnormal rework is written off as a period cost.
8. Accounting for scrap is similar to the accounting for byproducts discussed in Chapter 15. Companies differ as to both when and how scrap is recognized in the accounting records.

## APPENDIX: INSPECTION AND SPOILAGE AT INTERMEDIATE STAGES OF COMPLETION IN PROCESS COSTING

Consider how the timing of inspection at various stages of completion affects the amount of normal and abnormal spoilage. Assume that normal spoilage is 10% of the good units passing inspection in the Forging Department of the Dana Corporation, a manufacturer of automobile parts. Direct materials are added at the start of production in the Forging Department. Conversion costs are allocated evenly during the process.

Suppose inspection had occurred at the 20%, 50%, or 100% completion stage. A total of 8,000 units are spoiled in all cases. Note how the number of units of normal spoilage and abnormal spoilage change. Normal spoilage is computed on the number of *good units* that pass the inspection point *in the current period*. The following data are for October.



Flow of Production	Physical Units: Inspection at Stage of Completion		
	at 20%	at 50%	at 100%
Work in process, beginning (25%)*	11,000	11,000	11,000
Started during October	74,000	74,000	74,000
To account for	<u>85,000</u>	<u>85,000</u>	<u>85,000</u>
Good units completed and transferred out (85,000 – 8,000 spoiled – 16,000 ending)	61,000	61,000	61,000
Normal spoilage	6,600 <sup>†</sup>	7,700 <sup>‡</sup>	6,100 <sup>§</sup>
Abnormal spoilage (8,000 – normal spoilage)	1,400	300	1,900
Work in process, ending (75%)*	<u>16,000</u>	<u>16,000</u>	<u>16,000</u>
Accounted for	<u>85,000</u>	<u>85,000</u>	<u>85,000</u>

\*Degree of completion for conversion costs of this department at the dates of the work-in-process inventories.

<sup>†</sup>10% × (74,000 units started – 8,000 units spoiled), since only the units started passed the 20% completion inspection point in the current period. Beginning work in process is excluded from this calculation since it is 25% complete.

<sup>‡</sup>10% × (85,000 units – 8,000 units spoiled), since *all* units passed the 50% completion inspection point in the current period.

<sup>§</sup>10% × 61,000, since 61,000 units were fully completed and inspected in the current period.

Exhibit 18-7 shows the computation of equivalent units assuming inspection at the 50% completion stage. The calculations depend on how much direct materials and conversion costs were incurred to get the units to the point of inspection. In Exhibit 18-7 the spoiled units have a full measure of direct materials and a 50% measure of conversion costs. The computations of equivalent unit costs and the assignments of total costs to units completed and in ending work in process would be similar to those in previous illustrations. Since ending work in process has passed the inspection point in this example, these units would bear normal spoilage costs, just like the units that have been completed and transferred out.

#### EXHIBIT 18-7

Steps 1 and 2: Computing Equivalent Units with Spoilage, Forging Department of the Dana Corporation for October 19\_7

Flow of Production	(Step 1) Physical Units	(Step 2) Equivalent Units	
		Direct Materials	Conversion Costs
Good units completed and transferred out during current period	61,000	61,000	61,000
Normal spoilage	7,700	7,700	3,850
Abnormal spoilage	300	300	150
Work in process, ending*	<u>16,000</u>	<u>16,000</u>	<u>12,000</u>
Total	85,000	85,000	77,000
Deduct work in process, beginning <sup>†</sup>	<u>11,000</u>	<u>11,000</u>	<u>2,250</u>
Started during current period	<u>74,000</u>		
Work done in current period only		<u>74,000</u>	<u>74,750</u>

\*Degree of completion: direct materials, 100%; conversion costs, 75%.

<sup>†</sup>Degree of completion: direct materials, 100%; conversion costs, 25%.



## TERMS TO LEARN

This chapter and the Glossary at the end of this book contain definitions of the following important terms:

abnormal spoilage (p. 653)  
normal spoilage (653)

reworked units (652)  
spoilage (652)

## ASSIGNMENT MATERIAL

### QUESTIONS

- 18-1 Why is there an unmistakable trend in manufacturing to improve quality?
- 18-2 Distinguish among spoilage, reworked units, and scrap.
- 18-3 "Normal spoilage is planned spoilage." Discuss.
- 18-4 "Costs of abnormal spoilage are lost costs." Explain.
- 18-5 "What has been regarded as normal spoilage in the past is not necessarily acceptable as normal in the present or future." Explain.
- 18-6 "Abnormal units are inferred rather than identified." Explain.
- 18-7 "In accounting for spoiled goods, we are dealing with cost assignment rather than cost incurrence." Explain.
- 18-8 "Total input includes abnormal as well as normal spoilage and is therefore irrational as a basis for computing normal spoilage." Do you agree? Why?
- 18-9 "The point of inspection is the key to the allocation of spoilage costs." Do you agree? Explain.
- 18-10 "The unit cost of normal spoilage is the same as the unit cost of abnormal spoilage." Do you agree? Explain.
- 18-11 "In job-order costing, the costs of specific normal spoilage are charged to specific jobs." Do you agree? Explain.
- 18-12 "The costs of reworking defective units are always charged to the specific jobs where the defects were originally discovered." Do you agree? Explain.
- 18-13 "Abnormal rework costs should be charged to a loss account, not to manufacturing overhead." Do you agree? Explain.
- 18-14 When is a company justified in inventorying scrap?
- 18-15 How do company managements use information about scrap?

### EXERCISES

- H** 18-16 **Normal and abnormal spoilage in units.** The following data, in physical units, describe a grinding process for January:

Work process, beginning	19,000
Started during current period	150,000
To account for	169,000
Spoiled units	12,000
Good units completed and transferred out	132,000
Work in process, ending	25,000
Accounted for	169,000

Inspection occurs at the 100% conversion stage. Normal spoilage is 5% of the good units passing inspection.

#### REQUIRED

- 1. Compute the normal and abnormal spoilage in units.
- 2. Assume that the equivalent unit cost of a spoiled unit is \$10. Compute the amount of potential savings if all spoilage were eliminated, assuming that all other costs would be unaffected. Comment on your answer.



**18-17 Equivalent units, equivalent unit costs, spoilage.** (CMA adapted) Consider the following data for November 19\_7 from the Gray Manufacturing Company, which makes silk pennants and operates a process-costing system. All direct materials are added at the beginning of the process and conversion costs are added evenly during the process. Spoilage is detected upon inspection at the completion of the process. Spoiled units are disposed of at zero net disposal price.

	Physical Units (Pennants)	Direct Materials	Conversion Costs
Work in process, November 1*	1,000	\$ 1,300	\$ 1,250
Started in November 19_7	?		
Good units completed and transferred out during November 19_7	9,000		
Normal spoilage	100		
Abnormal spoilage	50		
Work in process, November 30†	2,000		
Costs added during November 19_7		\$12,180	\$27,750

\*Degree of completion: direct materials, 100%; conversion costs, 50%.

†Degree of completion: direct materials, 100%; conversion costs, 30%.

### REQUIRED

1. Compute the equivalent units of work done in the current period for direct materials and conversion costs. Show physical units in the first column.
2. Calculate the cost per equivalent unit of beginning work in process and of work done in the current period for direct materials and conversion costs.

**18-18 Weighted-average method, spoilage.** Anderson Plastics makes plastic rear lamps for cars using an injection molding process. Spoiled units are detected upon inspection at the end of the process and are disposed of at zero net disposal price. Assume normal spoilage is 15% of the good output produced. Anderson Plastics uses the weighted-average method of process costing. The following information about actual costs for April 19\_8 is available.

	Direct Materials		Conversion Costs	
	Equivalent Units	Total Costs	Equivalent Units	Total Costs
Work in process, April 1 (15,000 units)	15,000	\$120,000	14,000	\$140,000
Work done during April 19_8	25,000	210,000	28,000	301,000
To account for	40,000	\$330,000	42,000	\$441,000
Good units completed and transferred out during April 19_8	20,000	?	20,000	?
Normal and abnormal spoilage	4,000		4,000	
Work in process, April 30 (20,000 units)	16,000	?	18,000	?

### REQUIRED

1. Calculate the cost per equivalent unit of beginning work in process and of work done in the current period for direct materials and conversion costs.
2. Summarize total costs to account for, and assign these costs to units completed (and transferred out), normal spoilage, abnormal spoilage, and ending work in process using the weighted-average method.
3. What is the cost of a good unit completed and transferred out under the weighted-average method?

**18-19 FIFO method.** Refer to the information in Exercise 18-18.



**REQUIRED**

Do Exercise 18-18 using the FIFO method.

- 18-20 Standard costing method.** Refer to the information in Exercise 18-18. Suppose Anderson determines standard costs of \$8.20 per (equivalent) unit for direct materials and \$10.20 per (equivalent) unit for conversion costs for both beginning work in process and work done in the current period.

**REQUIRED**

Do Exercise 18-18 using the standard costing method.



- 18-21 Weighted-average method, spoilage.** Superchip specializes in the manufacture of microchips for aircraft. Direct materials are added at the start of the production process. Conversion costs are added evenly during the process. Some units of this product are spoiled as a result of defects not detectable before inspection of finished goods. Normally, the spoiled units are 15% of the good units transferred out. Spoiled units are disposed of at zero net disposal price.

Superchip uses the weighted-average method of process costing. Summary data for September 19\_7 are

	Physical Units (Microchips)	Direct Materials	Conversion Costs
Work in process, September 1*	400	\$ 64,000	\$ 10,200
Started in September 19_7	1,700		
Good units completed and transferred out during September 19_7	1,400		
Work in process, September 30†	300		
Costs added during September 19_7		\$378,000	\$153,600

\*Degree of completion: direct materials, 100%; conversion costs, 30%.

†Degree of completion: direct materials, 100%; conversion costs, 40%.

**REQUIRED**

- For each cost element, compute the equivalent units of work done in September 19\_7. Show physical units in the first column.
- For each cost element, calculate the cost per equivalent unit of beginning work in process and of work done in September 19\_7.
- Summarize the total costs to account for, and assign these costs to units completed (and transferred out), normal spoilage, abnormal spoilage, and ending work in process using the weighted-average method.



- 18-22 FIFO method, spoilage.** Refer to the information in Exercise 18-21.

**REQUIRED**

Do Exercise 18-21 using the FIFO method of process costing.

- 18-23 Standard costing method, spoilage.** Refer to the information in Exercise 18-21. Suppose Superchip determines standard costs of \$205 per (equivalent) unit for direct materials and \$80 per (equivalent) unit for conversion costs for both beginning work in process and work done in the current period.

**REQUIRED**

Do Exercise 18-21 using standard costs.

- 18-24 Spoilage and job costing.** (L. Bamber) Bamber Kitchens produces a variety of items in accordance with special job orders from hospitals, plant cafeterias, and university dormitories. An order for 2,500 cases of mixed vegetables costs \$6 per case: direct materials, \$3; direct manufacturing labor, \$2; and manufacturing overhead allocated, \$1. The manufacturing overhead rate includes a provision for normal spoilage. Consider each requirement independently. Omit explanations of journal entries.



### REQUIRED

1. Assume that a laborer dropped 200 cases. Suppose that part of the 200 cases could be sold to a nearby prison for \$200 cash. Prepare a journal entry to record this event. Calculate and explain briefly the unit cost of the remaining 2,300 cases.
2. Refer to the original data. Tasters at the company reject 200 of the 2,500 cases. The 200 cases are disposed of for \$400. Assume that this rejection rate is considered normal. Prepare a journal entry to record this event, and calculate the unit cost if
  - a. The rejection is attributable to exacting specifications of this particular job.
  - b. The rejection is characteristic of the production process and is not attributable to this specific job.Are unit costs the same in requirements 2a and 2b? Explain your reasoning briefly.
3. Refer to the original data. Tasters rejected 200 cases that had insufficient salt. The product can be placed in a vat, salt added, and reprocessed into jars. This operation, which is considered normal, will cost \$200. Prepare a journal entry to record this event, and calculate the unit cost of all the cases if
  - a. This additional cost was incurred because of the exacting specifications of this particular job.
  - b. This additional cost occurs regularly because of difficulty in seasoning.Are unit costs the same in requirements 3a and 3b? Explain your reasoning briefly.

**18-25 Reworked units, costs of rework.** White Goods assembles washing machines at its Auburn plant. In February 19\_8, 60 tumbler units that cost \$44 each from a new supplier were defective and had to be disposed of at zero disposal price. White Goods was able to rework all 60 washing machines by substituting new tumbler units purchased from one of its existing suppliers. Each replacement tumbler cost \$50.

### REQUIRED

1. What alternative approaches are there to account for the materials costs of reworked units?
2. Should White Goods use the \$44 or \$50 amount as the costs of materials reworked? Explain.
3. What other costs might White Goods include in its analysis of the total costs of rework due to the tumbler units purchased from the (now) bankrupt supplier?

**18-26 Scrap, job-order costing.** The Mendoza Company has an extensive job-costing facility that uses a variety of metals. Consider each requirement independently. Omit explanations of journal entries.

### REQUIRED

1. Job 372 uses a particular metal alloy that is not used for any other job. Assume that scrap is accounted for at the time of sale of scrap. The scrap is sold for \$490. Prepare the journal entry.
2. The scrap from Job 372 consists of a metal used by many other jobs. No record is maintained of the scrap generated by individual jobs. Assume that scrap is accounted for at the time of its sale. Scrap totaling \$4,000 is sold. Prepare two journal entries that could be used to account for the sale of scrap.
3. Suppose the scrap generated in requirement 2 is returned to the store-room for future use and a journal entry is made to record the scrap. A month later, the scrap is reused as direct material on a subsequent job. Prepare the journal entries to record these transactions.



- 18-27 Physical units, inspection at various stages of completion.** (Chapter Appendix) Normal spoilage is 6% of the good units passing inspection in a forging process. In March, a total of 10,000 units were spoiled. Other data include units started during March, 120,000; work in process, beginning, 14,000 units (20% completed for conversion costs); work in process, ending, 11,000 units (70% completed for conversion costs).

**REQUIRED**

In columnar form, compute\* the normal and abnormal spoilage in units, assuming inspection at 15%, 40%, and 100% stages of completion.

**PROBLEMS**

- 18-28 Weighted-average method, spoilage.** Spicer uses the weighted-average method of process costing. Consider the following data for the Cooking Department of Spicer, Inc., for the month of January

	Physical Units	Direct Materials	Conversion Costs
Work in process, January 1*	11,000	\$ 220,000	\$ 30,000
Started in January	74,000		
Good units completed and transferred out during January	61,000		
Spoiled units	8,000		
Work in process, January 31†	16,000		
Costs added during January		\$1,480,000	\$942,000

\*Degree of completion: direct materials, 100%; conversion costs, 25%.

†Degree of completion: direct materials, 100%; conversion costs, 75%.

Inspection occurs when production is 100% completed. Normal spoilage is 11% of good units completed and transferred out during the current period. Spoiled units are disposed of at zero net disposal price.

**REQUIRED**

1. Summarize total costs to account for, and assign these costs to units completed (and transferred out), normal spoilage, abnormal spoilage, and ending work in process using the weighted-average method.
2. What is the cost of a good unit completed and transferred out under the weighted-average method?

- 18-29 FIFO method, spoilage.** Refer to the information in Problem 18-28.

**REQUIRED**

Do Problem 18-28 using the FIFO method of process costing. If you did Problem 18-28, comment on the cost differences under the weighted-average and FIFO methods.

- 18-30 Standard costing method, spoilage.** Refer to the information in Problem 18-28. Suppose Superchip determines standard costs of \$20 per (equivalent) unit for direct materials and \$11 per (equivalent) unit for conversion costs for both beginning work in process and work done in the current period.

**REQUIRED**

Do Problem 18-28 using the standard costing method of process costing.

- 18-31 Weighted-average method, spoilage.** The Alston Company operates under a weighted-average method of process costing. It has two departments, Cleaning and Milling. For both departments, conversion costs are added uniformly throughout the processes. However, direct materials are added at the beginning of the process in the Cleaning Department, and additional direct materials are added at the end of the milling process. The costs and unit production statistics for May follow. All unfinished work at the end of May is 25% completed as to conversion costs. The beginning in-



ventory (May 1) was 80% completed as to conversion costs as of May 1. All completed work is transferred to the next department.

	Cleaning	Milling
<b>Beginning Inventories</b>		
Cleaning: \$1,000 direct materials, \$800 conversion costs	\$1,800	
Milling: \$6,450 previous department cost (transferred-in cost) and \$2,450 conversion costs		\$8,900
<b>Costs Added during Current Period</b>		
Direct materials	\$9,000	\$ 640
Conversion costs	\$8,000	\$4,950
<b>Physical Units</b>		
Units in beginning inventory	1,000	3,000
Units started this month	9,000	7,400
Good units completed and transferred out	7,400	6,000
Normal spoilage	740*	300†
Abnormal spoilage	260	100

\*Normal spoilage in the Cleaning Department is 10% of good units completed and transferred out.

†Normal spoilage in the Milling Department is 5% of good units completed and transferred out.

#### ADDITIONAL INFORMATION

1. Spoilage is assumed to occur at the end of each of the two processes when the units are inspected. Spoiled units are disposed of at zero net disposal price.
2. Assume that there is no shrinkage, evaporation, or abnormal spoilage other than that indicated in the information given.
3. Carry unit cost calculations to three decimal places where necessary. Calculate final totals to the nearest dollar.

#### REQUIRED

Using the weighted-average method, summarize total costs to account for, and assign these costs to units completed (and transferred out), normal spoilage, abnormal spoilage, and ending work in process for the Cleaning Department. (Problem 18-33 explores additional facets of this problem.)

**18-32 FIFO method, spoilage.** Refer to the information in Problem 18-31.

#### REQUIRED

Do Problem 18-31 using the FIFO method of process costing. (Problem 18-34 explores additional facets of this problem.)

**18-33 Weighted-average method, Milling Department (continuation of 18-31).** Refer to the information in Problem 18-31.

#### REQUIRED

Use the weighted-average method to summarize total costs to account for, and assign these costs to units completed (and transferred out), normal spoilage, abnormal spoilage, and ending work in process for the Milling Department.

**18-34 FIFO method, Milling Department (continuation of 18-32).** Refer to the information in Problem 18-31.

#### REQUIRED

Use the FIFO method to summarize total costs to account for, and assign these costs to units completed (and transferred out), normal spoilage, abnormal spoilage, and ending work in process for the Milling Department.

**18-35 Job-cost spoilage and scrap.** (F. Mayne) Santa Cruz Metal Fabricators, Inc., has a large job, No. 2734, that calls for producing various ore bins, chutes, and metal boxes for enlarging a copper concentrator. The following charges were made to the job in November 19\_8:



Direct materials	\$26,951
Direct manufacturing labor	15,076
Manufacturing overhead	7,538

The contract with the customer called for the total price to be based on a cost-plus approach. The contract defined cost to include direct materials, direct manufacturing labor costs, and manufacturing overhead to be allocated at 50% of direct manufacturing labor costs. The contract also provided that the total costs of all work spoiled were to be removed from the billable cost of the job and that the benefits from scrap sales were to reduce the billable cost of the job.

#### REQUIRED

- In accordance with the stated terms of the contract, prepare journal entries for the following two items:
  - A cutting error was made in production. The up-to-date job-cost record for the batch of work involved showed materials of \$650, direct manufacturing labor of \$500, and allocated overhead of \$250. Because fairly large pieces of metal were recoverable, the company believed that the scrap value was \$600 and that the materials recovered could be used on other jobs. The spoiled work was sent to the warehouse.
  - Small pieces of metal cuttings and scrap in November 19\_8 amounted to \$1,250, which was the price quoted by a scrap dealer. No journal entries have been made with regard to the scrap until the price was quoted by the scrap dealer. The scrap dealer's offer was immediately accepted.
- Consider normal and abnormal spoilage. Suppose the contract described above had contained the clause "a normal spoilage allowance of 1% of the job costs will be included in the billable costs of the job."
  - Is this clause specific enough to define exactly how much spoilage is normal and how much is abnormal? Explain.
  - Repeat requirement 1a with this "normal spoilage of 1%" clause in mind. You should be able to provide two slightly different journal entries.

**18-36 Job costing, rework.** The Bristol Corporation manufactures two brands of motors, SM-5 and RW-8. The costs of manufacturing each SM-5 motor, excluding rework costs, are direct materials, \$300; direct manufacturing labor, \$60; and manufacturing overhead, \$190. Defective units are sent to a separate rework area. Rework costs per SM-5 motor are direct materials, \$60; direct manufacturing labor, \$45; and manufacturing overhead, \$75.

In February 19\_8, Bristol manufactured 1,000 SM-5 and 500 RW-8 motors, and 80 of the SM-5 motors required rework. Bristol classifies 50 of these motors as normal rework for SM-5 and RW-8, and not specifically attributable to SM-5. None of the RW-8 motors required rework. Bristol allocates manufacturing overhead on the basis of machine-hours required to manufacture SM-5 and RW-8. Each SM-5 and RW-8 motor requires the same number of machine-hours.

#### REQUIRED

- Prepare journal entries to record the accounting for rework.
- What were the total rework costs charged to SM-5 motors in February 19\_8?

**18-37 Job costing, scrap.** The Wong Corporation makes two different types of hubcaps for cars—models HM3 and JB4. Circular pieces of metal are stamped out of steel sheets (leaving the edges as scrap), formed, and finished. The stamping operation is identical for both types of hubcaps. During March, Wong manufactured 20,000 units of HM3 and 10,000 units of JB4. In March, manufacturing costs per unit of HM3 and JB4 before accounting for the scrap are as follows:



	HM3	JB4
Direct materials	\$10	\$15
Direct manufacturing labor	3	4
Materials-related manufacturing overhead (materials handling, storage, etc.)	2	3
Other manufacturing overhead	6	8
Unit manufacturing costs	<u>\$21</u>	<u>\$30</u>

Materials-related manufacturing costs are allocated to products at 20% of direct materials costs. Other manufacturing overhead is allocated to products at 200% of direct manufacturing labor costs. Since the same metal sheets are used to make both types of hubcaps, Wong maintains no records of the scrap generated by the individual products. Scrap generated during manufacturing is accounted for at the time it is returned to the storeroom as an offset to materials-related manufacturing overhead. The value of scrap generated during March and returned to the storeroom was \$7,000.

#### REQUIRED

1. Prepare a journal entry to summarize the accounting for scrap during March.
2. Suppose the scrap generated in March was sold in April for \$7,000. Prepare a journal entry to account for this transaction.
3. What is the manufacturing cost per unit for HM3 and JB4 in March after accounting for scrap? Explain.

**18-38 Weighted-average, inspection at 80% completion.** (A. Atkinson) (Chapter Appendix) Ottawa Manufacturing produces a plastic toy in a two-stage manufacturing operation. The company uses a weighted-average process-costing system. During the month of June, the following data were recorded for the Finishing Department:

Units of beginning inventory	10,000
Percentage of beginning units completed	25%
Cost of direct materials in beginning work in process	\$ 0
Units started	70,000
Units completed	50,000
Units in ending inventory	20,000
Percentage of ending units completed	95%
Spoiled units	10,000
Costs added during current period	
Direct materials	\$655,200
Direct manufacturing labor	\$635,600
Manufacturing overhead	\$616,000
Work in process, beginning	
Conversion costs	\$ 42,000
Transferred-in costs	\$ 82,900
Cost of units transferred in during current period	\$647,500

Conversion costs are incurred evenly throughout the process. Direct materials costs are incurred when production is 90% complete. Inspection occurs when production is 80% complete. Normal spoilage is 10% of all good units that pass inspection. Spoiled units are disposed of at zero net disposal price.

#### REQUIRED

For the month of June, summarize total costs to account for, and assign these costs to units completed (and transferred out), normal spoilage, abnormal spoilage, and ending work in process.



**18-39 Process versus job costing, spoilage, ethics.** Chip Contractors assembles high-performance microchips for two customers—Prestige Jets and the U.S. Air Force. The emphasis the Air Force places on quality helps Chip impress potential customers about the quality of its chips. Kelly Gillis, the president of Chip Contractors, decides to use a double-testing procedure for chips sold to the U.S. Air Force. Tom Sanders, the controller of Chip Contractors, asks Gillis how she wants the cost of this extra testing shown in the accounting records. Each month Sanders compiles a production-cost report that he sends to Prestige Jets. Prestige pays Chip the actual production cost per chip purchased plus a 20% profit margin. The U.S. Air Force contract is for a fixed price per good chip.

Gillis tells Sanders to follow the normal practice of computing the cost of good chips at the total plant level rather than for each customer. Sanders strongly objects to this approach. He believes it will result in Chip Contractors overcharging Prestige Jets. Gillis believes that they should wait until Prestige Jets complains before they make any adjustments. She is adamant that no internal spoilage data should be shown to Prestige Jets.

Sanders decides to privately track cost and spoilage data in May 19\_7 for Chip's two product lines. This tracking is relatively easy because a separate production line is used for each customer:

	Prestige Jets	U.S. Air Force	Total Plant
<b>Physical Units for May</b>			
Work in process, beginning inventory	0	0	0
Started during May	6,000	4,000	10,000
Good units completed and transferred out during May	4,000	2,000	6,000
Work in process, ending inventory	1,500	1,100	2,600
Direct materials (both 100% complete)			
Conversion costs (both 70% complete)			
Normal spoilage (% of good units transferred out)	7.5%	25%	?
<b>Costs for May</b>			
Work in process, beginning inventory	\$0	\$0	\$0
Direct materials added during May	\$12,750,000	\$8,500,000	\$21,250,000
Conversion costs added during May	\$ 7,834,000	\$6,327,080	\$14,161,080

All direct materials are introduced at the beginning of the production process. Conversion costs are assigned evenly during the process. Inspection occurs at the end of the production process. Spoiled chips are disposed of at zero net disposal price. Chip Contractors uses the weighted-average method of process costing.

#### REQUIRED

1. Compute the actual cost per good chip transferred out in May for (a) Prestige Jets, (b) the U.S. Air Force, and (c) the total plant. Chip Contractors includes both normal and abnormal spoilage costs when computing actual costs for Prestige Jets.
2. Explain any differences between (a) and (b) in requirement 1.
3. What cost number per good chip sold in May 19\_7 should Sanders report to Prestige Jets? Explain any ethical dilemmas that he might face.
4. Suppose the purchasing officer of Prestige Jets receives the May 19\_7 bill based on the plant unit cost per good output unit. He immediately requests that Sanders provide full details on how the May unit cost amount was determined. What should Sanders do?



## COLLABORATIVE LEARNING PROBLEM

**18-40 Job costing, spoilage.** (CMA adapted) The Richport Company manufactures products that often require specification changes or modifications to meet its customers' needs. Still, Richport has been able to establish a normal spoilage rate of 2.5% of *normal input*. Normal spoilage is recognized during the budgeting process and classified as a component of manufacturing overhead when determining the overhead rate.

Rose Duncan, one of Richport's inspection managers, obtains the following information for Job No. N1192-122 that was recently completed. A total of 122,000 units were started, and 5,000 units were rejected at final inspection yielding 117,000 good units. Duncan noted that 900 of the first units produced were rejected because of a design defect that was considered very unusual; this defect was corrected immediately, and no further units were rejected for this reason. These units were disposed of after incurring an additional cost of \$1,200. Duncan was unable to identify a rejection pattern for the remaining 4,100 rejected units. These units can be sold at \$7 per unit.

The total costs for all 122,000 units of Job No. N1192-122 are presented here. The job has been completed, but the costs have yet to be transferred to finished goods.

Direct materials	\$2,196,000
Direct manufacturing labor	1,830,000
Manufacturing overhead	<u>2,928,000</u>
Total manufacturing costs	<u>\$6,954,000</u>

### INSTRUCTIONS

Form groups of two or more students to complete the following requirements.

### REQUIRED

1. Calculate the unit quantities of normal and abnormal spoilage.
2. Prepare the appropriate journal entry (or entries) to properly account for Job No. N1192-122 including spoilage, disposal, and transfer of costs to finished goods control.
3. How would the information in requirement 2 be useful to Richport?
4. How well do you think Richport is managing spoilage?







# 19

## CHAPTER

# COST MANAGEMENT: QUALITY, TIME, AND THE THEORY OF CONSTRAINTS



Customers are requiring companies to meet demanding quality levels and delivery schedules while maintaining competitive prices. To achieve these multiple goals, companies such as Hansford Manufacturing Company use sophisticated flexible robotic systems in their manufacturing operations and monitor performance using both financial and nonfinancial measures of quality and time.

## LEARNING OBJECTIVES

After studying this chapter, you should be able to

1. Explain four cost categories in a cost of quality program
2. Describe three methods that companies use to identify quality problems
3. Identify the relevant costs and benefits of quality improvements
4. Provide examples of nonfinancial quality measures of customer satisfaction and internal performance
5. Understand why companies use both financial and nonfinancial measures of quality
6. Describe customer-response time, and explain the reasons for and the cost of lines and delays
7. Define the three main measurements in the theory of constraints
8. Describe four steps in managing bottlenecks



As we stated in Chapter 1, global competition and demanding customers have forced managers to improve the quality of their products and to deliver them to customers faster. But achieving higher quality and faster delivery requires managers to identify and overcome a variety of organizational constraints. This chapter examines how management accounting can assist managers in taking initiatives in the quality and time areas, and in making decisions under many constraints.

## QUALITY AS A COMPETITIVE WEAPON

Many companies throughout the world—for example, Hewlett-Packard and Ford Motor Company in the United States and Canada; British Telecom in the United Kingdom; Fujitsu and Toyota in Japan; Crysel in Mexico; and Samsung in Korea—view total-quality management as one of the most important success factors of the 1990s because it reduces costs and increases customer satisfaction. Several prestigious, high-profile awards—for example, the Malcolm Baldrige Quality Award in the United States, the Deming Prize in Japan, and the Premio Nacional de Calidad in Mexico—have been instituted to recognize exceptional quality.

International quality standards have emerged. For example, ISO 9000, developed by the International Organization for Standardization, is a set of five international standards for quality management adopted by more than 60 countries. ISO 9000 was created to enable companies to effectively document and certify their quality system elements. Some companies, such as DuPont and General Electric, are increasingly requiring their suppliers to obtain ISO 9000 certification. Why? To reduce their own costs by evaluating, assessing, and working to improve the quality of their suppliers' products. Thus, certification and an emphasis on quality are rapidly becoming conditions for competing in the global market.

Why this emphasis on quality? Because quality costs can be as much as 10% to 20% of sales revenue for many organizations. Quality-improvement programs can result in substantial savings and higher revenues. Motorola, the telecommunications and electronics manufacturer, estimates that it saved \$2 billion in 1994 from quality programs. This amounts to savings of 9% on annual revenues of \$22.2 billion in 1994. Motorola's 1994 operating income was \$2.4 billion. Without the savings from its quality programs, Motorola's income would be considerably lower.<sup>1</sup>

Consider a general effect that quality has on revenues. If competitors are improving quality, then a company that does not invest in quality improvement will likely suffer a decline in its market share and revenues. In this case, the benefit of better quality is in preventing lower revenues, not in generating higher revenues.

Quality improvement also has nonfinancial and qualitative effects that improve a company's long-term performance. For example, managers and workers focusing on quality gain expertise about product and process. This knowledge may lead to lower costs in the future. Manufacturing a product of high quality can enhance a company's reputation and increase customer goodwill, which may lead to higher future revenues. Motorola believes that its quality initiatives, which have increased customer satisfaction, also fueled its 380% increase in revenues, 800% increase in profits, and 600% increase in stock price over the last 8 years.

As corporations' responsibilities toward the environment grow, many managers are paying increasing attention to environmental quality and the problems of air pollution, waste water, oil and chemical spills, hazardous waste, and waste management. The costs of environmental damage (failure costs) can be extremely high to corporations under the 1990 amendments to the Clean Air Act. Companies can be charged multimillion dollar fines. For example, Exxon paid \$125 million in fines and restitution on top of \$1 billion in civil payments for the Exxon Valdez oil spill, which harmed the Alaskan coast. In 1994, the International Organization for Standardization announced ISO 14000, an environmental management standard. The standard's goal is to nudge organizations to pursue environmental goals vigorously by developing (1) environmental management systems to improve the environmental impact of

<sup>1</sup>Based on discussions with Richard Buetow, Director of Quality, Motorola, Inc.



an organization's activities, products, and services, and (2) environmental auditing and performance evaluation systems to review and provide feedback on how well an organization has achieved its environmental goals.

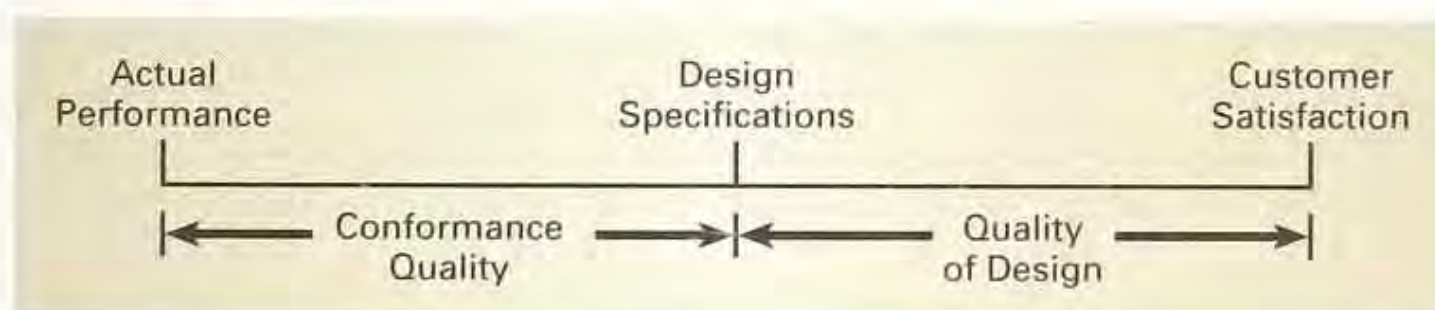
## TWO ASPECTS OF QUALITY

The term *quality* refers to a wide variety of factors—fitness for use, the degree to which a product satisfies the needs of a customer, and the degree to which a product conforms to design specification and engineering requirements.<sup>2</sup> We discuss two basic aspects of quality—*quality of design* and *conformance quality*.<sup>3</sup>

*Quality of design* measures how closely the characteristics of products or services match the needs and wants of customers. Suppose customers of photocopying machines want copiers that combine copying, faxing, scanning, and electronic printing. Photocopying machines that fail to meet these customer needs fail in the quality of their design. Similarly, if customers of a bank want an automated payment system for their monthly bills, not providing this facility would be a quality of design failure.

*Conformance quality* is the performance of a product or service according to design and production specifications. For example, if a photocopying machine mishandles paper or breaks down, it will have failed to satisfy conformance quality. Products not conforming to specifications must be repaired, reworked, or scrapped at an additional cost to the organization. If nonconformance errors are not corrected within the plant and the product breaks down at the customer site, even greater repair costs as well as the loss of customer goodwill—often the highest quality cost of all—may result. In the banking industry, depositing a customer's check into the wrong bank account is an example of conformance quality failure.

The following diagram illustrates our framework:



To travel the road from actual performance to customer satisfaction, companies must meet design specifications through conformance quality, but they must also design products to satisfy customers through quality of design.

## COSTS OF QUALITY

The **costs of quality (COQ)** are costs incurred to prevent or rectify the production of a low-quality product. These costs focus on conformance quality and are incurred in all areas of the value chain. They are classified into four categories:

1. **Prevention costs**—costs incurred in precluding the production of products that do not conform to specifications.
2. **Appraisal costs**—costs incurred in detecting which of the individual units of products do not conform to specifications.

### OBJECTIVE 1

Explain four cost categories in a cost of quality program

<sup>2</sup>The American Society for Quality Control defines *quality* as the totality of features and characteristics of a product made or a service performed according to specifications, to satisfy customers at the time of purchase and during use. ANSI/ASQC A3-1978, *Quality Systems Terminology* (Milwaukee, Wis.: American Society for Quality Control, 1978).

<sup>3</sup>See R. DeVor, T. Chang, and J. Sutherland, *Statistical Quality Design and Control* (New York: Macmillan, 1992); and J. Evans and W. Lindsay, *The Management and Control of Quality* (St. Paul: West, 1993).



EXHIBIT 19-1  
Items Pertaining to Costs of Quality Reports

Prevention Costs	Appraisal Costs	Internal Failure Costs	External Failure Costs
Design engineering	Inspection	Spoilage	Customer support
Process engineering	On-line product manufacturing and process inspection	Rework	Transportation costs
Quality engineering	Product testing	Scrap	Manufacturing/process engineering
Supplier evaluations		Breakdown maintenance	Warranty repair costs
Preventive equipment maintenance		Manufacturing/process engineering on internal failure	Liability claims
Quality training			
New materials used to manufacture products			

3. **Internal failure costs**—costs incurred when a nonconforming product is detected before it is shipped to customers.

4. **External failure costs**—costs incurred when a nonconforming product is detected after it is shipped to customers.

Exhibit 19-1 presents examples of individual cost of quality items in each of these four categories reported on COQ reports. Note that the items included in Exhibit 19-1 come from all value-chain business functions and are broader than the internal failure costs of spoilage, rework, and scrap in manufacturing considered in Chapter 18.

We illustrate the various issues in managing quality—from computing the costs of quality, to identifying quality problems, to taking actions to improve quality—using the Photon Corporation as example. Photon makes many products. Our presentation focuses on Photon's photocopying machines, which earned an operating income of \$24 million on sales of \$300 million (20,000 copiers) in 19\_8. Photon determines its costs of quality using an activity-based approach with five steps.

**Step 1: Identify All Quality-Related Activities and Activity Cost Pools** Column 1 of Exhibit 19-2, Panel A, classifies costs into prevention, appraisal, internal failure, and external failure categories, and indicates the value-chain functions in which the costs occur. One such activity is inspecting (including testing) the photocopying machines.

**Step 2: Determine the Quantity of the Cost-Allocation Base for Each Quality-Related Activity** (See Exhibit 19-2, Panel A, column 2.) For example, Photon identifies inspection hours, the primary cost driver, as the cost-allocation base of the inspection activity. Assume that photocopying machines use 240,000 hours (12 hours per copier  $\times$  20,000 copiers) of the cost-allocation base.

**Step 3: Compute the Rate per Unit of Each Cost-Allocation Base** (See Exhibit 19-2, Panel A, column 3.) Due to space considerations, we do not provide details of the calculations.<sup>4</sup> In the Photon example, the total (fixed and variable) costs of inspection are \$40 per hour.

**Step 4: Compute the Costs of Each Quality-Related Activity for Photocopying Machines by Multiplying the Quantity of the Cost-Allocation Base Determined in Step 2 by the Rate per Unit of the Cost-Allocation Base Computed in Step 3** (See Exhibit 19-2, Panel A, column 4.) In our example, quality-related inspection costs are \$9,600,000 (240,000 hours  $\times$  \$40 per hour).

<sup>4</sup>Allocation rates are computed using methods described in Chapter 4 (p. 96–97), Chapter 5 (p. 146), and Chapter 14 (p. 510–511).



EXHIBIT 19-2  
Activity-Based COQ Analysis for the Photon Corporation

PANEL A: COQ REPORT

Costs of Quality and Value-Chain Category (1)	Allocation Base or Cost Driver		Total Costs (4) = (2) × (3)	Percentage of Sales (5) = (4) ÷ \$300,000,000
	Quantity (2)	Rate (Number Assumed) (3)		
<i>Prevention costs</i>				
Design engineering (R&D/Design)	40,000* hours	\$80 per hour	\$ 3,200,000	1.07%
Process engineering (R&D/Design)	45,000* hours	\$60 per hour	2,700,000	0.90
Total prevention costs			5,900,000	1.97
<i>Appraisal costs</i>				
Inspection (Manufacturing)	240,000† hours	\$40 per hour	9,600,000	3.20
Total appraisal costs			9,600,000	3.20
<i>Internal failure costs</i>				
Rework (Manufacturing)	2,500‡ copiers reworked	\$4,000 per copier reworked	10,000,000	3.33
Total internal failure costs			10,000,000	3.33
<i>External failure costs</i>				
Customer support (Marketing)	3,000§ copiers repaired	\$200 per copier repaired	600,000	0.20
Transportation costs (Distribution)	3,000 copiers repaired	\$240 per copier repaired	720,000	0.24
Warranty repair (Customer service)	3,000 copiers repaired	\$4,400 per copier repaired	13,200,000	4.40
Total external failure costs			14,520,000	4.84
Total costs of quality			\$40,020,000	13.34%

PANEL B: OPPORTUNITY COST ANALYSIS

Costs of Quality Category (1)	Quantity of Lost Sales (2)	Contribution Margin per Copier (Number Assumed) (3)	Total Estimated Contribution Margin Lost (4) = (2) × (3)	Percentage of Sales (5) = (4) ÷ \$300,000,000
<i>External failure costs</i>				
Estimated forgone contribution margin and income on lost sales	2,000# copiers	\$6,000	\$12,000,000	4.00%
Total costs of quality			<u>\$12,000,000</u>	<u>4.00%</u>

\*Based on special studies.

†12 hours per copier × 20,000 copiers.

‡12.5% of 20,000 copiers manufactured required rework.

§15% of 20,000 copiers manufactured required warranty repair service.

#Estimated by Photon's Market Research Department.

**Step 5: Obtain the Total Costs of Quality by Adding the Costs of all Quality-Related Activities for Photocopying Machines in All Value-Chain Business Functions** Exhibit 19-2, Panel A, shows Photon's total costs of quality reported on the COQ report for photocopying machines at \$40.02 million, of which the largest categories are \$14.52 million in total external failure costs and \$10 million in total



internal failure costs—a sum of \$24.52 million. Total reported costs of quality are 13.34% of current sales.

Do not assume, however, that costs reported on COQ reports represent the total costs of quality for a company. COQ reports typically exclude opportunity costs, such as forgone contribution margins and income from lost sales, lost production, or lower prices, that result from poor quality. Why? Because opportunity costs are difficult to estimate and generally not recorded in accounting systems. Nevertheless, opportunity costs can be substantial and important driving forces in quality-improvement programs. Exhibit 19-2, Panel B, presents the analysis of the opportunity costs of poor quality at Photon. Photon Corporation's Market Research Department estimates lost sales of 2,000 photocopying machines because of external failures. The forgone contribution and operating income of \$12 million measures the financial costs from dissatisfied customers who have returned machines to Photon and from sales lost because of quality problems. Total costs of quality (including opportunity costs) equal \$52.02 million (Panel A, \$40.02 million + Panel B, \$12 million), or 17.34% of current sales. Opportunity costs account for 23% (\$12 million ÷ \$52.02 million) of Photon's total costs of quality.

The COQ report and the opportunity cost analysis highlight Photon's high internal and external failure costs. To reduce costs of quality, Photon must identify and reduce failures caused by quality problems.

## METHODS USED TO IDENTIFY QUALITY PROBLEMS

### OBJECTIVE 2

Describe three methods that companies use to identify quality problems

### Control Charts

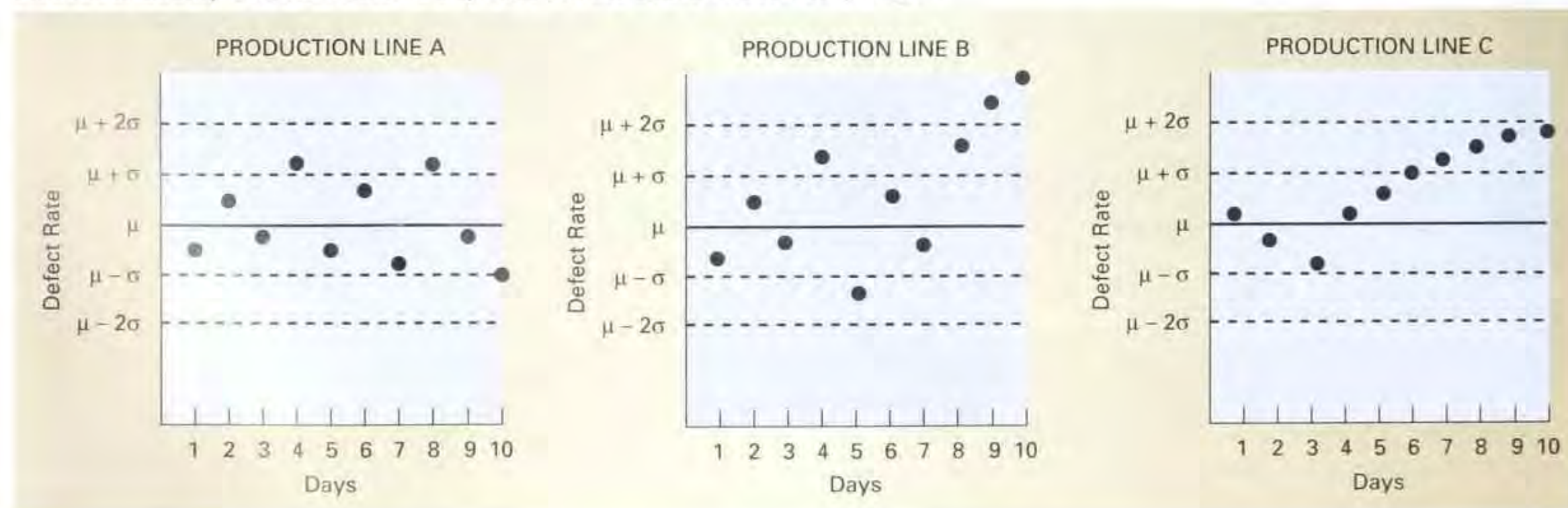
Statistical quality control (SQC) or statistical process control (SPC) is a formal means of distinguishing between random variation and nonrandom variation in an operating process. A key tool in SQC is a control chart. A **control chart** is a graph of a series of successive observations of a particular step, procedure, or operation taken at regular intervals of time. Each observation is plotted relative to specified ranges that represent the expected distribution. Only those observations outside the specified limits are ordinarily regarded as nonrandom and worth investigating.

Exhibit 19-3 presents control charts for the daily defect rates observed at Photon's three production lines. Defect rates in the prior 60 days for each plant were assumed to provide a good basis from which to calculate the distribution of daily defect rates. The arithmetic mean ( $\mu$ , read mu) and standard deviation ( $\sigma$ , read sigma) are the two parameters of the distribution that are used in the control charts in Exhibit 19-3. On the basis of experience, the company decides that any observation outside the  $\mu \pm 2\sigma$  range should be investigated.

For production line A in Exhibit 19-3, all observations are within the range of  $\pm 2\sigma$  from the mean. Management, then, believes no investigation is necessary. For

EXHIBIT 19-3

Statistical Quality-Control Charts: Daily Defect Rate at the Photon Corporation





production line B, the last two observations signal that an out-of-control occurrence is highly likely. Given the  $\pm 2\sigma$  rule, both observations would lead to an investigation. Production line C illustrates a process that would not prompt an investigation under the  $\pm 2\sigma$  rule but may well be out of control. Note that the last eight observations show a clear direction and that the direction by day 5 (the third point in the last eight) is away from the mean. Statistical procedures have been developed using the trend as well as the level of the variable in question to evaluate whether a process is out of control.

## Pareto Diagrams

Observations outside control limits serve as inputs to *Pareto diagrams*. A **Pareto diagram** indicates how frequently each type of failure (defect) occurs. Exhibit 19-4 presents a Pareto diagram for Photon's quality problems. Fuzzy and unclear copies are the most frequently recurring problem.

The fuzzy copy problem results in high rework costs because, in many cases, Photon discovers the fuzzy image problem only after the copier has been built. Sometimes fuzzy images occur at customer sites, resulting in high warranty and repair costs.

## Cause-and-Effect Diagrams

The most frequently occurring problems identified by the Pareto diagram are analyzed using *cause-and-effect diagrams*. A **cause-and-effect diagram** identifies potential causes of failures or defects. As a first step, Photon analyzes the causes of the most frequently occurring failure, fuzzy and unclear copies. Exhibit 19-5 presents the cause-and-effect diagram for this problem. The exhibit identifies four major categories of potential causes of failure—human factors, methods and design factors, machine-related factors, and materials and components factors. As additional arrows are added for each cause, the general appearance of the diagram begins to resemble a fishbone (hence, cause-and-effect diagrams are also called *fishbone diagrams*).<sup>5</sup>

<sup>5</sup>Managers in U.S. electronics companies consider the following factors (ranked in order of importance with 1 = most important) as contributing to improvements in quality:

1. Better product design
2. Improved process design
3. Improved training of operators
4. Improved products from suppliers
5. Investments in technology and equipment

See G. Foster and L. Sjoblom, "Survey of Quality Practices in the U.S. Electronics Industry," Working Paper, Stanford University, 1993.

EXHIBIT 19-4  
Pareto Diagram for the Photon Corporation

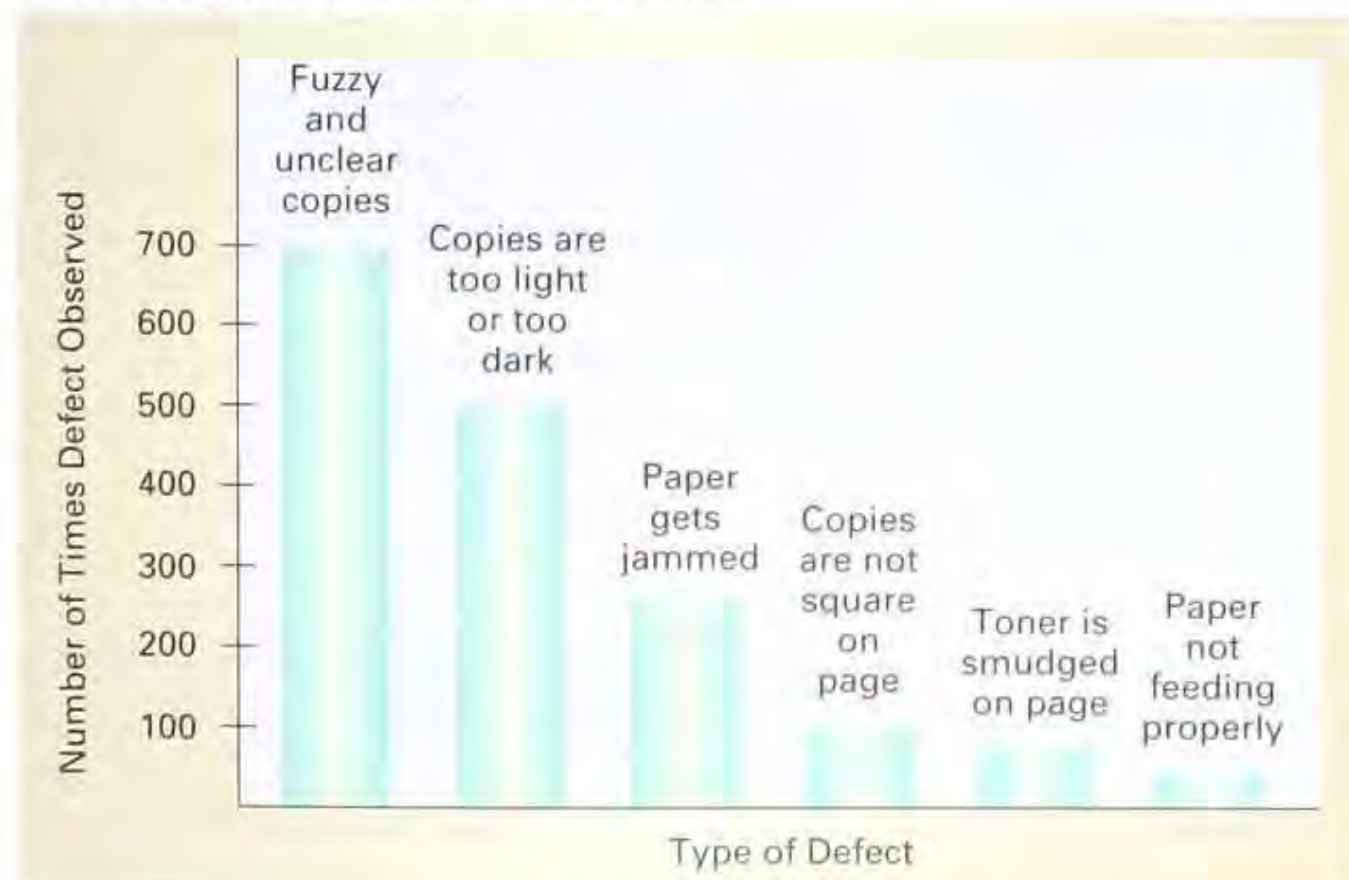
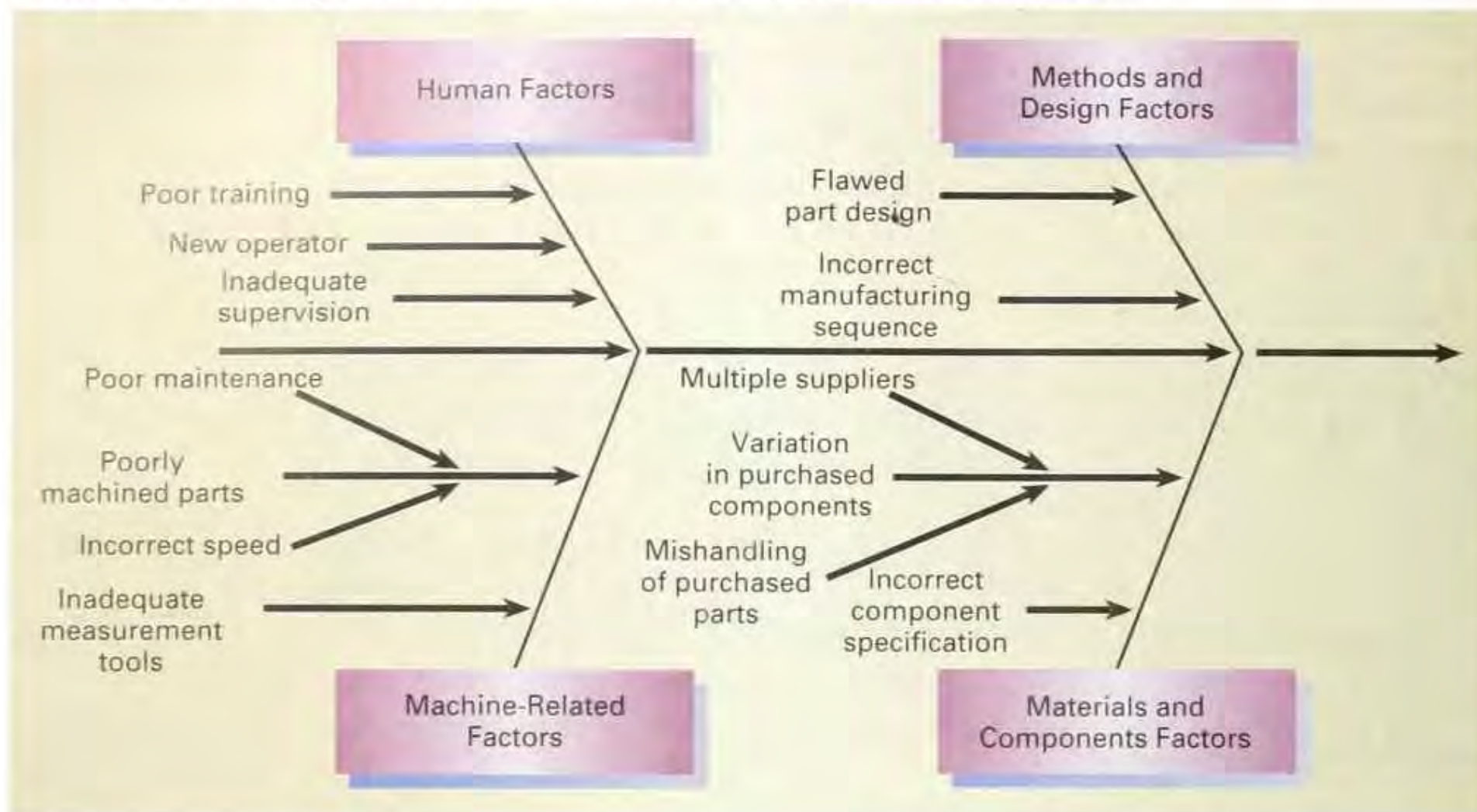




EXHIBIT 19-5

Cause-and-Effect Diagram for Fuzzy and Unclear Copies at the Photon Corporation



## RELEVANT COSTS AND BENEFITS OF QUALITY IMPROVEMENT

Careful analysis of the cause-and-effect diagram reveals that the steel frame (or chassis) of the copier is often mishandled as it travels from the suppliers' warehouses to Photon's plant. The frame must satisfy very precise specifications and tolerances; otherwise, various copier components (such as drums, mirrors, and lenses) attached to the frame will be improperly aligned. Mishandling causes the dimensions of the frame to vary from specifications, resulting in fuzzy images.

Suppose the team of engineers working to solve the fuzzy image problem offers two alternative solutions: (1) to improve the inspection of the frame immediately upon delivery, or (2) to redesign and strengthen the frame and the containers used to transport them to better withstand mishandling during transportation.

### OBJECTIVE 3

Identify the relevant costs and benefits of quality improvements

Should Photon inspect incoming frames more carefully or redesign them and their containers? Exhibit 19-6 shows the costs and benefits of each choice. Management estimates that additional inspection will cost \$400,000 (\$40 per hour  $\times$  10,000 hours). Redesign will cost an additional \$460,000 (design engineering, \$80 per hour  $\times$  2,000 hours; process engineering, \$60 per hour  $\times$  5,000 hours). The potential benefits of incurring these costs are lower internal and external failure costs. The key question here is, What are the relevant cost savings and other relevant benefits? Photon considers only a 1-year time horizon for analyzing this decision because Photon plans to introduce a completely new line of copiers at the end of the year. Photon believes that even as it improves quality, it will not be able to save any of the fixed costs of internal and external failure. To identify the relevant cost savings, Photon divides each category of failure costs into its fixed and variable components.

Consider first the internal failure costs of rework. Fixed and variable costs for each reworked copier are


Variable costs (including direct materials, direct rework labor, and supplies)	\$1,600
Allocated fixed costs (equipment, space, and allocated overhead)	2,400
Total costs (Exhibit 19-2, Panel A, column 3)	<u>\$4,000</u>

If Photon chooses to inspect the frame more carefully, it expects to eliminate rework on 600 copiers and save variable costs of \$960,000 (\$1,600  $\times$  600) in rework. See Exhibit 19-6, column 1. Photon believes that fixed rework costs will be unaffected. If Photon chooses the redesign alternative, it expects to eliminate rework on 800 copiers, saving \$1,280,000 (\$1,600  $\times$  800). See Exhibit 19-6, column 2.



## EXHIBIT 19-6

Estimated Effect of Quality-Improvement Actions on Costs of Quality  
for the Photon Corporation

Description	Incremental Costs and Benefits of	
	Further Inspecting Incoming Frame (1)	Redesigning Frame (2)
<i>Costs of Quality Items</i>		
Additional design engineering costs \$80 × 2,000 hours	—	\$ 160,000
Additional process engineering costs \$60 × 5,000 hours	—	300,000
Additional inspection and testing costs \$40 × 10,000 hours	\$ 400,000	—
Savings in rework costs		
\$1,600 × 600 fewer copiers reworked	(960,000)	
\$1,600 × 800 fewer copiers reworked		(1,280,000)
Savings in customer-support costs		
\$80 × 500 fewer copiers repaired	(40,000)	
\$80 × 700 fewer copiers repaired		(56,000)
Savings in transportation costs for repair parts		
\$180 × 500 fewer copiers repaired	(90,000)	
\$180 × 700 fewer copiers repaired		(126,000)
Savings in warranty repair costs		
\$1,800 × 500 fewer copiers repaired	(900,000)	
\$1,800 × 700 fewer copiers repaired		(1,260,000)
<i>Opportunity Costs</i>		
Contribution margin from increased sales		
\$6,000 × 250 additional copiers sold	(1,500,000)	
\$6,000 × 300 additional copiers sold	—	(1,800,000)
<i>Net cost savings and additional contribution margin</i>	<u>\$ (3,090,000)</u>	<u>\$ (4,062,000)</u>
<i>Difference in favor of redesigning frame</i>		

Next consider external failure costs. Photon currently repairs 3,000 copiers at customer sites. If incoming frames are inspected more carefully, Photon estimates that 500 fewer copiers will require warranty repair and that it will be able to sell 250 additional copiers. If the frame is redesigned, Photon estimates that 700 fewer copiers will require warranty repair and that it will be able to sell 300 additional copiers.

Variable and fixed costs per copier repaired of individual external failure COQ items described in Exhibit 19-2 (Panel A, column 4) are as follows:

	Variable Costs	Fixed Costs	Total Costs
Customer-support costs	\$ 80	\$ 120	\$ 200
Transportation costs	180	60	240
Warranty repair costs	1,800	2,600	4,400

As Photon eliminates repair work on copiers, it expects to save only the variable costs of customer support, transportation, and warranty repair.



## Crysel Wins Premio Nacional de Calidad—Mexico's Premier Quality Award

Crysel, a member of the Mexican industrial group CYDSA (*Celulosa y Derivados Society Anonimos*), is the largest producer of acrylic fiber in Latin America and among the top-ten producers of acrylic fiber in the world. In 1991, Crysel was awarded the Premio Nacional de Calidad, Mexico's equivalent of the Malcolm Baldrige quality award.

One element of the Premio Nacional de Calidad's evaluation criteria is a company's costs of quality reporting. Companies vary as to which items they include in their COQ reports, choosing those cost categories that management feels warrant the greatest emphasis. Crysel classifies its costs of failure into six main classes:

1. *Consumption factors*—excess or wasted direct materials, steam, or energy.
2. *Maintenance*—costs of repairing machines that break down.
3. *Human resources*—costs of extra workers and staff, such as a rework crew employed to correct quality problems.
4. *Accounts receivable*—finance costs of not receiving money from customers on time.
5. *Substandard quality*—contribution margin lost from selling inferior-grade rather than top-grade fiber.
6. *Sales volume*—contribution margin lost from selling less than the available plant capacity because of quality problems.

The first three classes appear in the COQ reports that most companies prepare. Crysel's innovation in quality reporting is to include the last three classes: accounts receivable, substandard quality, and sales volume. Each of these three classes measures an opportunity cost of poor quality, a cost not generally found in COQ reports. The following table indicates that these opportunity costs are a significant percentage of Crysel's total costs of failure. Including them in the COQ reports signals to all employees that top management believes these classes deserve close attention.

Costs of Quality as a Percentage of Sales

	1985	1989	1992
<b>Items Generally Recorded in COQ Reports</b>			
Consumption factors	3.8%	4.1%	2.6%
Maintenance	0.8	0.9	0.8
Human resources	0.6	0.5	0.4
Total	5.2%	5.5%	3.8%
<b>Opportunity Cost Items Generally Not Recorded in COQ Reports</b>			
Accounts receivable	3.7%	0.9%	0.5%
Substandard quality	1.0	0.4	0.8
Sales volume	8.5	2.4	1.6
Total	13.2	3.7	2.9
Total costs of quality as a percentage of sales	18.4%	9.2%	6.7%

An important component of the Premio Nacional de Calidad is a company's safety record. Crysel's safety index, measured by the number of accidents per million labor-hours, declined from 6.3 in 1986 to 3.0 in 1992. Crysel eliminated accidents by redesigning machines, training operators in safety practices, and implementing safe operating procedures.

Source: Based on a presentation by Raul Gil Dufoo, Director General of Crysel, and discussions with company management.





Note that the savings per copier in rework costs, customer-support costs, transportation costs, and warranty repair costs in Exhibit 19-6 differ from the costs per copier for each of these items in Exhibit 19-2. Why? Because Exhibit 19-6 shows only the variable costs that Photon expects to save. Exhibit 19-2 shows the *total* (fixed and variable) costs of each of these items. Also note that Exhibit 19-6 includes the incremental contribution margin from the estimated increases in sales due to the improved quality and performance of Photon's copiers.

Photon's management chooses to redesign the frame since Exhibit 19-6 indicates that the net estimated cost savings are \$972,000 greater under this alternative. The costs of a poorly designed frame appear in the form of higher manufacturing, marketing, distribution, and customer-service costs, as internal and external failures begin to mount. But these costs are locked in when the frame is designed. Thus, it is not surprising that redesign will yield significant savings.

In the Photon example, lost contribution margin occurs because Photon's repeated external failures damage its reputation for quality, resulting in lost sales. Lost contribution margin can also occur as a result of internal failures. Suppose Photon's manufacturing capacity is fully used. In this case, rework uses up valuable manufacturing capacity and causes the company to forgo contribution margin from producing and selling additional copiers. Suppose Photon could produce (and subsequently) sell an additional 600 copiers by improving quality and reducing rework. The costs of internal failure would then include lost contribution margin of \$3,600,000 (\$6,000 contribution margin per copier  $\times$  600 copiers). This \$3,600,000 is the opportunity cost of poor quality.

Photon can use its COQ report to examine interdependencies across the four categories of quality-related costs. In our example, redesigning the frame increases costs of prevention activities (design and process engineering), decreases costs of internal failure (rework), and decreases costs of external failure (warranty repairs). Costs of quality give more insight when managers compare trends over time. (See Concepts in Action, p. 690). In successful quality programs, the costs of quality as a percentage of sales and the costs of internal and external failure as a percentage of total costs of quality should decrease over time. Many companies, for example, Digital Equipment Corporation, Solectron, and Toyota, believe they should eliminate all failure costs and have zero defects.

## QUALITY AND CUSTOMER-SATISFACTION MEASURES

Even if products and services are defect-free and fully satisfy conformance quality, they will not be effective or sell well unless they also have design quality—that is, unless they satisfy customer needs. Yet there is more to customer satisfaction than just design quality. Motorola describes its program of total customer satisfaction as

- ◆ Giving the customer product-performance features that are perceived by the customer as providing fair value.
- ◆ Delivering the product when promised.
- ◆ Delivering the product with no defects.
- ◆ Ensuring that the product will not experience early failure.
- ◆ Ensuring that the product will not fail excessively in service.

To evaluate how well they are doing, Motorola and other companies track customer-satisfaction trends over time. Customer satisfaction is difficult to measure precisely, but companies can choose among many indicators in their search for answers.

### Financial Measures of Customer Satisfaction

Costs of external failures—such as warranty repair costs, liability claims, forgone contribution margin on lost sales, and lower prices for products sold—are all financial indicators of poor customer satisfaction. But financial measures do not indicate the specific areas that need improvement, nor do they reveal the future needs and



preferences of customers. For these reasons, most companies also use nonfinancial measures. Cost and management accountants are often responsible for maintaining and presenting these nonfinancial measures.

### Nonfinancial Measures of Customer Satisfaction

#### OBJECTIVE 4

Provide examples of nonfinancial quality measures of customer satisfaction and internal performance

Nonfinancial measures of customer satisfaction include

- ◆ The number of defective units shipped to customers as a percentage of total units of products shipped
- ◆ The number of customer complaints (Companies estimate that for every customer who actually complains, there are 10–20 others who have had bad experiences with the product but have not complained.)
- ◆ Excessive customer-response time (the difference between scheduled delivery date and date requested by the customer)
- ◆ On-time delivery (percentage of shipments made on or before the scheduled delivery date)

Federal Express tracks similar measures for customer satisfaction in its overnight delivery business. Management steps in and investigates if these numbers deteriorate over time.

In addition to these routine nonfinancial measures, many companies such as Xerox conduct surveys to measure customer satisfaction. Surveys serve two objectives. First, they provide a deeper perspective into customer experiences and preferences. Second, they provide a glimpse into features that customers would like future products to have.

## QUALITY AND INTERNAL PERFORMANCE MEASURES

Prevention costs, appraisal costs, and internal failure costs are examples of financial measures of quality performance inside the company. Most companies monitor both financial and nonfinancial measures of internal quality.

What nonfinancial measures might a business use? Analog Devices, a semiconductor manufacturer, follows trends in these gauges of quality:

- ◆ The number of defects for each product line
- ◆ Process yield (ratio of good output to total output)
- ◆ Manufacturing lead time (the time taken to convert direct materials into finished output)
- ◆ Employee turnover (ratio of the number of employees who left the company to the total number of employees)

By themselves, nonfinancial measures of quality have limited meaning. They are more informative when management examines trends over time. To prepare this report, the management accountant must review the numbers to ensure that nonfinancial measures are calculated accurately and consistently, and must then present the information to help management evaluate internal quality performance. Management accountants help companies improve quality in multiple ways—they compute the costs of quality, assist in developing cost-effective solutions to quality problems, and provide feedback about quality improvement.

## EVALUATING QUALITY PERFORMANCE

#### OBJECTIVE 5

Understand why companies use both financial and nonfinancial measures of quality

Measuring the financial costs of quality and the nonfinancial aspects of quality have distinctly different advantages.

### Advantages of the Costs of Quality (COQ) Measures

1. COQ focuses attention on how costly poor quality can be.
2. Financial COQ measures are a useful way of comparing different quality-improvement programs and setting priorities for achieving maximum cost reduction.



3. Financial COQ measures serve as a common denominator for evaluating trade-offs among prevention and failure costs. COQ provides a single, summary measure of quality performance.

### Advantages of Nonfinancial Measures of Quality

1. Nonfinancial measures of quality are often easy to quantify and easy to understand.
2. Nonfinancial measures direct attention to physical processes and hence focus attention on the precise problem areas that need improvement.
3. Nonfinancial measures provide immediate short-run feedback on whether quality improvement efforts have, in fact, succeeded in improving quality.

The advantages cited for COQ are disadvantages of nonfinancial measures, and vice versa. Most organizations use both financial and nonfinancial quality measures to measure quality performance.

Management accountants at some companies (for example, Analog Devices, Milliken, and Octel) present both financial and nonfinancial measures of quality performance in a single report, sometimes called a *balanced scorecard*.<sup>6</sup> The balanced scorecard helps top management evaluate whether lower-level managers have improved one area at the expense of others. For example, a manager at risk of not meeting operating income goals may start to ship high-margin products and delay deliveries of low-margin products. The balanced scorecard will recognize the improvement in financial performance but will also reveal that operating income targets were achieved by sacrificing on-time performance. Moreover, corporations often use multiple measures of quality in managers' bonus plans. For example, Motorola explicitly ties employee bonuses to improvements in customer satisfaction, yield, and cycle time.

## TIME AS A COMPETITIVE WEAPON

Companies increasingly view time as a key variable in competition.<sup>7</sup> Doing things faster helps to increase revenues and decrease costs. For example, a moving company such as United Van Lines will be able to generate more revenues if it can move goods from one place to another faster and on time. Companies such as AT&T and Texas Instruments also report lower costs from their emphasis on time. They cite, for example, the need to carry less inventory because of their ability to respond rapidly to customer demands.

In this chapter, we focus on *operational measures of time*, which reveal how quickly companies respond to customers' demands for their products and services and the reliability with which these companies meet scheduled delivery dates. Another important aspect of time is *new product development time* and the financial success a company derives from bringing new products to market quickly. We discuss capital budgeting for new products and *breakeven time*, the time it takes to recover investments in new products, in Chapter 22.

## OPERATIONAL MEASURES OF TIME

Companies need to measure time in order to manage it properly. Two common operational measures of time are customer-response time and on-time performance.

### Customer-Response Time

**Customer-response time** is the amount of time from when a customer places an order for a product or requests a service to when the product or service is delivered to the customer. A timely response to customer requests is a key competitive factor

#### OBJECTIVE 6

Describe customer-response time, and explain the reasons for and the cost of lines and delays

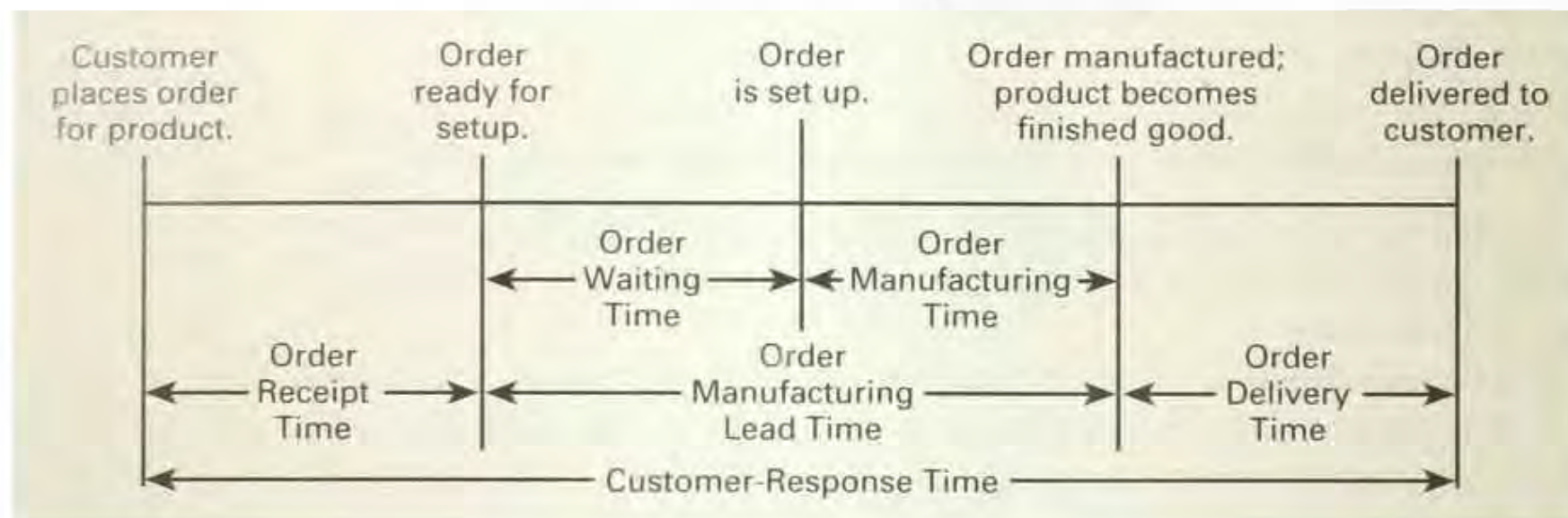
<sup>6</sup>See R. Kaplan and D. Norton, "Using the Balanced Scorecard as a Strategic Management System," *Harvard Business Review* (Jan.-Feb. 1996).

<sup>7</sup>See G. Stalk and T. Hout, *Competing Against Time* (New York: Free Press, 1990).



in many industries. Consider a manufacturer of custom machine tools such as Yamazaki Mazak. Yamazaki's customers value faster delivery because it enables them to produce and sell products made using the new machine tools sooner. Customer-response time is critical in many other industries, especially service industries such as banking, car-rental, and fast-food.

The following diagram describes components of customer-response time.



In the Yamazaki Mazak example, *order receipt time* is the time it takes Mazak's Marketing Department to describe the customer's exact specifications and to place an order with manufacturing. **Manufacturing lead (or cycle) time** is the time when the order is ready to start on the production line (ready to be set up) to when it becomes a finished good. Manufacturing lead time includes waiting time plus manufacturing time for the order. An order for machine tools, in the Mazak example, may need to wait and be delayed because the equipment the order requires is busy processing orders that arrived earlier. *Order delivery time* is the time it takes distribution to pick up the order from manufacturing and deliver it to the customer.

Several companies have adopted manufacturing lead time as the base for allocating indirect manufacturing costs to products. The Zytex Corporation, a manufacturer of computer equipment, believes that using manufacturing lead time motivates managers to reduce the time taken to manufacture products. In turn, total overhead costs decrease and operating income rises.

### Effects of Uncertainty and Bottlenecks on Delays

A **time driver** is any factor where change in the factor causes a change in the speed with which an activity is undertaken. What are the drivers of time? We consider two of the most important: (1) Uncertainty about when customers will order products or services. For example, the more randomly Mazak receives orders for its machine tools, the more likely that queues will form and delays will occur. (2) Limited capacity and bottlenecks. A **bottleneck** is an operation where the work required to be performed approaches or exceeds the available capacity. For example, a bottleneck is created when products that need to be processed at a particular machine arrive while the machine is busy processing other products. The demand for time on the machine exceeds available capacity, and delays occur.

The management accountant is frequently called upon to evaluate the profitability of a new product given capacity constraints (Chapter 11, p. 396–398). In some instances, introducing a new product causes delays in the delivery of all products. When time is a key dimension of competitiveness, the management accountant must recognize and consider the costs of delays when calculating the costs and benefits of introducing a new product. To calculate the costs of delays, the management accountant must first understand the reasons for, and the magnitude of, the resulting delays. We illustrate these ideas using the Falcon Works example.

Falcon Works (FW) uses one turning machine to convert steel bars into one specialty component, A22. FW makes this component only after FW's customers order the component. To focus on manufacturing lead time, we assume that FW's order receipt time and order delivery time are minimal.



FW expects it will receive 30 orders, but it could actually receive 10, 20, or 50 orders of A22. Each order is for 1,000 units. Each order will take 100 hours of manufacturing time (8 hours of setup time to clean and prepare the machine, and 92 hours of processing time). The annual capacity of the machine is 4,000 hours. If FW receives the number of orders it expects, the total amount of manufacturing time required on the machine will be 3,000 ( $100 \times 30$ ) hours, which is within the available machine capacity of 4,000 hours. Even though expected capacity utilization is not strained, queues and delays will still occur. Why? Because uncertainty about when FW's customers will place an order may cause the order to be received while the machine is processing another order.

In the single-product case, under certain assumptions about the pattern of customer orders and how orders will be processed,<sup>8</sup> the **average waiting time**, the average amount of time that an order will wait in line before it is set up and processed, equals

$$\frac{\text{Average number of orders of A22} \times \left( \text{Manufacturing time for A22} \right)^2}{2 \times \left[ \text{Annual machine capacity} - \left( \text{Average number of orders of A22} \times \text{Manufacturing time for A22} \right) \right]}$$

$$= \frac{30 \times (100)^2}{2 \times [4,000 - (30 \times 100)]} = \frac{30 \times 10,000}{2 \times (4,000 - 3,000)} = \frac{300,000}{2 \times 1,000} = \frac{300,000}{2,000} = 150 \text{ hours}$$

The denominator in this formula measures excess capacity or cushion. The smaller the cushion, the greater the delays. Manufacturing time enters the numerator in the formula as a squared term. The longer the manufacturing time, the greater the chance that the machine will be busy when an order arrives, and the longer the delays.

Our formula describes only the average waiting time. A particular order may happen to arrive when the machine is free, in which case manufacturing will start immediately. In other situations, FW may receive an order while two other orders are waiting to be processed. In this case, the delay will be longer than 150 hours. The average manufacturing lead time for an order of A22 is 250 hours (150 hours of average waiting time + 100 hours of manufacturing time). Throughout this section, we use manufacturing lead time to refer to manufacturing lead time for an order.

FW is considering whether to introduce a new product, C33. FW expects to receive ten orders of C33 (each order for 800 units) in the coming year. Each order will take 50 hours of manufacturing time (4 hours of setup time and 46 hours of processing time). The expected demand for A22 will be unaffected whether or not FW introduces C33.

The average waiting time *before* an order is set up and processed is given by the following formula, which is an extension of the formula described earlier for the single-product case.

$$\frac{\left[ \text{Average number of orders of A22} \times \left( \text{Manufacturing time for A22} \right)^2 \right] + \left[ \text{Average number of orders of C33} \times \left( \text{Manufacturing time for C33} \right)^2 \right]}{2 \times \left[ \text{Annual machine capacity} - \left( \text{Average number of orders of A22} \times \text{Manufacturing time for A22} \right) - \left( \text{Average number of orders of C33} \times \text{Manufacturing time for C33} \right) \right]}$$

$$= \frac{[30 \times (100)^2] + [10 \times (50)^2]}{2 \times [4,000 - (30 \times 100) - (10 \times 50)]} = \frac{(30 \times 10,000) + (10 \times 2,500)}{2 \times (4,000 - 3,000 - 500)}$$

$$= \frac{300,000 + 25,000}{2 \times 500} = \frac{325,000}{1,000} = 325 \text{ hours}$$

Introducing C33 causes average waiting time to more than double from 150 hours to 325 hours. To understand why, think of excess capacity as a cushion for

<sup>8</sup>The precise technical assumptions are that customer orders for the product follow a Poisson distribution with a mean equal to the expected number of orders (30 in the case of A22) and that orders are processed on a first-in first-out (FIFO) basis. The Poisson arrival pattern for customer orders has been found to be reasonable in many real-world settings. The FIFO assumption can be modified. The basic queuing and delay effects will still occur, but the precise formulas will be different.



absorbing the shocks of variability and uncertainty in the arrival of customer orders. Introducing C33 causes excess capacity to shrink, increasing the chance that at any point in time, new orders will arrive while existing orders are being manufactured.

Average manufacturing lead time for A22 is 425 hours (325 hours of average waiting time + 100 hours of manufacturing time), and for C33 it is 375 hours (325 hours of average waiting time + 50 hours of manufacturing time). Note that C33 spends 86.67% ( $325 \div 375$ ) of its manufacturing lead time just waiting for manufacturing to start!

### On-Time Performance

**On-time performance** refers to situations in which the product or service is actually delivered at the time it is scheduled to be delivered. Customer orders for products or services generally specify quantity, cost, and delivery time. For example, Federal Express specifies a price per package and a next-day delivery time for its overnight courier service. Delivering packages early the next day, say by 9 A.M. rather than 10:30 A.M., would decrease customer-response time. On-time performance, on the other hand, measures how often Federal Express meets its stated delivery time of 10:30 A.M. There is a trade-off, however, between customer-response time and on-time performance. Simply scheduling longer customer-response times, say, delivery by 1 P.M. the next day, makes achieving on-time performance easier.

On-time performance is an important element of customer satisfaction because customers want and expect to receive things when they are supposed to. An airline that gets passengers to their destination on time is likely to enjoy competitive advantage. On-time performance in the airline industry is becoming increasingly prominent. For example, on the basis of statistics maintained by the Department of Transportation, Northwest Airlines reported that it was rated the number one U.S. airline for on-time performance in December 1994 (84.7% of its daily flights arrived within 15 minutes of the scheduled time). Management accountants track information on customer-response time and on-time performance because companies use these measures to evaluate managers.

## COSTS OF TIME

### Relevant Revenues and Relevant Costs

Should FW introduce product C33? Consider the following information:

Product	Average Number of Orders	Average Selling Price per Order If Average Manufacturing Lead Time		Direct Material Costs per Order	Inventory Carrying Costs per Order per Hour
		Less than 300 Hours	More than 300 Hours		
A22	30	\$22,000	\$21,500	\$16,000	\$1.00
C33	10	10,000	9,600	8,000	0.50

Note that manufacturing lead times affect both revenues and costs in our example. Revenues are affected because customers are willing to pay a slightly higher price for faster delivery. Direct materials costs and inventory carrying costs are the only costs affected by the decision to introduce C33. Inventory carrying costs usually consist of the opportunity costs of investment tied up in inventory (see Chapter 11, p. 395–396) and the relevant costs of storage such as space rental, spoilage, deterioration, and materials handling. Companies usually calculate inventory carrying costs on a per order per year basis. To simplify computations, we express inventory carrying costs on a per order per hour basis. FW incurs inventory carrying costs for the duration of the wait time and manufacturing time.

Exhibit 19-7 presents relevant revenues and relevant costs that the management accountant would calculate for this decision. The preferred alternative is not to introduce C33. Note that C33 is rejected despite having a positive contribution



# EXHIBIT 19-7

## Determining Expected Relevant Revenues and Expected Relevant Costs for Falcon Works' Decision to Introduce C33

Relevant Items	Alternative 1: Introduce C33 (1)	Alternative 2: Do Not Introduce C33 (2)	Difference (3) = (1) - (2)
Expected revenues	\$741,000*	\$660,000†	\$81,000
Expected variable costs	560,000‡	480,000§	80,000
Expected inventory carrying costs	14,625#	7,500	7,125
Expected costs	574,625	487,500	87,125
Expected revenues minus expected costs	\$166,375	\$172,500	\$ (6,125)

\* $(\$21,500 \times 30) + (\$9,600 \times 10) = \$741,000$ ; average manufacturing lead times will be more than 300 hours.

† $\$22,000 \times 30 = \$660,000$ ; average manufacturing lead times will be less than 300 hours.

‡ $(\$16,000 \times 30) + (\$8,000 \times 10) = \$560,000$ .

§ $\$16,000 \times 30 = \$480,000$ .

# $(A22's \text{ average manufacturing lead time} \times A22's \text{ unit carrying costs per order} \times A22's \text{ expected number of orders}) + (C33's \text{ average manufacturing lead time} \times C33's \text{ unit carrying costs per order} \times C33's \text{ expected number of orders}) = (425 \times \$1.00 \times 30) + (375 \times \$0.50 \times 10) = \$12,750 + 1,875 = \$14,625$ .

||  $A22's \text{ average manufacturing lead time hours} \times A22's \text{ unit carrying costs per order} \times A22's \text{ expected number of orders} = 250 \times \$1.00 \times 30 = \$7,500$ .

margin of at least \$1,600 ( $\$9,600 - \$8,000$ ) per order. Recall, too, that FW's machine has the capacity to process C33 because the machine will, on average, use only 3,500 of the available 4,000 hours. Why is C33 rejected? *The key is to recognize the negative effects of C33 on the existing product A22.* The following table presents the expected loss in revenues and expected increase in costs of using up extra capacity on the turning machine to manufacture C33.

Product	Effect of Increasing Average Manufacturing Lead Times		Expected Loss in Revenues plus Expected Increase in Costs of Introducing C33 (3) = (1) + (2)
	Expected Loss in Revenues for A22 (1)	Expected Increase in Carrying Costs for All Products (2)	
A22	\$15,000*	\$5,250†	\$20,250
C33	—	1,875‡	1,875
Total	\$15,000	\$7,125	\$22,125

\* $(\$22,000 - \$21,500) \times 30 \text{ expected orders} = \$15,000$ .

† $(425 \text{ hours} - 250 \text{ hours}) \times \$1.00 \times 30 \text{ expected orders} = \$5,250$ .

‡ $(375 \text{ hours} - 0) \times \$0.50 \times 10 \text{ expected orders} = \$1,875$ .

*Introducing C33 causes the average manufacturing lead time of A22 to increase from 250 hours to 425 hours.* This increases inventory carrying costs. Introducing C33 also causes A22's revenues to decrease because it would, on average, take more than 300 hours to manufacture A22. The expected costs of introducing C33 equal \$22,125, which exceeds C33's expected contribution margin of \$16,000 ( $\$1,600 \text{ per order} \times 10 \text{ expected orders}$ ). FW should choose not to produce C33.

We have described a simple setting to explain the effects of uncertainty and capacity constraints and the relevant revenues and relevant costs of time.<sup>9</sup> How can delays be reduced? Increasing the capacity of the bottleneck resource can reduce lines, delays, and inventories. When demand uncertainty is high, *some* excess capacity is desirable. Companies can increase capacity in several ways. One way, for example, is

<sup>9</sup>Other complexities such as analyzing a network of machines, priority scheduling, and allowing for uncertainty in processing times are beyond the scope of this book. In these cases, the basic queuing and delay effects persist, but the precise formulas are different.



to reduce the time required for setups and processing by doing these activities more efficiently. Another is to invest in new equipment. Many companies are investing in flexible manufacturing systems that can be programmed to quickly switch from producing one product to producing another. Delays can also be reduced through careful scheduling of orders on machines—for example, by batching similar jobs together for processing.

## THEORY OF CONSTRAINTS AND THROUGHPUT CONTRIBUTION ANALYSIS

### OBJECTIVE 7

Define the three main measurements in the theory of constraints

We now expand the discussion of the previous section by considering products that are made from multiple parts and processed on different machines. With multiple parts and multiple machines, dependencies arise among operations; some operations cannot be started until parts from a previous operation are available. Some operations are bottlenecks; others are not.

The **theory of constraints (TOC)** describes methods to maximize operating income when faced with some bottleneck and some nonbottleneck operations.<sup>10</sup> It defines three measurements:

1. **Throughput contribution**, equal to sales revenue minus direct materials costs.
2. **Investments (inventory)**, equal to the sum of materials costs of direct materials inventory, work-in-process inventory, and finished goods inventory; R&D costs; and costs of equipment and buildings.
3. **Operating costs**, equal to all operating costs (other than direct materials) incurred to earn throughput contribution. Operating costs include salaries and wages, rent, utilities, and depreciation.

### OBJECTIVE 8

Describe four steps in managing bottlenecks

The objective of TOC is to increase throughput contribution while decreasing investments and operating costs. *The theory of constraints considers short-run time horizons and assumes other current operating costs to be fixed costs.* The key steps in managing bottleneck resources are as follows:

**Step 1** Recognize that the bottleneck resource determines throughput contribution of the plant as a whole.

**Step 2** Search and find the bottleneck resource by identifying resources with large quantities of inventory waiting to be worked on.

**Step 3** Keep the bottleneck operation busy and subordinate all nonbottleneck resources to the bottleneck resource. That is, the needs of the bottleneck resource determine the production schedule of nonbottleneck resources.

Step 3 represents a key notion described in Chapter 11: To maximize overall contribution margin, the plant must maximize contribution margin (in this case, throughput contribution) of the constrained or bottleneck resource (see pp. 396–398). For this reason, step 3 suggests that the bottleneck machine always be kept running, not waiting for jobs. To achieve this, companies often maintain a small buffer inventory of jobs waiting for the bottleneck machine. The bottleneck machine sets the pace for all nonbottleneck machines. That is, the output at the nonbottleneck operations are tied or linked to the needs of the bottleneck machine. For example, workers at nonbottleneck machines are not motivated to improve their productivity if the additional output cannot be processed by the bottleneck machine. Producing more nonbottleneck output only creates excess inventory; it does not increase throughput contribution.

<sup>10</sup>See E. Goldratt and J. Cox, *The Goal* (New York: North River Press, 1986); E. Goldratt, *The Theory of Constraints* (New York: North River Press, 1990); E. Noreen, D. Smith, and J. Mackey, *The Theory of Constraints and Its Implications for Management Accounting* (New York: North River Press, 1995).



**Step 4** Take actions to increase bottleneck efficiency and capacity—the objective is to increase throughput contribution minus the incremental costs of taking such actions. The management accountant plays a key role in step 4 by calculating throughput contribution, identifying relevant and irrelevant costs, and doing a cost-benefit analysis of alternative actions to increase bottleneck efficiency and capacity.

We illustrate step 4 using the example of Cardinal Industries (CI). CI manufactures car doors in two operations—stamping and pressing. Additional information is as follows:

	Stamping	Pressing
Capacity per hour	20 units	15 units
Annual capacity (6,000 hours of capacity available in each of stamping and pressing)	120,000 units	90,000 units
Annual production	90,000 units	90,000 units
Fixed operating costs (excluding direct materials)	\$720,000	\$1,080,000
Fixed operating costs per unit produced (\$720,000 ÷ 90,000; \$1,080,000 ÷ 90,000)	\$8 per unit	\$12 per unit

Each door sells for \$100 and has direct materials costs of \$40. Variable costs in other functions of the value chain—R&D, design of products and processes, marketing, distribution, and customer service—are negligible. CI's output is constrained by the capacity of 90,000 units at the pressing operation. What can CI do to relieve the bottleneck constraint at the pressing operation?

- Eliminate idle time (time when the pressing machine is neither being set up to process products nor actually processing products) at the bottleneck operation.* CI is considering permanently positioning two workers at the pressing operation. Their sole responsibility would be to unload finished units as soon as one batch of units is processed and to set up the machine to process the next batch. Suppose the annual cost of this action is \$48,000 and the effect of this action is to increase bottleneck output by 1,000 units per year. Should CI incur the additional costs? Yes, because CI's relevant throughput contribution increases by \$60,000 [1,000 units × (selling price, \$100 – direct materials costs, \$40)], which exceeds the additional cost of \$48,000. All other costs are irrelevant.
- Process only those parts or products that increase sales and throughput contribution, not parts or products that remain in finished goods or spare parts inventory.* Manufacturing products that sit in inventory does not increase throughput contribution.
- Shift products that do not have to be made on the bottleneck machine to nonbottleneck machines or to outside facilities.* Suppose the Spartan Corporation, an outside contractor, offers to press 1,500 doors at \$15 per door from direct materials that CI supplies. Spartan's quoted price is greater than CI's own operating costs in the Pressing Department of \$12 per door. Should CI accept the offer? Yes, because pressing is the bottleneck operation. Getting additional doors pressed from outside increases throughput contribution by \$90,000 [(\$100 – \$40) × 1,500 doors], while relevant costs increase by \$22,500 (\$15 × 1,500). The fact that CI's unit cost is less than Spartan's quoted price is irrelevant.

Suppose Gemini Industries, another outside contractor, offers to stamp 2,000 doors from direct materials that CI supplies at \$6 per door. Gemini's price is lower than CI's operating cost of \$8 per door in the Stamping Department. Should CI accept the offer? Since other operating costs are fixed costs, CI will not save any costs by subcontracting the stamping operations. Total costs will be greater by \$12,000 (\$6 × 2,000) under the subcontracting alternative. Stamping more doors will not increase throughput contribution, which is constrained by pressing capacity. CI should not accept Gemini's offer.

- Reduce setup time and processing time at bottleneck operations (for example, by simplifying the design or reducing the number of parts in the product).* Suppose CI can reduce setup time at the pressing operation by incurring additional costs of \$55,000 a year. Suppose further that reducing setup time enables CI to press



## Throughput Accounting at Allied-Signal Skelmersdale, United Kingdom

Allied-Signal in Skelmersdale, United Kingdom, manufactures turbochargers for the automotive industry. In the late 1980s and early 1990s, the Skelmersdale plant was forced to change from producing few products in large quantities to producing many products in small quantities in a very competitive market. The plant also had to cope with frequent changes in its sales mix. The plant often missed delivery dates and incurred high transportation costs to ship via air those parts urgently needed by its automotive customers. John Darlington, the controller of the Skelmersdale plant, recognized the important role finance and accounting could play in this environment, but "we were just not supporting, communicating with, and complementing shop-floor management—not until we began emphasizing throughput contributions."

The format designed by the Allied-Signal accountants for the throughput contribution-based operating income statement is as follows:



### Throughput Operating Income Statement (in thousands)

Sales revenues		£50,000
Direct materials costs		<u>28,500</u>
Throughput contribution		21,500
Operating costs		
Direct manufacturing labor	£ 4,275	
Engineering costs	1,767	
Other manufacturing costs	11,585	
Marketing costs	<u>1,873</u>	
Total operating costs		<u>19,500</u>
Operating income		<u>£ 2,000</u>

The Skelmersdale management viewed operating costs, other than direct materials costs, as fixed in the short-run. The key to improving profitability was maximizing throughput contribution by identifying and optimizing the use of bottleneck resources. Management reduced the load on the bottleneck machines by shifting operations performed there onto other machines. New investments to improve efficiency at nonbottleneck machines were turned down because greater efficiency at nonbottleneck machines did nothing to improve throughput contribution. Instead, Allied-Signal made additional investments to increase bottleneck capacity.

To motivate workers to improve throughput, Allied-Signal managers designed new performance measures. Instead of measuring localized efficiency such as direct labor efficiency at various operations, management introduced "adherence to schedule" as the key performance measure. Workers at nonbottleneck operations were asked not to produce more than what was required according to the bottleneck schedule. In the surplus time available to these workers, they received training in TQM practices and in improving operator skills. The Skelmersdale plant also introduced four other performance measures—costs of quality, customer due-date delivery, days inventory on hand, and manufacturing lead time—all with the objective of satisfying customers and maximizing throughput contribution. Over a 4-year period, the Skelmersdale plant showed dramatic increases in each of these measures and in profitability, cash flow, and return on investment.

Source: Adapted from J. Darlington, J. Innes, F. Mitchell, and J. Woodward, "Throughput Accounting: The Garrett Automotive Experience," *Management Accounting* (April 1992); P. Coughlan and J. Darlington, "As Fast as the Slowest Operation: The Theory of Constraints," *Management Accounting* (June 1993); and discussions with Allied-Signal, Skelmersdale, management.



2,500 more doors a year. Should CI incur the costs to reduce setup time? Yes, because throughput contribution increases by \$150,000  $[(\$100 - \$40) \times 2,500]$ , which exceeds the additional costs incurred of \$55,000. Will CI find it worthwhile to incur costs to reduce machining time at the stamping operation? No. Other operating costs will increase, but throughput contribution will remain unaffected. Throughput contribution increases only by increasing bottleneck output; increasing nonbottleneck output has no effect.

- e. *Improve the quality of parts or products manufactured at the bottleneck operation.* Poor quality is often more costly at a bottleneck operation than it is at a nonbottleneck operation. The cost of poor quality at a nonbottleneck operation is the cost of materials wasted. If CI produces 1,000 defective doors at the stamping operation, the cost of poor quality is \$40,000 (direct materials cost per unit, \$40  $\times$  1,000 doors). No throughput contribution is forgone because stamping has excess capacity. Despite the defective production, stamping can produce and transfer 90,000 doors to the pressing operation. At a bottleneck operation, the cost of poor quality is the cost of materials wasted *plus* the opportunity cost of lost throughput contribution. Bottleneck capacity not wasted in producing defective units could be used to generate additional sales and throughput contribution. If CI produces 1,000 defective units at the pressing operation, the cost of poor quality is \$100,000: direct materials cost of \$40,000 (direct materials cost per unit, \$40  $\times$  1,000 units) plus forgone throughput contribution of \$60,000  $[(\$100 - \$40) \times 1,000 \text{ doors}]$ .

The high costs of poor quality at the bottleneck operation means that bottleneck time should not be wasted processing units that are defective. That is, inspection should be done before processing parts at the bottleneck to ensure that only good-quality units are transferred to the bottleneck operation. Also, quality-improvement programs should focus on ensuring that bottlenecks produce minimal defects.

The theory of constraints emphasizes the management of bottlenecks as the key to improving the performance of the system as a whole. It focuses on the short-run maximization of throughput contribution—revenues minus materials costs. It is less useful for the long-run management of costs because it does not model the behavior of costs or identify individual activities and cost drivers. Instead, it regards operating costs as given and fixed.

## PROBLEM FOR SELF-STUDY

### PROBLEM

Let us revisit the Falcon Works (FW) example. FW has convinced all its customers to place orders for A22 in order sizes of 500 units. FW expects to receive and manufacture 60 orders of A22. Each order will take 54 hours of manufacturing time (8 hours of setup time plus 46 hours of processing time). Assume the following with respect to A22: Average selling price per order, if average manufacturing lead time is less than 300 hours, is \$11,000; average selling price per order, if average manufacturing lead time is greater than 300 hours, is \$10,750; direct materials costs per order are \$8,000; and inventory carrying costs per order are \$0.50 per order per hour. Assume the same data for C33 as in the chapter example (p. 695). Given this new information, FW is reconsidering whether it should introduce C33. What should FW do?

### SOLUTION

Average waiting time for A22 if C33 is not introduced (using the formula from p. 695) is

$$\frac{60 \times (54)^2}{2 \times [4,000 - (60 \times 54)]} = \frac{60 \times 2,916}{2 \times (4,000 - 3,240)} = \frac{174,960}{2 \times 760} = \frac{174,960}{1,520} = 115 \text{ hours}$$



Average waiting time for A22 if C33 is introduced (using the formula from p. 695) is

$$\frac{[60 \times (54)^2] + [10 \times (50)^2]}{2 \times [4,000 - (60 \times 54) - (10 \times 50)]} = \frac{(60 \times 2,916) + (10 \times 2,500)}{2 \times (4,000 - 3,240 - 500)} \\ = \frac{174,960 + 25,000}{2 \times 260} = \frac{199,960}{520} = 385 \text{ hours}$$

Average manufacturing lead time for A22 = 385 + 54 = 439 hours

Average manufacturing lead time for C33 = 385 + 50 = 435 hours

The following table describes the expected loss in revenues and expected increase in costs from introducing C33.

Product	Effect of Increasing Average Manufacturing Lead Times		Expected Loss in Revenues plus Expected Increase in Costs of Introducing C33 (3) = (1) + (2)
	Expected Loss in Revenues for A22 (1)	Expected Increase in Carrying Costs for All Products (2)	
A22	\$15,000*	\$ 9,720†	\$24,720
C33	—	2,175‡	2,175
Total	<u>\$15,000</u>	<u>\$11,895</u>	<u>\$26,895</u>

\*(\$11,000 - \$10,750) × 60 orders = \$15,000.

†(439 hours - 115 hours) × \$0.50 × 60 orders = \$9,720.

‡(435 hours - 0) × \$0.50 × 10 orders = \$2,175.

FW is better off not introducing C33. The additional costs of \$26,895 exceed C33's expected contribution of \$16,000 (\$1,600 per order × 10 orders).

## SUMMARY

The following points are linked to the chapter's learning objectives.

1. Four cost categories in a costs of quality program are *prevention costs* (costs incurred in precluding the manufacture of products that do not conform to specifications), *appraisal costs* (costs incurred in detecting which of the individual products produced do not conform to specifications), *internal failure costs* (costs incurred when a nonconforming product is detected before its shipment to customers), and *external failure costs* (costs incurred when a nonconforming product is detected after its shipment to customers).
2. Three methods that companies use to improve quality are *control charts*, to distinguish random variations from other sources of variation in an operating process; *Pareto diagrams*, which indicate how frequently each type of failure occurs; and *cause-and-effect diagrams*, which identify potential factors or causes of failure.
3. The relevant costs of quality improvement are the incremental costs incurred to implement the quality program. The relevant benefits are the savings in total costs and the estimated increase in contribution margin from the higher sales that will result from the quality improvements.
4. Nonfinancial measures of customer satisfaction include the number of customer complaints, the on-time delivery rate, and the customer-response time. Nonfinancial measures of internal performance include product defect levels, process yields, and manufacturing lead times.



5. Financial measures are helpful to evaluate trade-offs among prevention and failure costs. They focus attention on how costly poor quality can be. Nonfinancial measures help focus attention on the precise problem areas that need attention.
6. *Customer-response time* is the amount of time from when a customer places an order for a product or requests service to when the product or service is delivered to the customer. Lines and delays occur because of (a) uncertainty about when customers will order products or services, and (b) limited capacity and bottlenecks. Bottlenecks are operations at which the work to be performed approaches or exceeds the available capacity. The costs of lines and delays include lower revenues and increased inventory carrying costs.
7. The three main measurements in the theory of constraints are throughput contribution (equal to sales dollars minus direct materials costs); investments or inventory (equal to the sum of materials costs of direct materials inventory, work-in-process inventory and finished goods inventory; R&D costs; and costs of equipment and buildings); and operating costs (equal to all operating costs other than direct materials costs incurred to earn throughput contribution).
8. The four steps in managing bottlenecks are (a) recognize that the bottleneck operation determines throughput contribution, (b) search for and find the bottleneck, (c) keep the bottleneck busy and subordinate all nonbottleneck operations to the bottleneck operation, and (d) increase bottleneck efficiency and capacity.

## TERMS TO LEARN

This chapter and the Glossary at the end of this book contain definitions of the following important terms:

appraisal costs (p. 683)	manufacturing cycle time (694)
average waiting time (695)	manufacturing lead time (694)
bottleneck (694)	on-time performance (696)
cause-and-effect diagram (687)	Pareto diagram (687)
control chart (686)	prevention costs (683)
costs of quality (COQ) (683)	theory of constraints (TOC) (698)
customer-response time (693)	throughput contribution (698)
external failure costs (684)	time driver (694)
internal failure costs (684)	

## ASSIGNMENT MATERIAL

### QUESTIONS

- 19-1 Describe some of the benefits of improving quality.
- 19-2 How does conformance quality differ from quality of design? Explain.
- 19-3 Name two items classified as prevention costs.
- 19-4 Distinguish between internal failure costs and external failure costs.
- 19-5 Describe three methods that companies use to identify quality problems.
- 19-6 "Companies should focus on financial measures of quality because these are the only measures of quality that can be linked to bottom-line performance." Do you agree? Explain.
- 19-7 Give two examples of nonfinancial measures of customer satisfaction.
- 19-8 Give two examples of nonfinancial measures of internal performance.
- 19-9 Distinguish between customer-response time and manufacturing lead time.
- 19-10 "There is no trade-off between customer-response time and on-time performance." Do you agree? Explain.



- 19-11 Give two reasons why waiting lines and delays occur.
- 19-12 "Companies should always make and sell all products whose selling prices exceed variable costs." Do you agree? Explain.
- 19-13 Describe the three main measures used in the theory of constraints.
- 19-14 Describe the four key steps in managing bottleneck resources.
- 19-15 Describe three ways to improve the performance of a bottleneck operation.

## EXERCISES

- 19-16 **Cost of quality program, nonfinancial quality measures.** Baden Engineering manufactures automotive parts. A major customer has just given Baden an edict: "Improve quality or no more business." Hans Reichelstein, the controller of Baden Engineering, is given the task of developing a COQ program. He seeks your advice on classifying each of items a–g as (i) a prevention cost, (ii) an appraisal cost, (iii) an internal failure cost, or (iv) an external failure cost.
- Cost of inspecting products on the production line by Baden quality inspectors.
  - Payment of travel costs for a Baden Engineering customer representative to meet with a customer who detected defective products.
  - Costs of reworking defective parts detected by Baden Engineering's quality-assurance group.
  - Labor cost of the product designer at Baden Engineering whose task is to design components that will not break under extreme temperature variations.
  - Cost of automotive parts returned by customers.
  - Seminar costs for "Vendor Day," a program aimed at communicating to vendors the new quality requirements for purchased components.
  - Costs of spoiled parts.

### REQUIRED

- Classify the seven individual cost items into one of the four categories of prevention, appraisal, internal failure, or external failure.
- Give two examples of nonfinancial performance measures Baden Engineering could monitor as part of a total-quality-control effort.

- H 19-17 Costs of quality analysis, nonfinancial quality measures.** The Hartono Corporation manufactures and sells industrial grinders. The following table presents financial information pertaining to quality in 19\_6 and 19\_7 (in thousands):

	19_7	19_6
Sales	\$12,500	\$10,000
Line inspection	85	110
Scrap	200	250
Design engineering	240	100
Cost of returned goods	145	60
Product-testing equipment	50	50
Customer support	30	40
Rework costs	135	160
Preventive equipment maintenance	90	35
Product liability claims	100	200
Incoming materials inspection	40	20
Breakdown maintenance	40	90
Product-testing labor	75	220
Training	120	45
Warranty repair	200	300
Supplier evaluation	50	20



**REQUIRED**

1. Classify the cost items in the table into prevention, appraisal, internal failure, or external failure categories.
2. Calculate the ratio of each COQ category to sales in 19\_6 and 19\_7. Comment on the trends in costs of quality between 19\_6 and 19\_7.
3. Give two examples of nonfinancial quality measures that Hartono Corporation could monitor as part of a total-quality-control effort.

**19-18 Costs of quality analysis, nonfinancial quality measures.** Ontario Industries manufactures two types of refrigerators, Olivia and Solta. Information on each refrigerator is as follows:

	Olivia	Solta
Units manufactured and sold	10,000 units	5,000 units
Selling price	\$2,000	\$1,500
Variable costs per unit	\$1,200	\$800
Hours spent on design	6,000	1,000
Testing and inspection hours per unit	1	0.5
Percentage of units reworked in plant	5%	10%
Rework costs per refrigerator	\$500	\$400
Percentage of units repaired at customer site	4%	8%
Repair costs per refrigerator	\$600	\$450
Estimated lost sales from poor quality	—	300 units

The labor rates per hour for various activities are as follows:

Design	\$75 per hour
Testing and inspection	\$40 per hour

**REQUIRED**

1. Calculate the costs of quality for Olivia and Solta classified into prevention, appraisal, internal failure, and external failure categories.
2. For each type of refrigerator, calculate the ratio of each COQ item as a percentage of sales. Compare and comment on the costs of quality for Olivia and Solta.
3. Give two examples of nonfinancial quality measures that Ontario Industries could monitor as part of a total-quality-control effort.

**19-19 Quality improvement, relevant costs and revenues, service.** The Sloan Corporation is a moving company that transports household goods from one city to another within the continental United States. It measures service quality in terms of (a) time required to transport goods, (b) on-time delivery (within two days of agreed-upon delivery date), and (c) lost or damaged shipments. Sloan is considering investing in a new scheduling and tracking system costing \$160,000 per year that should help it improve performance with respect to items (b) and (c). The following information describes Sloan's current performance and the expected performance if the new system is implemented:

	Current Performance	Future Expected Performance
On-time delivery performance	85%	95%
Variable costs per carton lost or damaged	\$60	\$60
Number of cartons lost or damaged per year	3,000 cartons	1,000 cartons

Sloan expects that each percentage point increase in on-time performance will result in sales increases of \$20,000 per year. Sloan's contribution margin percentage is 45%.



**REQUIRED**

1. What are the annual additional costs to Sloan of choosing the new scheduling and tracking system?
2. What are the annual additional benefits of the new system?
3. Should Sloan acquire the new system?

**19-20 Quality improvement, relevant costs, and relevant revenues.** The Photon Corporation manufactures and sells 20,000 copiers each year. The variable and fixed costs of reworking and repairing copiers are as follows:

	Variable Costs	Fixed Costs	Total Costs
Rework costs per copier	\$1,600	\$2,400	\$4,000
Repair costs per copier			
Customer-support costs	80	120	200
Transportation costs for repair parts	180	60	240
Warranty repair costs	1,800	2,600	4,400

Photon's engineers are currently working to solve the problem of copies being too light or too dark. They propose changing the lens of the copier. The new lens will cost \$50 more than the old lens. Each copier uses one lens. Photon uses a 1-year time horizon for this decision, since it plans to introduce a new copier at the end of the year. Photon believes that even as it improves quality, it will not be able to save any of the fixed costs of rework or repair.

By changing the lens, Photon expects that it will (1) rework 300 fewer copiers, (2) repair 200 fewer copiers, and (3) sell 100 additional copiers. Photon's unit contribution margin on its existing copier is \$6,000.

**REQUIRED**

1. What are the additional costs of choosing the new lens?
2. What are the additional benefits of choosing the new lens?
3. Should Photon use the new lens?

**19-21 Waiting time, banks.** Regal Bank has a small branch in Orillia, Canada. The counter is staffed by one teller. The counter is open for 5 hours (300 minutes) each day (the operational capacity). It takes 5 minutes to serve a customer (service time). The Orillia branch expects to receive 40 customers each day. (Note that the number of customers corresponds to the number of orders in the chapter discussion.)

**REQUIRED**

1. Using the formula on p. 695, calculate how long, on average, a customer will wait in line before being served.
2. How long, on average, will a customer wait in line if the branch expects 50 customers each day?
3. The bank is considering ways to reduce waiting time. How long will customers have to wait on average, if the time to serve a customer is reduced to 4 minutes and the bank expects to serve 50 customers each day?

**19-22 Waiting time, relevant costs, and relevant revenues.** The Orillia branch of Regal Bank is thinking of offering additional services to its customers. Its counter is open for 5 hours (300 minutes) each day (the operational capacity). If it introduces the new services, the bank expects to serve an average of 60 customers each day instead of the 40 customers it currently averages. It will take 4 minutes to serve each customer (service time) regardless of whether or not the new services are offered. (Note that the number of customers corresponds to the number of orders in the chapter discussion.)

**REQUIRED**

1. Using the formula on p. 695, calculate how long, on average, a customer will wait in line before being served.



2. Regal Bank's policy is that the average waiting time in the line should not exceed 5 minutes. The bank cannot reduce the time to serve a customer below 4 minutes without significantly affecting quality. To reduce average waiting time for the 60 customers it expects to serve each day, the bank decides to keep the counter open for 336 minutes each day. Verify that by keeping the counter open for a longer time, the bank will be able to achieve its goal of an average waiting time of 5 minutes or less.
3. The bank expects to generate, on average, \$30 in additional operating income each day as a result of offering the new services. The teller is paid \$10 per hour and is employed in increments of an hour (that is, the teller can be employed for 5, 6, 7 hours, and so on, but not for a fraction of an hour). If the bank wants average waiting time to be no more than 5 minutes, should the bank offer the new services?

**19-23 Theory of constraints, throughput contribution, relevant costs.** The Mayfield Corporation manufactures filing cabinets in two operations—machining and finishing. Additional information is as follows.

	Machining	Finishing
Annual capacity	100,000 units	80,000 units
Annual production	80,000 units	80,000 units
Fixed operating costs (excluding direct materials)	\$640,000	\$400,000
Fixed operating costs per unit produced ( $\$640,000 \div 80,000$ ; $\$400,000 \div 80,000$ )	\$8 per unit	\$5 per unit

Each cabinet sells for \$72 and has direct materials costs of \$32 incurred at the start of the machining operation. Mayfield has no other variable costs. Mayfield can sell whatever output it produces. The following requirements refer only to the preceding data; there is *no connection* between the situations.

**REQUIRED**

1. Mayfield is considering using some modern jigs and tools in the finishing operation that would increase annual finishing output by 1,000 units. The annual cost of these jigs and tools is \$30,000. Should Mayfield acquire these tools?
2. The production manager of the Machining Department has submitted a proposal to do faster setups that would increase the annual capacity of the Machining Department by 10,000 units and cost \$5,000 per year. Should Mayfield implement the change?

**19-24 Theory of constraints, throughput contribution, relevant costs.** Refer to the information in Exercise 19-23 in answering the following requirements; there is no connection between the situations.

**REQUIRED**

1. An outside contractor offers to do the finishing operation for 12,000 units at \$10 per unit, double the \$5 per unit that it costs Mayfield to do the finishing in-house. Should Mayfield accept the subcontractor's offer?
2. The Hunt Corporation offers to machine 4,000 units at \$4 per unit, half the \$8 per unit that it costs Mayfield to do the machining in-house. Should Mayfield accept the subcontractor's offer?

**19-25 Theory of constraints, throughput contribution, quality.** Refer to the information in Exercise 19-23 in answering the following requirements; there is no connection between the situations.

**REQUIRED**

1. Mayfield produces 2,000 defective units at the machining operation. What is the cost to Mayfield of the defective items produced? Explain your answer briefly.
2. Mayfield produces 2,000 defective units at the finishing operation. What is the cost to Mayfield of the defective items produced? Explain your answer briefly.



## PROBLEMS

**19-26 Quality improvement, relevant costs, and relevant revenues.** The Thomas Corporation sells 300,000 V262 valves to the automobile and truck industry. Thomas has a capacity of 110,000 machine-hours and can produce 3 valves per machine-hour. V262's contribution margin per unit is \$8. Thomas sells only 300,000 valves because 30,000 valves (10% of the good valves) need to be reworked. It takes 1 machine-hour to rework 3 valves so that 10,000 hours of capacity are lost in the rework process. Thomas's rework costs are \$210,000. Rework costs consist of

Direct materials and direct rework labor (variable costs)	\$3 per unit
Fixed costs of equipment, rent, and overhead allocation	\$4 per unit

Thomas's process designers have come up with a modification that would maintain the speed of the process and would ensure 100% quality and no rework. The new process would cost \$315,000 per year. The following additional information is available:

- ◆ The demand for Thomas's V262 valves is 370,000 per year.
- ◆ The Jackson Corporation has asked Thomas to supply 22,000 T971 valves if Thomas implements the new design. The contribution margin per T971 valve is \$10. Thomas can make two T971 valves per machine-hour on the existing machine with 100% quality and no rework.

### REQUIRED

1. Suppose Thomas's designers implemented the new design. Should Thomas accept Jackson's order for 22,000 T971 valves? Explain.
2. Should Thomas implement the new design?
3. What nonfinancial and qualitative factors should Thomas consider in deciding whether to implement the new design?

**19-27 Quality improvement, relevant costs, and relevant revenues.** The Tan Corporation makes multicolor plastic lamps in two operations, molding and welding. The molding operation has a capacity of 200,000 units per year; welding has a capacity of 300,000 units per year. Annual costs of quality information recorded by Tan is as follows:

◆ Design of product and process costs	\$240,000
◆ Inspection and testing costs	170,000
◆ Scrap costs (all in the molding department)	750,000

The demand for lamps is very strong. Tan will be able to sell whatever output quantities it can produce at \$40 per lamp.

Tan can start only 200,000 units into production in the Molding Department because of capacity constraints on the molding machines. If a defective unit is produced at the molding operation, it must be scrapped, and the scrap yields no revenue. Of the 200,000 units started at the molding operation, 30,000 units (15%) are scrapped. Scrap costs, based on total (fixed and variable) manufacturing costs incurred up to the molding operation, equal \$25 per unit as follows:

Direct materials (variable)	\$16 per unit
Direct manufacturing labor, setup labor, and materials-handling labor (variable)	3 per unit
Equipment, rent, and other allocated overhead including inspection and testing costs on scrapped parts (fixed)	6 per unit
	<u>\$25 per unit</u>

The good units from the Molding Department are sent to the Welding Department. Variable manufacturing costs at the Welding Department are \$2.50 per unit. There is no scrap in the Welding Department. Therefore, Tan's total sales quantity equals the Molding Department's output. Tan incurs no other variable costs.



Tan's designers have determined that adding a different type of material to the existing direct materials would reduce scrap to zero, but it would increase the variable costs per unit in the Molding Department by \$3. Recall that only 200,000 units can be started each year.

#### REQUIRED

1. What is the additional direct materials cost of implementing the new method?
2. What is the additional benefit to Tan from using the new material and improving quality?
3. Should Tan use the new material?
4. What other nonfinancial and qualitative factors should Tan consider in making a decision?

**19-28 Statistical quality control, airline operations.** Peoples Skyway operates daily round-trip flights on the London–New York route using a fleet of three 747s, the *Spirit of Birmingham*, the *Spirit of Glasgow*, and the *Spirit of Manchester*. The budgeted quantity of fuel for each round-trip flight is the mean (average) fuel usage. Over the last 12 months, the average fuel usage per round-trip is 100 gallon-units with a standard deviation of 10 gallon-units. A gallon-unit is 1,000 gallons.

Cilla Black, the operations manager of Peoples Skyway, uses a statistical quality control (SQC) approach in deciding whether to investigate fuel usage per round-trip flight. She investigates those flights with fuel usage greater than two standard deviations from the mean.

In October, Black receives the following report for round-trip fuel usage by the three planes operating on the London–New York route:

Flight	<i>Spirit of Birmingham</i> (Gallon-Units)	<i>Spirit of Glasgow</i> (Gallon-Units)	<i>Spirit of Manchester</i> (Gallon-Units)
1	104	103	97
2	94	94	104
3	97	96	111
4	101	107	104
5	105	92	122
6	107	113	118
7	111	99	126
8	112	106	114
9	115	101	117
10	119	93	123

#### REQUIRED

1. Using the  $\pm 2\sigma$  rule, what variance investigation decisions would be made?
2. Present SQC charts for round-trip fuel usage for each of the three 747s in October. What inferences can you draw from them?
3. Some managers propose that Peoples Skyway present its SQC charts in monetary terms rather than in physical quantity terms (gallon-units). What are the advantages and disadvantages of using monetary fuel costs rather than gallon-units in the SQC charts?

**19-29 Compensation linked with profitability, on-time delivery, and external quality performance measures; balanced scorecard.** Pacific-Dunlop supplies tires to major automotive companies. It has two tire plants in North America, in Detroit and Los Angeles. The quarterly bonus plan for each plant manager has three components:

- a. *Profitability performance.* Add 2% of operating income.
- b. *On-time delivery performance.* Add \$10,000 if on-time delivery performance to the ten most important customers is 98% or better. If on-time performance is below 98%, add nothing.



c. *Product quality performance.* Deduct 50% of cost of sales returns from the ten most important customers.

Quarterly data for 19\_7 on the Detroit and Los Angeles plants are as follows:

	January–March	April–June	July–September	October–December
<b>Detroit</b>				
Operating income	\$800,000	\$850,000	\$700,000	\$900,000
On-time delivery	98.4%	98.6%	97.1%	97.9%
Cost of sales returns	\$18,000	\$26,000	\$10,000	\$25,000
<b>Los Angeles</b>				
Operating income	\$1,600,000	\$1,500,000	\$1,800,000	\$1,900,000
On-time delivery	95.6%	97.1%	97.9%	98.4%
Cost of sales returns	\$35,000	\$34,000	\$28,000	\$22,000

#### REQUIRED

1. Compute the bonuses paid each quarter of 19\_7 to the plant managers of the Detroit and Los Angeles plants.
2. Discuss the three components of the bonus plan as measures of profitability, on-time delivery, and product quality.
3. Why would you want to evaluate plant managers on the basis of both operating income and on-time delivery?
4. Give one example of what might happen if on-time delivery were dropped as a performance-evaluation measure.

**19-30 Waiting times, manufacturing lead times.** The SRG Corporation uses an injection molding machine to make a plastic product, Z39. SRG makes products only after receiving firm orders from its customers. SRG estimates that it will receive 50 orders for Z39 (each order is for 1,000 units) during the coming year. Each order of Z39 will take 80 hours of machine time (4 hours to clean and prepare the machine, called setup, and 76 hours to process the order). The annual capacity of the machine is 5,000 hours.

#### REQUIRED

1. What percentage of the total available machine capacity does SRG expect to use during the coming year?
2. Calculate the average amount of time that an order for Z39 will wait in line before it is processed and the average manufacturing lead time per order for Z39.
3. SRG is considering introducing a new product, Y28. SRG estimates that, on average, it will receive 25 orders of Y28 (each order for 200 units) in the coming year. Each order of Y28 will take 20 hours of machine time (2 hours to clean and prepare the machine, and 18 hours to process the order). The average demand for Z39 will be unaffected by the introduction of Y28. Calculate the average waiting time for an order received and the average manufacturing lead time per order for each product, if SRG introduces Y28.
4. If SRG introduces Y28, on average what fraction of the total manufacturing lead time will each order of Y28 spend just waiting to be processed?
5. Briefly describe why delays occur in the processing of Z39 and Y28.

**H 19-31 Waiting times, relevant revenues and relevant costs (continuation of 19-30).** SRG is still deciding whether or not it should introduce and sell Y28. The following table provides information on selling prices, variable costs, and inventory carrying costs for Z39 and Y28. SRG will incur additional variable costs and inventory carrying costs for Y28 only if it introduces Y28. Fixed costs equal to 40% of variable costs are allocated to all products produced and sold during the year.



Product	Average Number of Orders	Average Selling Price per Order if Average Manufacturing Lead Time Is		Variable Costs per Order	Inventory Carrying Costs per Order per Hour
		Less than 320 Hours	More than 320 Hours		
Z39	50	\$27,000	\$26,500	\$15,000	\$0.75
Y28	25	8,400	8,000	5,000	0.25

#### REQUIRED

1. Should SRG manufacture and sell Y28? Show all your computations.
2. What is the cutoff price per order above which SRG should manufacture and sell Y28 and below which SRG should choose not to manufacture and sell Y28?

**19-32 Waiting times, manufacturing lead times.** The Casiopia Corporation makes wire harnesses for the aircraft industry. Casiopia is uncertain about when and how many customer orders will be received. Casiopia makes harnesses only after receiving firm orders from its customers. Casiopia has recently purchased a new machine to make two wire harnesses, G72 and R76. Casiopia's marketing manager, Peter Chalos, estimates that Casiopia will receive 125 orders for G72 during the coming year. Each order of G72 will take 40 hours of machine time. The marketing manager also estimates that Casiopia will receive 10 orders for R76 during the upcoming year. Each order of R76 will take 50 hours of machine time. The annual capacity of the new machine is 6,000 hours.

#### REQUIRED

1. Calculate the average manufacturing lead times per order of G72 and R76 if Casiopia manufactures both products.
2. Calculate the average manufacturing lead time per order if Casiopia only manufactures G72.

**19-33 Waiting times, relevant revenues and relevant costs (continuation of 19-32).** The following table provides information on the average number of orders, selling prices, variable costs, and inventory carrying costs for G72 and R76 for next year. Casiopia will incur additional variable costs and inventory carrying costs for R76 only if it produces R76. Fixed costs equal to 30% of variable costs are allocated to all products produced and sold.

Product	Average Number of Orders	Average Selling Price per Order if Average Manufacturing Lead Time Is		Variable Costs per Order	Inventory Carrying Costs per Order per Hour
		Less than 200 Hours	More than 200 Hours		
G72	125	\$15,000	\$14,400	\$10,000	\$0.50
R76	10	13,500	12,960	9,000	0.45

Peter Chalos and the CEO, Laura Minton, met to discuss which products the company should make and sell.

Laura Minton: The numbers indicate that both G72 and R76 are profitable products. I think we should manufacture and market both products.

Peter Chalos: I am not so sure. Since both products use a common machine, freeing up capacity—for example, by not producing and selling R76—could enable us to reduce the manufacturing lead time to make and sell G72 resulting in higher revenues per order of G72.

#### REQUIRED

1. Suppose Casiopia is choosing between the two following alternatives: (a) making and selling both G72 and R76, and (b) making and selling only G72. What should Casiopia do?



2. What is the cutoff price per order above which Casiopia should manufacture and sell R76 and below which Casiopia should not manufacture and sell R76?
3. What other factors should Casiopia Corporation consider in choosing among the alternatives described in requirement 1?

**19-34 Theory of constraints, throughput contribution, relevant costs.** Colorado Industries manufactures electronic testing equipment. Colorado also installs the equipment at the customer's site and ensures that it functions smoothly. Additional information on the Manufacturing and Installation Departments is as follows (capacities are expressed in terms of the number of units of equipment):

	Equipment Manufactured	Equipment Installed
Annual capacity	400 units per year	300 units per year
Equipment manufactured and installed	300 units per year	300 units per year

Colorado manufactures only 300 units per year because the Installation Department has only enough capacity to install 300 units. The equipment sells for \$40,000 per unit (installed) and has direct materials costs of \$15,000. All costs other than direct materials costs are fixed. The following requirements refer only to the preceding data; there is no connection between the situations.

#### REQUIRED

1. Colorado's engineers have found a way to reduce equipment manufacturing time. The new method would cost an additional \$50 per unit and would allow Colorado to manufacture 20 additional units a year. Should Colorado implement the new method?
2. Colorado's designers have proposed a change in the direct materials that would increase direct materials costs by \$2,000 per unit. This change would enable Colorado to install 320 units of equipment each year. If Colorado makes the change, it will implement the new design on all equipment sold. Should Colorado use the new design?
3. A new installation technique has been developed that will enable Colorado's engineers to install 10 additional units of equipment a year. The new method will increase installation costs by \$50,000 each year. Should Colorado implement the new technique?
4. Colorado is considering how to motivate workers to improve their productivity (output per hour). One proposal is to evaluate and compensate workers in the Manufacturing and Installation Departments on the basis of their productivities. Do you think the new proposal is a good idea? Explain briefly.

**19-35 Theory of constraints, throughput contribution, quality, relevant costs.** Aardee Industries manufactures pharmaceutical products in two departments—Mixing and Tablet-Making. Additional information on the two departments follows. Each tablet contains 0.5 gram of direct materials.

	Mixing	Tablet Making
Capacity per hour	150 grams	200 tablets
Monthly capacity (2,000 hours available in each of mixing and tablet making)	300,000 grams	400,000 tablets
Monthly production	200,000 grams	390,000 tablets
Fixed operating costs (excluding direct materials)	\$16,000	\$39,000
Fixed operating costs per tablet (\$16,000 ÷ 200,000; \$39,000 ÷ 390,000)	\$0.08 per gram	\$0.10 per tablet



The Mixing Department makes 200,000 grams of direct materials mixture (enough to make 400,000 tablets) because the Tablet-Making Department has only enough capacity to process 400,000 tablets. All direct materials costs are incurred in the Mixing Department. Aardee incurs \$156,000 in direct materials costs. The Tablet-Making Department manufactures only 390,000 tablets from the 200,000 grams of mixture processed; 2.5% of the direct materials mixture is lost in the tablet-making process. Each tablet sells for \$1. All costs other than direct materials costs are fixed costs. The following requirements refer only to the preceding data; there is no connection between the situations.

#### REQUIRED

1. An outside contractor makes the following offer: If Aardee will supply the contractor with 10,000 grams of mixture, the contractor will manufacture 19,500 tablets for Aardee (allowing for the normal 2.5% loss during the tablet-making process) at \$0.12 per tablet. Should Aardee accept the contractor's offer?
2. Another firm offers to prepare 20,000 grams of mixture a month from direct materials Aardee supplies. The company will charge \$0.07 per gram of mixture. Should Aardee accept the company's offer?
3. Aardee's engineers have devised a method that would improve quality in the tablet-making operation. They estimate that the 10,000 tablets currently being lost would be saved. The modification would cost \$7,000 a month. Should Aardee implement the new method?
4. Suppose that Aardee also loses 10,000 grams of mixture in its mixing operation. These losses can be reduced to zero if the company is willing to spend \$9,000 per month in quality-improvement methods. Should Aardee adopt the quality-improvement method?
5. What are the benefits of improving quality at the mixing operation compared with the benefits of improving quality at the tablet-making operation?

**19-36 Quality improvement, Pareto charts, fishbone diagrams.** The Murray Corporation manufactures, sells, and installs photocopying machines. Murray has placed heavy emphasis on reducing defects and failures in its production operations. Murray wants to apply the same total-quality management (TQM) principles to managing its accounts receivables.

#### REQUIRED

1. On the basis of your knowledge and experience, what would you classify as failures in accounts receivables?
2. Give examples of prevention activities that could reduce failures in accounts receivables.
3. Draw a Pareto diagram of the types of failures in accounts receivables and a fishbone diagram of possible causes of one type of failure in accounts receivables.

**19-37 Ethics and quality.** Mary Hughes, the assistant controller of Grant Semiconductors, had recently prepared the following quality report comparing 19\_8 and 19\_7 quality performances.

	19_8	19_7
Sales	\$90,000,000	\$80,000,000
On-line inspection	\$ 700,000	\$ 600,000
Warranty liability	\$ 2,250,000	\$ 3,600,000
Product testing	\$ 2,000,000	\$ 1,000,000
Scrap	\$ 2,700,000	\$ 2,000,000
Design engineering	\$ 1,800,000	\$ 800,000
Percentage of customers complaining about quality	3%	4%



Just 2 days after preparing the report, John Emerson, the controller, had called Hughes into his office. "Our plant manager, Harry Davis, is quite upset with the recent costs of quality and nonfinancial measures of quality reports that you prepared. He feels his workers have made significant progress in improving quality at the plant but that our reports are just not showing this. He wants to apply for various quality awards that would bring a lot of prestige to Grant, but he obviously cannot do so on the basis of the numbers we are reporting. Can you look over these quality numbers, and see what you can do? I think Harry has a point. Nobody wants Grant to miss out on all the wonderful press we'd get if we won one of these quality awards." Hughes is quite certain that her numbers are correct. Yet she would very much like Grant to win these prestigious quality awards. She is confused about how to handle Emerson's request.

#### REQUIRED

1. Calculate the ratio of each costs of quality category (prevention, appraisal, internal failure and external failure) to sales in 19\_7 and 19\_8.
2. What do the reports indicate about the plant's quality performance?
3. Is John Emerson's suggestion to Hughes to recalculate her quality numbers unethical? Would it be unethical for Hughes to modify her analysis? What steps should Hughes take to resolve this situation?

### COLLABORATIVE LEARNING PROBLEM

**19-38 Quality improvement, relevant costs, and relevant revenues.** The Wellesley Corporation makes printed cloth in two operations, weaving and printing. Direct materials costs are Wellesley's only variable costs. The demand for Wellesley's cloth is very strong. Wellesley can sell whatever output quantities it produces at \$1,250 per roll to a distributor who then markets, distributes, and provides customer service for the product.

	Weaving	Printing
Monthly capacity	10,000 rolls	15,000 rolls
Monthly production	9,500 rolls	8,550 rolls
Direct material variable costs per roll of cloth processed at each operation	\$500	\$100
Fixed operating costs	\$2,850,000	\$427,500
Fixed operating costs per roll (\$2,850,000 ÷ 9,500; \$427,500 ÷ 8,550)	\$300 per roll	\$50 per roll

Monthly costs of quality information recorded by Wellesley are as follows:

◆ Product and process design costs	\$300,000
◆ Scrap costs in Weaving Department	392,500
◆ Scrap costs in Printing Department	883,500

Wellesley can start only 10,000 rolls of cloth in the Weaving Department because of capacity constraints at the weaving machines. If the weaving operation produces defective cloth, the cloth must be scrapped and yields zero net revenue. Of the 10,000 rolls of cloth started at the weaving operation, 500 rolls (5%) are scrapped. Scrap costs per roll, based on total (fixed and variable) manufacturing costs per roll incurred up to the end of the weaving operation, equal \$785 per roll as follows:

Direct materials costs per roll (variable)	\$500
Fixed operating costs per roll (\$2,850,000 ÷ 10,000 rolls)	285
Total manufacturing costs per roll in Weaving Department	<u>\$785</u>

The good rolls from the Weaving Department (called grey cloth) are sent to the Printing Department. Of the 9,500 good rolls started at the



printing operation, 950 rolls (10%) are scrapped and yield zero net revenue. Scrap costs based on total (fixed and variable) manufacturing costs per unit incurred up to the end of the printing operation, equal \$930 per roll calculated as follows:

Total manufacturing costs per roll in Weaving Department	\$785
Printing Department manufacturing costs	
Direct materials costs per roll (variable)	\$100
Fixed operating costs per roll (\$427,500 ÷ 9,500 rolls)	<u>45</u>
Total manufacturing costs per roll in Printing Department	<u>145</u>
Total manufacturing costs per roll	<u>\$930</u>

The Wellesley Corporation's total monthly sales of printed cloth equals the Printing Department's output. The following requirements refer only to the preceding data; there is no connection between the situations.

### INSTRUCTIONS

Form groups of three students to complete the following requirements.

### REQUIRED

1. The Printing Department is considering buying 5,000 rolls of grey cloth from an outside supplier at \$900 per roll. The Printing Department manager is concerned that the cost of purchasing the grey cloth is much higher than Wellesley's cost of manufacturing the grey cloth. The quality of the grey cloth acquired from outside is very similar to that manufactured in-house. The Printing Department expects that 10% of the rolls obtained from the outside supplier will be scrapped. Should the Printing Department buy the grey cloth from the outside supplier?
2. How much does Wellesley lose if a defective roll is produced in the Printing Department?
3. What is the expected loss to Wellesley if a defective roll is produced in the Weaving Department? Use the expected monetary value criterion described in the Appendix to Chapter 3 (p. 75–79).
4. Wellesley's engineers have developed a method that would lower the Printing Department's scrap rate to 6% at the printing operation. Implementing the new method would cost \$350,000 per month. Should Wellesley implement the change?
5. The design engineering team has proposed a modification that would lower the Weaving Department's scrap rate to 3%. The modification would cost the company \$175,000 per month. Should Wellesley implement the change?
6. From your answers to requirements 1–5, what general conclusions can you draw about implementing TQM programs?







# 20

## CHAPTER

# OPERATION COSTING, JUST-IN-TIME SYSTEMS, AND BACKFLUSH COSTING



Changes in companies' production systems are leading to changes in their accounting systems. American Greetings recently invested in new information systems and technology to improve product flow and reduce work-in-process inventory, as in a just-in-time system. As companies implement such changes, they will also simplify their costing systems.

## LEARNING OBJECTIVES

After studying this chapter, you should be able to

1. Explain how hybrid-costing systems develop in relation to production systems
2. Develop an understanding for an operation-costing system
3. Prepare journal entries for an operation-costing system
4. Describe a just-in-time production system
5. Identify the major features of a just-in-time production system
6. Explain how just-in-time systems simplify job costing
7. Describe journal entries for backflush-costing systems



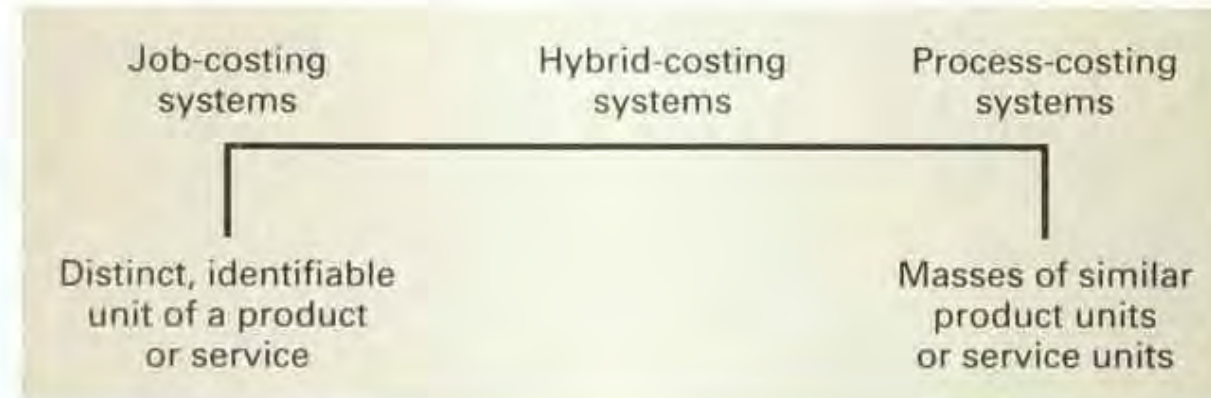
Product-costing systems do not always fall into the neat categories of job costing or process costing. Product-costing systems must often be designed to fit the particular characteristics of different production systems. In this chapter, we examine two specific production systems—a hybrid production system with both job and process characteristics and a just-in-time production system—and the costing methods associated with them.

## HYBRID AND SIMPLIFIED JOB-COSTING SYSTEMS

### OBJECTIVE 1

Explain how hybrid-costing systems develop in relation to production systems

**Hybrid-costing systems** are blends of characteristics from both job-costing systems and process-costing systems. Recall that job-costing and process-costing systems are best viewed as opposite ends of a continuum:



As we have seen, job costing usually accompanies the custom-order manufacturing of relatively heterogeneous (different) products or services (for example, printing posters, building custom-made machines, and constructing a homeowner's patio). In contrast, process costing usually accompanies the mass production and continuous-flow manufacturing of homogeneous (uniform) and standardized products (for example, printing rolls of wallpaper, stitching shirts, and bagging cement).

Obviously, a product-costing system should be tailored to the underlying production system. Hybrid-costing systems are developed to match hybrid production systems, which are blends of custom-order manufacturing and mass-production manufacturing. Manufacturers of a relatively wide variety of closely related standardized products tend to use a hybrid system. Consider the Ford Motor Company. Automobiles are manufactured in a continuous flow, but each can be customized with a special combination of motor, transmission, radio, and so on. Companies develop hybrid-costing systems to meet these individual needs.

An important and significant innovation in production systems in recent years is the Just-in-Time (JIT) system. JIT is designed to produce goods and services, as needed by customers, using minimal inventories. A feature of JIT systems and of holding minimal inventories is that the physical sequences of purchasing, production, and sales occur in quick succession. How do the unique features of JIT production affect the costing system? Streamlining the production process *simplifies job costing*—instead of costing products as they sequentially move from direct materials, to work in process and finished goods to sales, the recording of costs is often delayed until after the goods are completed or sold.

## OPERATION COSTING

### OBJECTIVE 2

Develop an understanding for an operation-costing system

### Overview of Operation Costing

An **operation** is a standardized method or technique that is performed repetitively regardless of the distinguishing features of the finished good. Operations are usually conducted within departments. For instance, a suit maker may have a cutting operation and a hemming operation within a single department. The term *operation*, however, is often used loosely. It may be a synonym for a department or a process; for example, some companies may call their finishing department a finishing process or a finishing operation.



**Operation costing** is a hybrid costing system applied to batches of similar products. Each batch of products is often a variation of a single design and proceeds through a sequence of selected (though not necessarily the same) activities or operations. Within each operation, all product units are treated exactly alike, using identical amounts of the operation's resources. Batches are also termed *production runs*.

Consider a business that makes suits. Management may select a single basic design for every suit that the company manufactures. Depending on specifications, batches of suits vary from each other. One batch may use wool; another batch, cotton. One batch may require special hand stitching; another batch, machine stitching. Other products that are often manufactured in batches are semiconductors, textiles, and shoes.

An operation-costing system uses work orders that specify the needed direct materials and step-by-step operations. Product costs are compiled for each work order. Direct materials that are unique to different work orders are specifically identified with the appropriate work order as in job-costing systems. The conversion cost for each unit passing through a given operation is the same regardless of the work order. Why? Because each unit passing through an operation uses identical amounts of that operation's resources. A single average conversion cost per unit is calculated as in process costing. For each operation, this amount is computed by aggregating conversion costs and dividing by all units passing through that operation. Our examples assume only two cost categories, direct materials and conversion costs. Of course, operation costing can have more than two cost categories. The costs in each category are identified with work orders using job-costing or process-costing methods as appropriate.

Managers often find operation costing useful in cost management. Why? Because operation costing focuses on the physical processes, or operations, of a given production system. For example, in the manufacturing of clothing, managers are concerned with fabric waste, the number of fabric layers that can be cut at one time, and so on. Operation costing captures the financial impact of the control of physical processes. Feedback from an operation-costing system can therefore provide essential insight into the control of physical processes and the management of operational costs.

## An Illustration of Operation Costing

Consider the Baltimore Company, a clothing manufacturer that produces two lines of blazers for department stores. Wool blazers use better-quality materials and undergo more operations than do polyester blazers. Let's look at the following operations in 19\_7:

	Work Order 423	Work Order 424
Direct materials	Wool Satin full lining Bone buttons	Polyester Rayon partial lining Plastic buttons
Operations		
1. Cutting cloth	Use	Use
2. Checking edges	Use	Do not use
3. Sewing body	Use	Use
4. Checking seams	Use	Do not use
5. Machine sewing of collars and lapels	Do not use	Use
6. Hand sewing of collars and lapels	Use	Do not use

Suppose work order 423 is for 50 wool blazers and work order 424 is for 100 polyester blazers. The following costs are assumed for these two work orders, which were started and completed in March 19\_7:



	Work Order 423	Work Order 424
Number of blazers	50	100
Direct materials costs	\$ 6,000	\$3,000
Conversion costs allocated:		
Operation 1	580	1,160
Operation 2	400	—
Operation 3	1,900	3,800
Operation 4	500	—
Operation 5	—	875
Operation 6	700	—
Total manufacturing costs	<u>\$10,080</u>	<u>\$8,835</u>

As in process costing, all product units in any work order are assumed to consume identical amounts of conversion costs of a particular operation. The Baltimore Company's operation-costing system uses a budgeted rate to calculate the conversion costs of each operation. For example, the costs of operation 1 might be budgeted as follows (amounts assumed):

$$\begin{aligned}
 \text{Operation 1 budgeted} &= \frac{\text{Operation 1 budgeted}}{\text{conversion cost}} &= \frac{\text{conversion costs in 19}_7}{\text{Operation 1 budgeted}} \\
 \text{rate in 19}_7 & & \text{product units in 19}_7 \\
 & &= \frac{\$232,000}{20,000 \text{ units}} \\
 & &= \$11.60 \text{ per unit}
 \end{aligned}$$

The budgeted conversion costs of operation 1 include labor, power, repairs, supplies, depreciation, and other overhead of this operation. If some units have not been completed so that all units in operation 1 have not received the same amounts of conversion costs, the conversion cost rate is computed by dividing budgeted conversion costs by the *equivalent units* of conversion costs, as in Chapters 17 and 18.

As goods are manufactured, conversion costs are allocated to the work orders processed in operation 1 by multiplying the \$11.60 conversion costs per unit by the number of product units processed. The conversion costs of operation 1 for 50 wool blazers (work order 423) are  $\$11.60 \times 50 = \$580$ , and for 100 polyester blazers (work order 424) are  $\$11.60 \times 100 = \$1,160$ . If work order 424 contained 75 units, its total costs in operation 1 would be \$870 ( $\$11.60 \times 75$ ), 150% rather than 200% of the cost of work order 423. If equivalent units have been used to calculate the conversion cost rate, costs are allocated to work orders by multiplying the conversion cost per equivalent unit by the number of equivalent units in the work order. Direct materials costs of \$6,000 for the 50 wool blazers (work order 423) and \$3,000 for the 100 polyester blazers (work order 424) are specifically identified with each order as in a job-costing system. Note that operational unit costs are assumed to be the same regardless of the work order but direct materials costs vary across orders as the materials themselves vary.

### OBJECTIVE 3

Prepare journal entries for an operation-costing system

### Journal Entries

Actual conversion costs for operation 1 in March 19<sub>7</sub> (assumed to be \$24,400) are entered into a Conversion Costs account:

1. Conversion Costs	24,400
Various accounts (such as, Wages Payable and Accumulated Depreciation)	24,400

*Summary journal entries for assigning costs to the polyester blazers (work order 424) follow. Entries for the wool blazers would be similar.*

Of the \$3,000 of direct materials for work order 424, \$2,975 are used in operation 1. The journal entry for the use of direct materials, which are traced directly to particular batches, for the 100 polyester blazers is:



2. Work in Process, Operation 1	2,975	
Materials Inventory Control		2,975

The allocation of conversion costs to products in operation costing uses the budgeted rate \$11.60 times the 100 units processed, or \$1,160.

3. Work in Process, Operation 1	1,160	
Conversion Costs Allocated		1,160

The transfer of the polyester blazers from operation 1 to operation 3 (recall that the polyester blazers do not go through operation 2) would be journalized as follows:

4. Work in Process, Operation 3	4,135	
Work in Process, Operation 1		4,135

After posting, Work in Process, Operation 1 account, appears as follows:

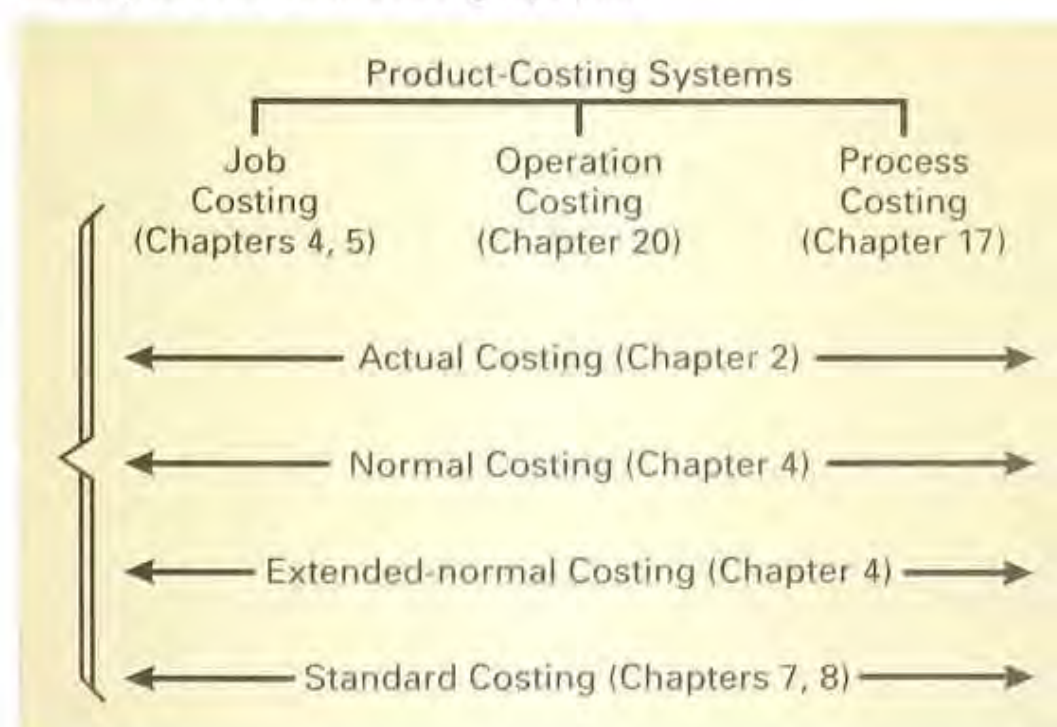
Work in Process, Operation 1			
2. Direct materials	2,975	4. Transferred to Operation 3	4,135
3. Conversion costs allocated	1,160		

The costs of the blazers are transferred through the pertinent operations and then to finished goods in the usual manner. Costs are added throughout the year in the Conversion Costs and Conversion Costs Allocated accounts. Any over- or under-allocation of conversion costs is disposed of in the same way as over- or under-allocated manufacturing overhead in a job-costing system. (See pp. 140–144 for discussion.)

## Relation of Operation Costing to Other Costing Systems

Exhibit 20-1 presents an overview of the various costing systems described in this book. Since operation costing has features of both job and process costing, it is placed on the continuum of product costing between job costing and process costing. Below the continuum, we indicate that product costs under these three product-costing systems can be computed using actual costing, normal costing, extended-normal costing, and standard costing (which were compared in Exhibit 8-5, p. 269). The Baltimore Company operation-costing example used normal costing, but actual costing, extended-normal costing, or standard costing could have been used instead. Activity-based costing may be combined with any form or combination of product-costing systems. As Chapters 4 and 5 explain, using several different cost drivers, as in activity-based costing, leads to the most accurate information for evaluating the performance of activity areas and for building up product costs. For example, in an operation-costing system, managers may use an activity-based costing system with many cost pools and cost drivers to allocate manufacturing overhead costs to individual operations.

**EXHIBIT 20-1**  
Variety of Cost Accounting Systems





## JUST-IN-TIME SYSTEMS

### OBJECTIVE 4

Describe a just-in-time production system

*Just-in-time* refers to a system in which materials arrive exactly as they are needed. Demand drives the procurement or production of any needed materials, and immediate delivery eliminates waiting times and the need for inventory. Managers in such companies as AT&T, Honda Motors, Polaroid, Siemens, and Texas Instruments, which have implemented just-in-time systems, believe inventory is waste that can be minimized, and even eliminated, through careful planning. A key element of just-in-time is *just-in-time production*.

**Just-in-time (JIT) production** is a system in which each component on a production line is produced immediately as needed by the next step in the production line.<sup>1</sup> In a JIT production line, manufacturing activity at any particular workstation is prompted by the need for that station's output at the following station. Demand triggers each step of the production process, starting with customer demand for a finished product at one end of the process and working all the way back to the demand for direct materials at the other end of the process. In this way, demand pulls a product through the production line. The demand-pull feature of JIT production systems achieves close coordination among work centers. It smoothes the flow of goods, despite low quantities of inventory.

The demand-pull system sharply differs from the traditional push-through system of manufacturing. A push-through system, often described as a *materials requirement planning (MRP)* system, uses (a) demand forecasts for the final products; (b) a bill of materials outlining the materials, components, and subassemblies for each final product; and (c) the quantities of materials, components, subassemblies, and product inventories to predetermine the necessary outputs at each stage of production. Taking into account the lead time required to purchase materials and to manufacture components and subassemblies, a master production schedule specifies the quantity and timing of each item to be produced. Once scheduled production starts, the output of each department is pushed through the system whether it is needed or not. The result is often the accumulation of inventory by workstations that receive parts they are not yet ready to process.

There are many ways to implement the demand-pull feature of JIT production, but perhaps the most common is a Kanban system. *Kanban* is the Japanese term for a visual record or card. In the simplest Kanban system, workers at one operation use a Kanban card to signal those at another operation to produce a specified quantity of a particular part. For example, suppose the assembly department of a muffler manufacturer receives an order for ten mufflers. The assembly department triggers production of the ten metal pipes it needs to make the ten mufflers by sending a Kanban card to the machining department. Only after receiving the Kanban card does the machining department begin production of the pipes. When production is complete, the machining department attaches the Kanban card to the box containing the metal pipes and ships the package downstream to the assembly department. The assembly department starts the cycle over again when it receives the next customer order.

## MAJOR FEATURES OF JIT PRODUCTION SYSTEMS

### OBJECTIVE 5

Identify the major features of a just-in-time production system

There are five main features in a JIT production system:

- ◆ Production is organized in **manufacturing cells**, a grouping of all the different types of equipment used to manufacture a given product.
- ◆ Workers are trained to be multiskilled so that they are capable of performing a variety of operations and tasks.
- ◆ Total quality management is aggressively pursued to eliminate defects.

<sup>1</sup>A detailed discussion of JIT production management can be found in M. Schniederjans, *Topics in Just-in-Time Management* (Needham Heights, Mass.: Allyn and Bacon, 1992). For case studies, see R. M. Lindsay and S. Kalagnanam, *The Adoption of Just-in-Time Production Systems in Canada and Their Association with Management Control Practices* (Hamilton, Canada: Society of Management Accountants, 1993).



- ◆ Emphasis is placed on reducing *setup time*, which is the time required to get equipment, tools, and materials ready to start the production of a component or product, and *manufacturing lead time*, which is the time from when an order is ready to start on the production line to when it becomes a finished good.
- ◆ Suppliers are carefully selected to obtain delivery of quality-tested parts in a timely manner.

## Organizing Manufacturing Cells

Conventional manufacturing plants generally have a *functional layout*, in which machines that perform the same function are located in the same area or department. JIT plants, however, organize machines in cells designed around products. Different types of machines that perform different functions needed to manufacture a product, or a family of products, are placed close to each other. Materials move from one machine to another where various operations are performed in sequence. Incoming and outgoing material stock points for individual cells are located near the cell rather than at a central location. Cells reduce materials handling costs. Forklifts and forklift operators are no longer needed to transport materials between central store rooms and between departments as in conventional manufacturing. Instead, workers or small conveyor belts carry materials from one cell station to the next.

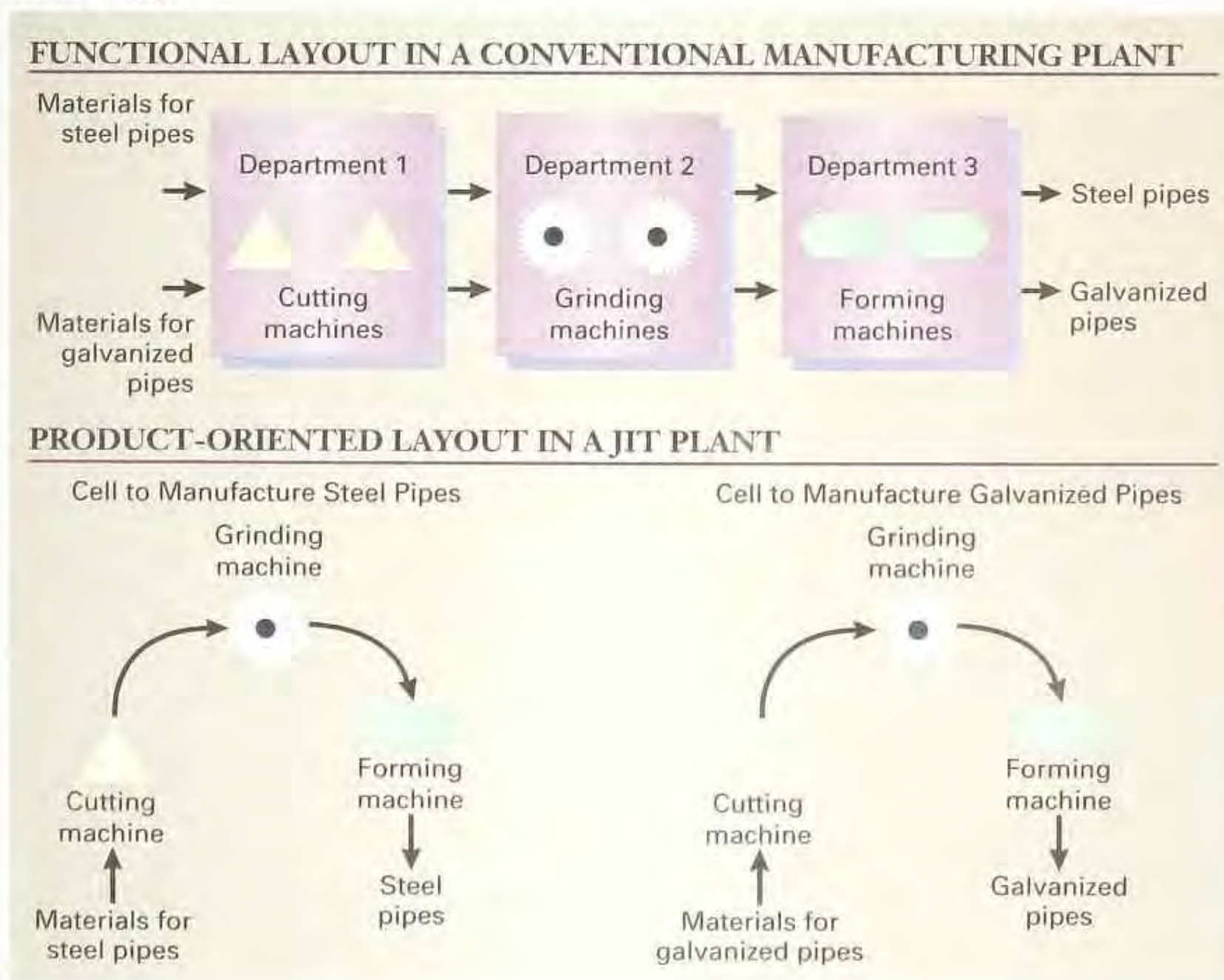
Consider the manufacture of metal pipes for muffler assembly described earlier. Exhibit 20-2 contrasts the functional layout in conventional manufacturing with the cell layout in JIT plants in this case. Note the U-shaped layout of the cell. This layout ensures that all machines and workers are located near each other. Multi-skilled workers may then be able to operate more than one machine.

## Multiskilled Workers

Workers in a cell are trained to perform all operations within the cell. Workers can then be assigned to different machines as needed to achieve smooth production flow.

### EXHIBIT 20-2

Comparing Layouts of Conventional Manufacturing and JIT Plants for the Manufacture of Metal Pipes





Workers are also trained and expected to perform minor repairs and do routine maintenance. Quality testing and inspection is also the responsibility of the workers in a cell rather than of a quality assurance department.

### Total Quality Management

If a worker at any cell discovers a defect, he or she must set off an alarm to alert others of the problem and that operation is shut down. Because of the dynamics of the demand-pull system, when one operation shuts down, all production shuts down until the problem is solved. JIT creates an urgency for solving problems immediately and eliminating the root causes of defects as quickly as possible. Therefore, total quality management is an essential component of any JIT production system.

In contrast, in many traditional production systems, extra parts and subassemblies are held at workstations in anticipation of shortages or production breakdowns. These inventories can service a downstream operation even if a defect occurs. Consequently, there is less need for and emphasis on preventing rework and spoilage relative to JIT systems.

### Reducing Manufacturing Lead Time and Setup Time

Reducing manufacturing lead time enables a company to respond better to changes in customer demand. For example, a short manufacturing lead time enables the Panasonic Corporation to rapidly restock those models of fax machines that, at any given time, are the most popular with consumers. An important aspect of reducing manufacturing lead time is reducing setup time. When setup time is long, plant managers tend to manufacture many units of a product because they want to spread the costs of the setup over as many units as possible. The higher production causes inventory to build up until such time that the units are eventually sold.

Reducing setup time makes production in smaller batches economical and worthwhile, which in turn reduces inventory levels. Companies use multiple approaches to reduce setup time. One way is to use manufacturing cells dedicated to the manufacture of a product or product family rather than multiple products. Another way is to improve setup processes and train workers to do setups more quickly. By far the most important way, however, is to automate the set up and production process by investing in *computer integrated manufacturing (CIM)*. In CIM plants, computers give instructions that automatically set up and run equipment.

### Strong Supplier Relationships

Many companies implementing JIT production also implement *JIT purchasing*. **Just-in-time (JIT) purchasing** is the purchase of goods or materials such that delivery immediately precedes demand or use. JIT plants expect JIT suppliers to provide high-quality goods and make frequent deliveries of the exact quantities specified on a timely basis. Suppliers often deliver materials directly to the plant floor to be immediately placed into production. Consequently, JIT plants require suppliers to inspect their own goods and guarantee their quality. These procedures completely eliminate nonvalue-adding costs of incoming inspection, storage, inventory, and materials handling, and this saves the JIT purchaser money.

Strong relationships with suppliers are a critical component of JIT purchasing because production stops if a supplier fails to deliver materials on time. Building partnerships with suppliers is time-consuming and costly. It entails the negotiation of long-run contracts so that minimal paperwork is involved in each individual transaction. A single telephone call or computer entry (also called electronic data interchange) triggers the delivery of material. Hence JIT companies choose to work with only a few reliable and dependable suppliers. For example, in implementing JIT purchasing, divisions of Apple Computer, IBM, and Xerox reduced the number of their suppliers by 80%, 95%, and 97%, respectively. Since JIT purchasing demands a lot from supplier companies, many suppliers are unable to provide the needed service levels.



## Financial Benefits of JIT

JIT tends to focus broadly on the control of *total manufacturing costs* instead of individual costs such as direct manufacturing labor. For example, idle time may rise because production lines are starved for materials more frequently than before. Nevertheless, many manufacturing costs will decline. JIT can provide many financial benefits, including

1. Lower investment in inventories
2. Reductions in carrying and handling costs of inventories
3. Reductions in risk of obsolescence of inventories
4. Lower investment in plant space for inventories and production
5. Reductions in setup costs and total manufacturing costs
6. Reduction in costs of waste and spoilage as a result of improved quality
7. Higher revenues as a result of responding faster to customers
8. Reductions in paperwork

Exhibit 20-3 summarizes the effects Hewlett-Packard reported from adopting JIT at several of its production plants.

## Product-Costing Benefits of JIT

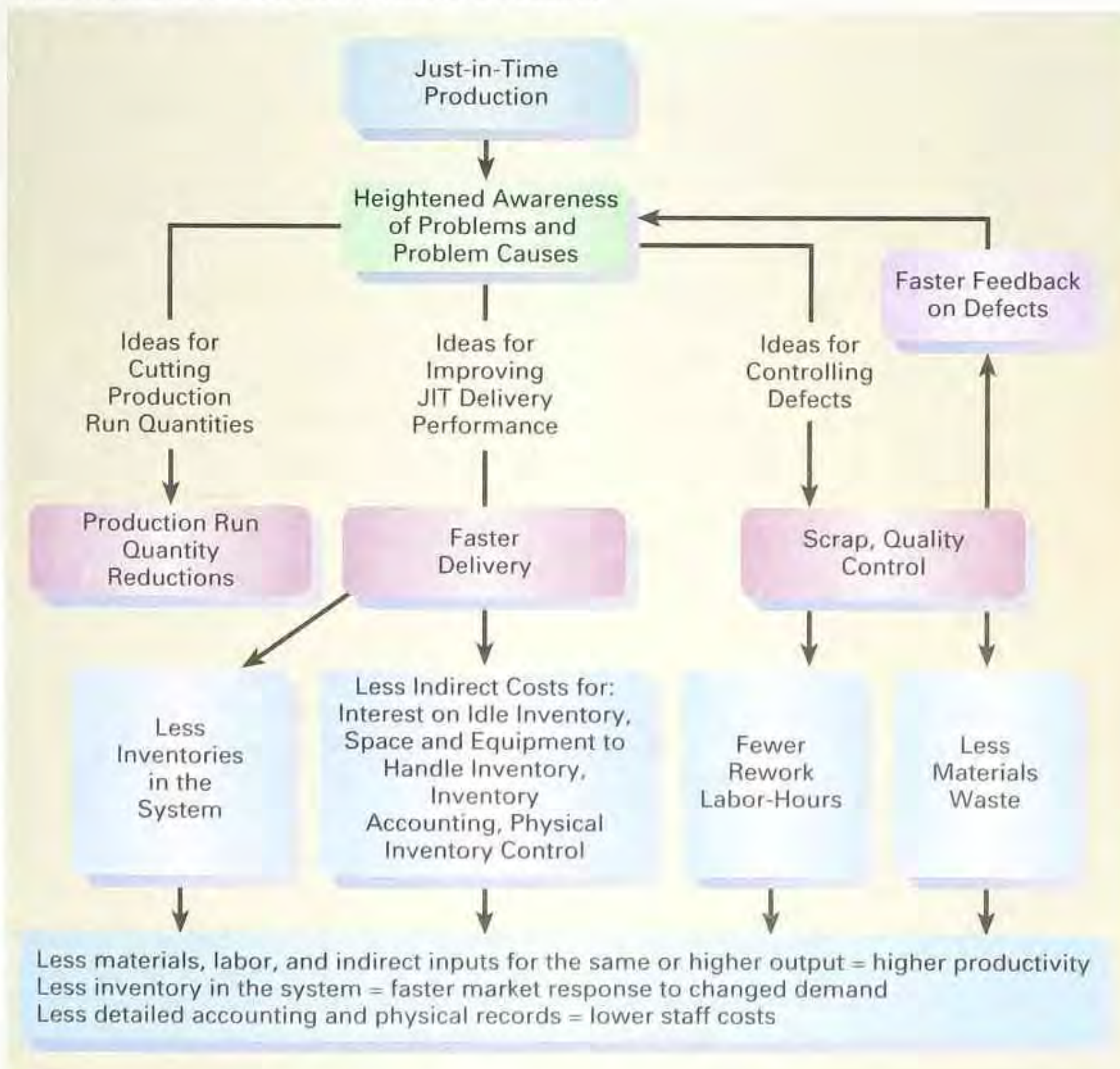
In reducing the need for materials handling, warehousing, inspection of supplies, and other activities, JIT systems reduce overhead costs. JIT systems also facilitate the direct tracing of some costs that were formerly classified as overhead. For example, the

### OBJECTIVE 6

Explain how just-in-time systems simplify job costing

EXHIBIT 20-3

The Effects of JIT Production at Hewlett-Packard





use of manufacturing cells makes it easy to trace materials handling and machine operating costs to specific products or product families made in specific cells. These costs then become direct costs of those products. Also, the use of multiskilled workers in these cells allows the costs of setup, minor maintenance, and quality inspection to become easily traced, direct costs.

## BACKFLUSH COSTING

A unique production system such as JIT leads to its own unique costing system. Organizing manufacturing in cells, reducing defects and manufacturing lead time, and ensuring timely delivery of materials enables purchasing, production, and sales to occur in quick succession with minimal inventories. The absence of inventories makes choices about cost-flow assumptions (such as, weighted-average or first-in, first-out) or inventory costing methods (such as, absorption or variable costing) unimportant—all manufacturing costs of a period flow directly into cost of goods sold. The rapid conversion of direct materials to finished goods that are immediately sold simplifies job costing.

### Simplified Budgeted or Standard Job Costing

Traditional and standard costing systems (discussed in Chapters 4, 7, and 8) use **sequential tracking** (also called **synchronous tracking**), which is any product-costing method in which the accounting system entries occur in the same order as actual purchases and production. These traditional systems track costs sequentially as products pass from direct materials, to work in process, to finished goods, and finally to sales. Sequential tracking is often expensive, especially if management tries to track direct materials requisitions and labor time tickets to individual operations and products.

An alternative to the sequential tracking approach in many costing systems is to delay the recording of journal entries until after the physical sequences have occurred. The term **backflush costing** (also called **delayed costing**, **endpoint costing**, or **post-deduct costing**) describes a costing system that delays recording changes in the status of a product being produced until good finished units appear; it then uses budgeted or standard costs to work backward to flush out manufacturing costs for the units produced. An extreme form of such delay is to wait until sale of finished units has occurred. Typically, no record of work in process appears in backflush costing.

In companies that adopt backflush costing, the following occurs:

1. Management wants a simple accounting system. Detailed tracking of direct costs through each step of the production system to the point of completion is deemed unnecessary.
2. Each product has a set of budgeted or standard costs.
3. Backflush costing reports approximately the same financial results as sequential tracking would generate.

If inventories are low, managers may not believe it worthwhile to spend resources tracking costs through Work in Process, Finished Goods, and Cost of Goods Sold. Backflush costing, therefore, is especially attractive in companies that have low inventories resulting from JIT. Backflush costing and sequential tracking will also produce approximately the same results, however, when inventory is present, provided inventories maintain stable values. Constant amounts of costs will be deferred in inventory each period.

The following examples illustrate backflush costing. To underscore basic concepts, we assume no direct materials variances in any of the examples. (We do, however, discuss variances in a separate section following Example 1.) These examples differ in the number and placement of points at which journal entries are made in the accounting system to accumulate production costs of units (also called trigger points):

### OBJECTIVE 7

Describe journal entries for backflush-costing systems



	Number of Journal Entry Trigger Points	Location of Journal Entry Trigger Points
Example 1	2	1. Purchase of direct materials (also called raw materials) 2. Completion of good finished units of product
Example 2	2	1. Purchase of raw materials 2. Sale of good finished units of product
Example 3	1	1. Completion of good finished units of product

## CONCEPTS IN ACTION

### Implementing JIT Production and Backflushing at the Eaton Corporation

In the late 1980s, the Eaton Corporation's plant in Lincoln, Illinois, was in trouble. A few short years later, this plant, which manufactures breaker boxes, safety switches, and meter centers, is booming. The key reason? Implementing the demand-pull JIT production system in place of the push-through MRP system to streamline and simplify the production process. The Lincoln plant changed its physical layout to form cells, trained its workers in multiple skills, emphasized quality, and reduced manufacturing and setup time. Inventory was reduced by a third. But it did something else. It gave up-to-date information about customer orders, quantities in inventory, due dates, and financial results to teams of workers, empowered to operate the cells. Workers in turn decided what to work on, and who worked where, when, and for how long.

The plant controller, Al Houser, and his staff devised backflushing as an elementary way to track inventory in the new JIT environment. Rather than report on the flow of raw material and work in process through 15 or so manufacturing steps, the staff calculates product costs only when the product is completed and ready to be shipped. Gone is the tedious accounting of work in process. Eaton uses information from the bill of materials about the material content of every finished item and data from the list of operations performed to adjust inventory downward automatically.

The shipping dock prints bar-coded documents for each customer shipment. That single document backflushes inventory, creates the necessary accounting entries, generates customer invoices, and drives the computerized manifests for Eaton's freight carriers. Simultaneously, Eaton's divisional sales headquarters in Milwaukee receives the accounting information it needs in one transaction.

The results from JIT have been impressive. In a 3-year span, the plant's breakeven point has come down by 18%, its gross margins have become stronger, and its labor productivity has increased 26%. It can now fulfill a customer order in one day rather than five and has only once missed its goal of shipping 95% of its products on time.

Source: Adapted from P. Houston, "Old System, New Life: Eaton Corporation Utilizes Just-in-Time Manufacturing," *Corporate Computing*, November 1992.



#### Example 1: Trigger Points Are Materials Purchases and Finished Goods Completion

This example uses two trigger points to illustrate how backflushing can eliminate the need for a separate Work in Process account. A hypothetical company, Silicon Valley



Computer (SVC), produces keyboards for personal computers. For April, there were no beginning inventories of raw materials. Moreover, there is zero beginning and ending work in process.

SVC has only one direct manufacturing cost category (direct or raw materials) and one indirect manufacturing cost category (conversion costs). All labor costs at the manufacturing facility are included in conversion costs. From its bill of materials (description of the types and quantities of materials) and an operations list (description of operations to be undergone), SVC determines the April standard direct materials costs per keyboard unit of \$19 and the standard conversion costs of \$12. SVC has two inventory accounts:

Type	Account Title
Combined direct materials and any direct materials in work in process	Inventory: Raw and In-Process Control
Finished goods	Finished Goods Control

Trigger point 1 occurs when materials are purchased. These costs are charged to Inventory: Raw and In-Process Control.

Actual conversion costs are recorded as incurred under backflush costing, just as in other costing systems, and charged to Conversion Costs Control. Conversion costs are allocated to products at trigger point 2—the transfer of units to Finished Goods. This example assumes that under- or overallocated conversion costs are written off to cost of goods sold monthly.

SVC takes the following steps when assigning costs to units sold and to inventories.

**Step 1: Record the Direct Materials Purchased During the Accounting Period** Assume April purchases of \$1,950,000:

Entry (a)	Inventory: Raw and In-Process Control	1,950,000	
	Accounts Payable Control		1,950,000

**Step 2: Record the Incurrence of Conversion Costs During the Accounting Period** Assume that conversion costs are \$1,260,000:

Entry (b)	Conversion Costs Control	1,260,000	
	Various accounts (such as, Accounts Payable Control and Wages Payable)		1,260,000

**Step 3: Determine the Number of Finished Units Manufactured During the Accounting Period** Assume that 100,000 keyboard units were manufactured in April.

**Step 4: Compute the Budgeted or Standard Costs of Each Finished Unit** The standard cost is \$31 (\$19 direct materials + \$12 conversion costs) per unit.

**Step 5: Record the Cost of Finished Goods Completed During the Accounting Period** In this case, 100,000 units  $\times$  \$31 = \$3,100,000. This step gives backflush costing its name. Up to this point in the operations, the costs have not been recorded sequentially with the flow of product along its production route. Instead, the output trigger reaches back and pulls the standard costs of direct materials from Inventory: Raw and In-Process and the standard conversion costs for manufacturing the finished goods.

Entry (c)	Finished Goods Control	3,100,000	
	Inventory: Raw and In-Process Control		1,900,000
	Conversion Costs Allocated		1,200,000



**Step 6: Record the Cost of Goods Sold During the Accounting Period** Assume that 99,000 units were sold in April ( $99,000 \text{ units} \times \$31 = \$3,069,000$ ).

Entry (d)	Cost of Goods Sold	3,069,000	
	Finished Goods Control		3,069,000

**Step 7: Record Under- or Overallocated Conversion Costs** Actual conversion costs may be under- or overallocated in any given accounting period. Chapter 5 (pp. 140–144) discussed various ways to account for under- or overallocated manufacturing overhead costs. Many companies write off underallocations or overallocations to cost of goods sold only at year-end; other companies, like SVC, do so monthly. Companies that use backflush costing typically have low inventories, so proration of under- or overallocated costs between finished goods and cost of goods sold is less often necessary. The journal entry for the \$60,000 difference between actual conversion costs incurred and standard conversion costs allocated would be

Entry (e)	Conversion Costs Allocated	1,200,000	
	Cost of Goods Sold	60,000	
	Conversion Costs Control		1,260,000

The April ending inventory balances are

Inventory: Raw and In-Process	\$50,000	(1,950,000 - 1,900,000)
Finished Goods, 1,000 units $\times$ \$31	31,000	
Total inventories	<u>\$81,000</u>	

Exhibit 20-4, Panel A summarizes the journal entries for this example. Exhibit 20-5 provides an overview of this version of backflush costing. The elimination of the typical Work in Process account reduces the amount of detail in the accounting system. Units on the production line may still be tracked in physical terms, but there is “no attaching of costs” to specific work orders as they flow along the production cycle. In fact, there are no work orders or labor time tickets in the accounting system. Champion International uses a method similar to Example 1 in its specialty papers plant.

## Accounting for Variances

The accounting for variances between actual costs incurred and standard costs allowed and the disposition of variances is basically the same under all standard costing systems. The procedures are described in Chapters 7 and 8. In Example 1, suppose the direct materials purchased had an unfavorable price variance of \$42,000. Entry (a) would then be

Inventory: Raw and In-Process Control	1,950,000	
Raw Materials Price Variance	42,000	
Accounts Payable Control		1,992,000

Direct materials are often a large proportion of total manufacturing costs, sometimes over 60%. Consequently, many companies will at least measure the direct materials efficiency variance in total by physically comparing what remains in direct materials inventory against what should be remaining, given the output of finished goods for the accounting period. In our example, suppose that such a comparison showed an unfavorable materials efficiency variance of \$90,000. The journal entry would be

Raw Materials Efficiency Variance	90,000	
Inventory: Raw and In-Process Control		90,000

The under- or overallocated manufacturing overhead costs may be split into various overhead variances (spending variance, efficiency variance, and production-volume



**EXHIBIT 20-4**
**Journal Entries in Backflush Costing**
**PANEL A, EXAMPLE 1: TWO TRIGGER POINTS: PURCHASES OF RAW MATERIALS AND FINISHED UNITS PRODUCED**
**Transactions**

a. Purchases of raw materials	Inventory: Raw and In-Process Control	1,950,000	
	Accounts Payable Control		1,950,000
b. Incur conversion costs	Conversion Costs Control	1,260,000	
	Various Accounts		1,260,000
c. Finished units produced	Finished Goods Control	3,100,000	
	Inventory: Raw and In-Process Control		1,900,000
	Conversion Costs Allocated		1,200,000
d. Finished units sold	Cost of Goods Sold	3,069,000	
	Finished Goods Control		3,069,000
e. Under- or overallocated conversion costs	Conversion Costs Allocated	1,200,000	
	Cost of Goods Sold	60,000	
	Conversion Costs Control		1,260,000

**PANEL B, EXAMPLE 2: TWO TRIGGER POINTS: PURCHASES OF RAW MATERIALS AND FINISHED UNITS SOLD**
**Transactions**

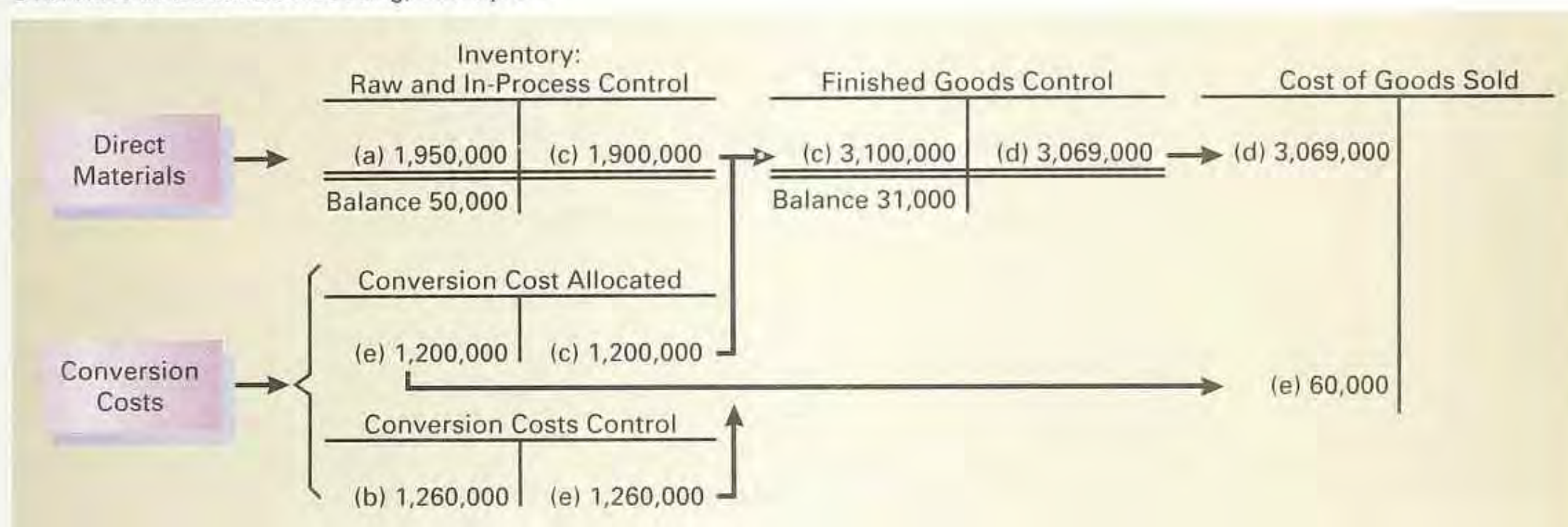
a. Purchases of raw materials	Inventory Control	1,950,000	
	Accounts Payable Control		1,950,000
b. Incur conversion costs	Conversion Costs Control	1,260,000	
	Various Accounts		1,260,000
c. Finished units produced		No entry	
d. Finished units sold	Cost of Goods Sold	3,069,000	
	Inventory Control		1,881,000
	Conversion Costs Allocated		1,188,000
e. Under- or overallocated conversion costs	Conversion Costs Allocated	1,188,000	
	Cost of Goods Sold	72,000	
	Conversion Costs Control		1,260,000

**PANEL C, EXAMPLE 3: ONE TRIGGER POINT: FINISHED UNITS PRODUCED**
**Transactions**

a. Purchases of raw materials		No entry	
b. Incur conversion costs	Conversion Costs Control	1,260,000	
	Various Accounts		1,260,000
c. Finished units produced	Finished Goods Control	3,100,000	
	Accounts Payable Control		1,900,000
	Conversion Costs Allocated		1,200,000
d. Finished units sold	Cost of Goods Sold	3,069,000	
	Finished Goods Control		3,069,000
e. Under- or overallocated conversion costs	Conversion Costs Allocated	1,200,000	
	Cost of Goods Sold	60,000	
	Conversion Costs Control		1,260,000



EXHIBIT 20-5  
Overview of Backflush Costing, Example 1



variance) as explained in Chapters 7 and 8. Using assumed numbers for the individual variances, entry (e) for the underallocated overhead of \$60,000 would then be

Conversion Costs Allocated	1,200,000
Conversion Costs Spending Variance	20,000
Conversion Costs Production-Volume Variance	50,000
Conversion Costs Efficiency Variance	10,000
Conversion Costs Control	1,260,000

If a company holds minimal Work in Process inventories, the backflush approach described in Example 1 closely approximates the costs computed using sequential tracking because the approach in Example 1 has no Work in Process inventory account.

### Example 2: Trigger Points Are Materials Purchases and Finished Goods Sales

This example, also based on SVC and using the same data, presents a backflush costing system that, relative to Example 1, is a more dramatic departure from a sequential tracking inventory costing system. The first trigger point in this example is the same as the first trigger point in Example 1 (the purchase of direct materials), but the second trigger point is the sale—not the completed manufacture—of finished units. Toyota's cost accounting at its Kentucky plant is similar to this type of costing system. There are two justifications for this accounting system:

- ◆ To remove the incentive for managers to produce for inventory. If the value of finished goods inventory includes conversion costs, managers can bolster operating income by producing more units than are sold. Having trigger point 2 as the sale instead of the completion of production, however, reduces the attractiveness of producing for inventory by recording conversion costs as period costs instead of capitalizing them as inventoriable costs.
- ◆ To increase managers' focus on selling units.

This variation of backflush costing is sometimes called "supervariable costing" or "throughput costing" and is described in Chapter 9. The approach immediately expenses conversion costs. Allied Signal Limited, Skelmersdale, United Kingdom, uses this approach.

The inventory account in this example is confined solely to direct materials (whether they are in storerooms, in process, or in finished goods). There is only one inventory account:

Type	Account Title
Combined direct materials inventory and any direct materials in work in process and finished goods	Inventory Control



Exhibit 20-4, Panel B presents the journal entries in this case. Entry (a) is prompted by the same trigger point 1 as in Example 1, the purchase of direct materials. Entry (b) for the conversion costs incurred is recorded in an identical manner as in Example 1. Trigger point 2 is the sale of good finished units (not their production, as in Example 1), so there is no entry corresponding to entry (c) of Example 1. The cost of finished units is computed only when finished units are sold (which corresponds to entry (d) of Example 1): 99,000 units sold  $\times$  \$31 = \$3,069,000, consisting of direct materials (99,000  $\times$  \$19 = \$1,881,000) and conversion costs allocated (99,000  $\times$  \$12 = \$1,188,000).

No conversion costs are inventoried. That is, compared to Example 1, Example 2 does not attach \$12,000 (\$12 per unit  $\times$  1,000 units) of conversion costs to finished goods inventory. Hence, Example 2 allocates \$12,000 less in conversion costs relative to Example 1. Of the \$1,260,000 in conversion costs, \$1,188,000 is allocated at standard cost to the units sold. The remaining \$72,000 (\$1,260,000 – \$1,188,000) of conversion costs is underallocated. Entry (e) in Exhibit 20-4, Panel B presents the journal entry if SVC, like many companies, writes off these underallocated costs monthly as additions to cost of goods sold.

The April ending balance of Inventory Control is \$69,000 (\$50,000 direct materials still on hand + \$19,000 direct materials embodied in the 1,000 units manufactured but not sold during the period). Exhibit 20-6 provides an overview of this version of backflush costing. Entries are keyed to Exhibit 20-4, Panel B. The approach described in Example 2 closely approximates the costs computed using sequential tracking when a company holds minimal work in process and finished goods inventories because the approach in Example 2 does not maintain these inventory accounts.

### Example 3: Trigger Point Is Finished Goods Completion

This example presents an extreme and simpler version of backflush costing. It has only one trigger point for making journal entries to inventory. The trigger point is SVC's completion of finished units. Exhibit 20-4, Panel C presents the journal entries in this case, using the same data as in Examples 1 and 2. Note that since the purchase of direct materials is not a trigger point, there is no entry corresponding to entry (a)—purchases of direct materials. Exhibit 20-7 provides an overview of this version of backflush costing. Entries are keyed to Exhibit 20-4, Panel C.

Compare entry (c) in Exhibit 20-4, Panel C with entries (a) and (c) in Exhibit 20-4, Panel A. The simpler version in Example 3 ignores the \$1,950,000 purchases of direct materials [entry (a) of Example 1, p. 730]. At the end of April, \$50,000 of direct materials purchased has not yet been placed into production (\$1,950,000 – \$1,900,000 = \$50,000), nor has it been entered into the inventory costing system. The Example 3 version of backflush costing is suitable for a JIT production system

EXHIBIT 20-6  
Overview of Backflush Costing, Example 2

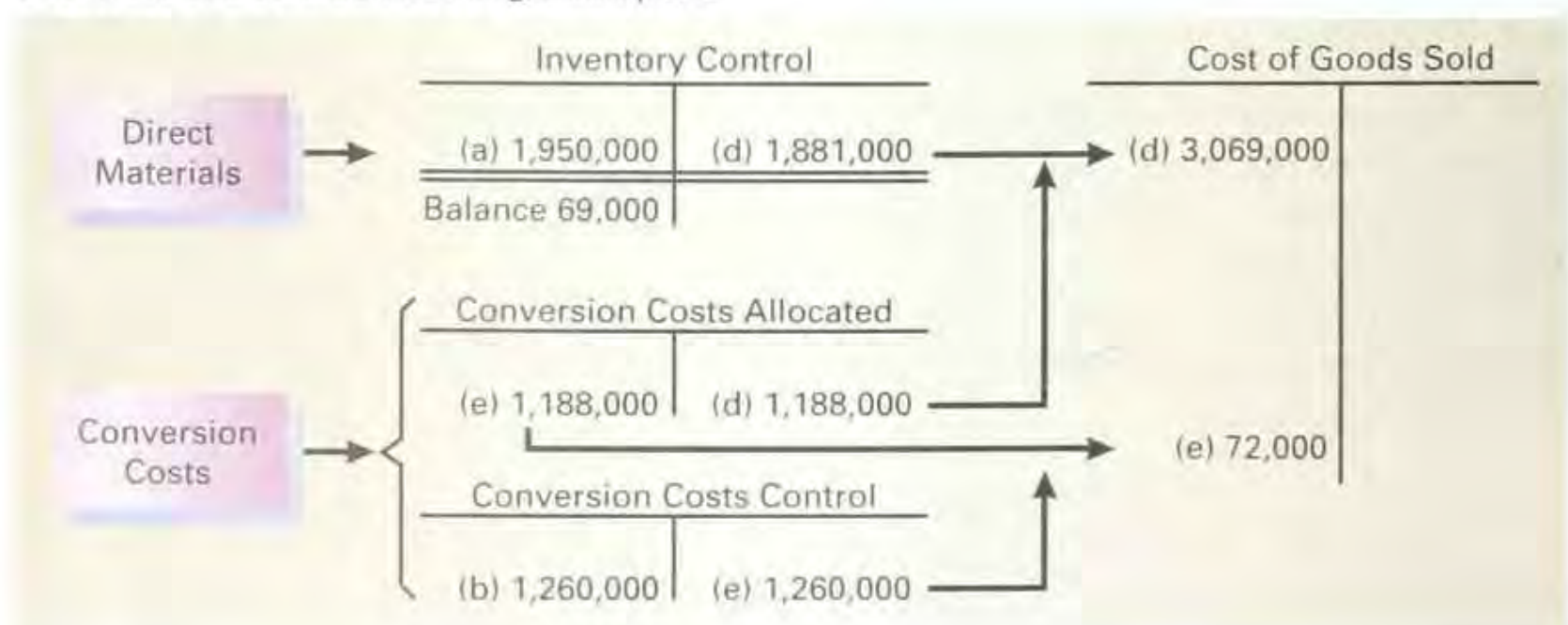
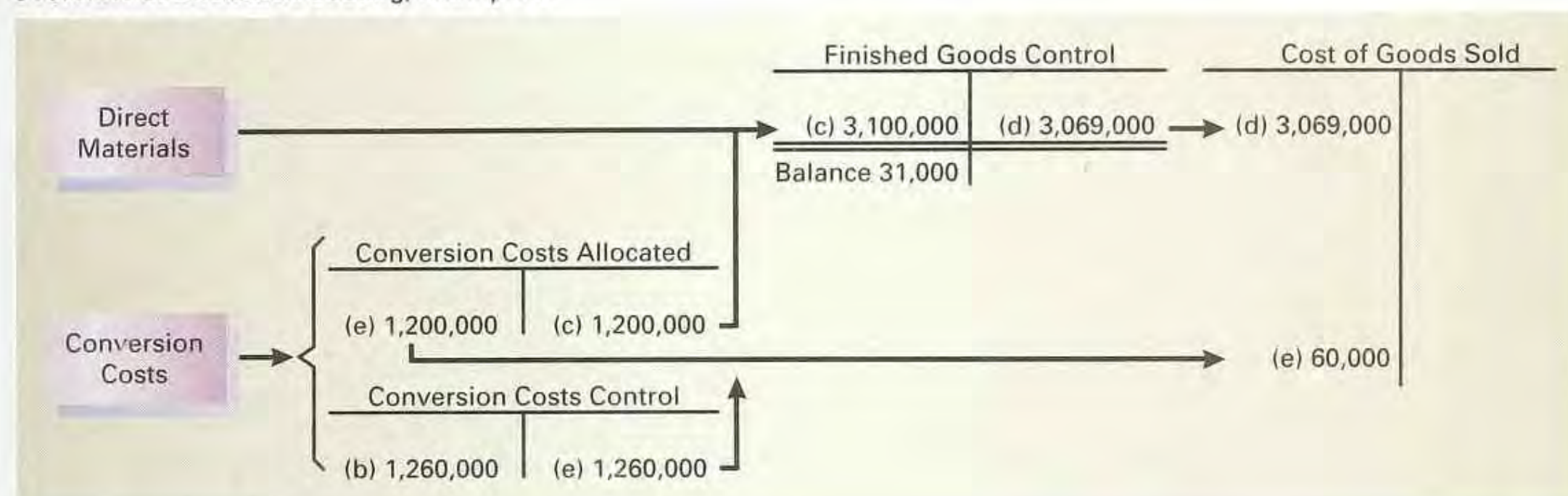




EXHIBIT 20-7  
Overview of Backflush Costing, Example 3



## SURVEYS OF COMPANY PRACTICE

### Adopt JIT and Simplify Your Life as a Management Accountant

Many companies adopting JIT production systems are reporting reductions in the complexity and detail of their management accounting systems. The results of a survey of 22 U.S. manufacturing companies implementing JIT support these claims. These manufacturers were made up of 11 machinery, 7 transportation, 2 computer, and 2 consumer products companies. On average, the companies had begun converting to JIT 4 years prior to the survey. At the time of the survey, they had converted an average 63% of their plant operations and inventory systems to JIT.

These are the key results from the survey:

- Mean reductions in four key areas following JIT adoption were
  - ◆ Number of vendors reduced by 67%
  - ◆ Quantity of rework and scrap reduced by 44%
  - ◆ Setup time for product changes on machines reduced by 47%
  - ◆ Quantity in total inventory reduced by 46%
- The types of cost accounting systems in use were

Type	Before JIT	After JIT
Job costing	70%	30%
Process costing	20	60
Hybrid costing	10	10

- Cost accounting systems following implementation of JIT were
  - ◆ Less complex 72.7%
  - ◆ More complex 27.3%
- Eight of the 22 companies adopted backflush costing after implementing JIT, eliminating accounting transactions for the movement of materials to work in process.
- Performance measurement systems following implementation of JIT were
  - ◆ Less complex 77.3%
  - ◆ More complex 22.7%

Source: Adapted from Swenson and Cassidy, "The Effect of JIT." Full citation is in Appendix A.



with virtually no direct materials inventory and minimal work-in-process inventories because Example 3 does not maintain these inventory accounts. It is less feasible otherwise.

Extending Example 3, backflush costing systems could also use the sale of finished goods (instead of the production of finished goods) as the only trigger point. This version of backflush costing would be most suitable for a JIT production system with minimal direct materials, work in process, and finished goods inventories. Why? Because this backflush costing system would maintain no inventory accounts.

### Special Considerations in Backflush Costing

The accounting illustrated in Examples 1, 2, and 3 does not strictly adhere to generally accepted accounting principles of external reporting. For example, work in process (an asset) exists but is not recognized in the accounting system. Advocates of backflush costing, however, cite the materiality concept in support of these versions of backflushing. They claim that if inventories are low or their total costs are not subject to significant change from one accounting period to the next, operating income and inventory costs developed in a backflush costing system will not differ materially from the results generated by a system that adheres to generally accepted accounting principles.

Suppose material differences in operating income and inventories do exist between the results of a backflush costing system and those of a conventional standard costing system. An adjustment can be recorded to make the backflush numbers satisfy external reporting requirements. For example, the backflush entries in Example 2 would result in expensing all conversion costs as a part of Cost of Goods Sold (\$1,188,000 at standard costs + \$72,000 write-off of under-allocated conversion costs = \$1,260,000). But suppose conversion costs were regarded as sufficiently material in amount to be included in Inventory Control. Then entry (d), closing the Conversion Costs accounts, would change as shown below:

Original entry (d)	Conversion Costs Allocated	1,188,000	
	Cost of Goods Sold	72,000	
	Conversion Costs Control		1,260,000
Revised entry (d)	Conversion Costs Allocated	1,188,000	
	Inventory Control (1,000 units × \$12)	12,000	
	Cost of Goods Sold	60,000	
	Conversion Costs Control		1,260,000

Criticisms of backflush costing focus mainly on the absence of audit trails—the ability of the accounting system to pinpoint the uses of resources at each step of the production process. The absence of large amounts of materials and work in process inventory means that managers can keep track of operations by personal observations, computer monitoring, and nonfinancial measures.

What are the implications of JIT and backflush costing systems for activity-based costing (ABC) systems? Simplifying the production process, as in a JIT system, makes more of the costs direct and so reduces the extent of overhead cost allocations. Simplified ABC systems are often adequate for companies implementing JIT. But even these simpler ABC systems can enhance backflush costing. Costs from ABC systems give relatively more accurate budgeted conversion costs per unit for different products, which are then used in the backflush costing system. The activity-based cost data are also useful for product costing, decision making, and cost management.



**PROBLEM**

A Dallas manufacturing company uses standard costs and an operation-costing system. It has a storeroom and several buffer stocks of parts and in-process inventories at various work centers along the production lines. No separate major cost category for direct manufacturing labor exists; all manufacturing labor is a part of conversion costs. For simplicity, assume that there are no beginning inventories and no standard cost variances of materials.

**REQUIRED**

1. Prepare summary journal entries (without disposing of under- or overallocated conversion costs) based on the following data (in thousands) for a given month.

Raw materials purchased	\$35,000
Conversion costs incurred	22,000
Raw materials used	30,000
Conversion costs allocated	20,000
Costs transferred to finished goods	47,500
Cost of goods sold	40,000

For simplicity, you are not given the data to prepare journal entries for each underlying transfer from, say, Work in Process, Operation 1 to Work in Process, Operation 2 to Work in Process, Operation 3. Instead, assume that there is only a single account, Work in Process Control, that is supported by subsidiary Work in Process accounts for each operation.

2. Post the entries in requirement 1 to T-accounts for Inventories (Materials, Work in Process, and Finished Goods), Conversion Costs Control, Conversion Costs Allocated, and Cost of Goods Sold.
3. The plant adopts a JIT production system and a backflush costing system with two trigger points for journal entries: the purchase of materials and the completion of good finished units. Prepare summary journal entries based on the same data as in requirement 1. Note, however, that the raw materials used and the conversion costs assigned would be affected by the goods completed, not the work in process. Assume that 95% of the work placed in process is completed.
4. Post the entries in requirement 3 to T-accounts for Inventories (Raw and In-Process, and Finished Goods), Conversion Costs Control, Conversion Costs Allocated, and Cost of Goods Sold.
5. Compare the applicable inventory balances in requirements 2 and 4. Explain any differences.

**SOLUTION**

1. a. Materials Inventory Control	35,000	
Accounts Payable Control		35,000
b. Conversion Costs Control	22,000	
Various Accounts		22,000
c. Work in Process Control	30,000	
Materials Inventory Control		30,000
d. Work in Process Control	20,000	
Conversion Costs Allocated		20,000
e. Finished Goods Control	47,500	
Work in Process Control		47,500
f. Cost of Goods Sold	40,000	
Finished Goods Control		40,000



✓2.

Materials Inventory Control		Work in Process Control		Finished Goods Control		Cost of Goods Sold	
(a) 35,000	(c) 30,000	(c) 30,000	(e) 47,500	(e) 47,500	(f) 40,000	(f) 40,000	
Balance 5,000		(d) 20,000		Balance 7,500			
		Balance 2,500					
Conversion Costs Control		Conversion Costs Allocated					
(b) 22,000			(d) 20,000				

3. a.	Inventory: Raw and In-Process Control	35,000	
	Accounts Payable Control		35,000
b.	Conversion Costs Control	22,000	
	Various Accounts		22,000
c.	Finished Goods Control	47,500	
	Inventory: Raw and In-Process Control		
	(0.95 × 30,000)		28,500
	Conversion Costs Allocated		
	(0.95 × 20,000)		19,000
d.	Cost of Goods Sold	40,000	
	Finished Goods Control		40,000

✓4.

Inventory: Raw and In-Process Control		Finished Goods Control		Cost of Goods Sold	
(a) 35,000	(c) 28,500	(c) 47,500	(d) 40,000	(d) 40,000	
Balance 6,500		Balance 7,500			
Conversion Costs Control		Conversion Costs Allocated			
(b) 22,000			(c) 19,000		

5.

	Sequential (Requirement 2)	Backflush (Requirement 4)
Materials inventory	\$ 5,000	\$ 0
Inventory: raw and in-process control	0	6,500
Work in process	2,500	0
Subtotal	7,500	6,500
Finished goods	7,500	7,500
Total inventories	\$15,000	\$14,000
Underallocated conversion costs	\$ 2,000	\$ 3,000
Cost of goods sold (at standard)	\$40,000	\$40,000

The \$1,000 difference in inventories is explained by the accounting for conversion costs. Conversion costs assigned in operation costing were \$1,000 greater than conversion costs allocated under backflush costing because the trigger point for assignment is work in process, not finished goods.

To ease comparisons between the journal entries for operation costing and backflush costing, the numbers used for the various inventory balances are identical except for the \$1,000 difference just explained. Advocates of JIT using backflush costing, however, maintain that inventories would decline substantially under JIT, particularly inventories of raw materials and work in process.



The following points are linked to the chapter's learning objectives:

1. Each output unit can, in some extreme cases, be classified either (a) as a distinct, identifiable unit of a product or service, or (b) as identical to numerous other units from that production system. A job-costing system is well suited to a production system yielding the first type of products, while a process-costing system is well suited to the second type of products. Many production systems have elements of both (a) and (b), the mix of which changes over time. Hybrid costing systems, such as operation costing, are blends of characteristics from both job-costing systems and process-costing systems.
2. Just-in-time (JIT) systems streamline the production process and minimize inventories. JIT systems simplify job costing by delaying the recording of costs until after the goods are completed or sold.
3. Operation costing is a hybrid costing system applied to batches of similar products. Production costs are compiled for each work order that will be made up of two or more similar (in many cases, homogeneous) units of a product.
4. Journal entries in an operation-costing system focus on a work-in-process account for a batch of similar products. As the batch proceeds through various operations, direct costs (typically direct materials) are assigned to work in process, as in a job-costing system. Within each operation, all product units are treated exactly alike, and conversion costs per unit are calculated as in a process-costing system.
5. Just-in-time production is a system in which each component on a production line is produced immediately as needed by the next step in the production line.
6. The five major features of a JIT production system are (a) organizing production in manufacturing cells, (b) hiring and training multiskilled workers, (c) emphasizing total quality management, (d) reducing manufacturing lead time and setup time, and (e) building strong supplier relationships.
7. Journal entries in a backflush costing system are not made sequentially to match the flow of a product in a plant. No journal entries are made for work in process. The accounting system does not record details of the changes in a product being produced until at least finished units appear. Working backward, budgeted or standard costs are used to assign manufacturing costs to products.

## TERMS TO LEARN

This chapter and the Glossary at the end of this book contain definitions of the following important terms:

backflush costing (p. 726)	manufacturing cells (722)
delayed costing (726)	operation (718)
endpoint costing (726)	operation costing (719)
hybrid costing system (718)	post-deduct costing (726)
just-in-time (JIT) production (722)	sequential tracking (726)
just-in-time (JIT) purchasing (724)	synchronous tracking (726)

## ASSIGNMENT MATERIAL

### QUESTIONS

- 20-1** "Hybrid production systems develop because there are hybrid costing systems." Do you agree? Explain.



- 20-2 "Operations and departments are synonyms." Do you agree?
- 20-3 "Operation costing means that *conversion costs* and *manufacturing overhead* are synonyms." Do you agree? Explain.
- 20-4 Give three examples of industries that are likely to use operation costing.
- 20-5 Identify (a) the major job-costing feature of operation costing, and (b) the major process-costing feature of operation costing.
- 20-6 Explain why JIT production systems simplify job costing.
- 20-7 Distinguish a demand-pull from a push-through system.
- 20-8 List five major features of JIT production systems.
- 20-9 Describe four financial benefits of implementing a JIT system.
- 20-10 Describe how JIT systems affect product costing.
- 20-11 Distinguish between the sequential tracking approach used in traditional budgeted or standard costing systems and the approach used in backflush costing.
- 20-12 Describe the essence of backflush costing.
- 20-13 Companies adopting backflush costing often meet three conditions. Describe these three conditions.
- 20-14 Outline how three different versions of backflush costing can differ.
- 20-15 "Backflush accounting should be prohibited. It is not in conformity with GAAP." Do you agree? Explain.

## EXERCISES

- H 20-16 Operation costing.** The Gabriel Corporation produces a standard-sized window in four operations—framing, assembly, staining, and painting. The windows differ in the type of wood (pine, oak) and glass (regular, tempered) used. The framing and assembly operations are common to all windows, but thereafter they are either stained or painted but not both. The total conversion costs for the month of June are

	Framing	Assembly	Staining	Painting
Total conversion costs	\$75,000	\$105,000	\$36,000	\$54,000

There is no beginning or ending inventory of windows in the month of June. A total of 3,000 windows are produced in June, half of which are stained and half of which are painted. The conversion cost for each unit passing through a given operation is the same.

Details of two work orders processed in June are as follows:

	Work Order 626	Work Order 750
Number of windows	50	100
Direct materials costs	\$5,500	\$9,800
Finishing operation	Painting	Staining

## REQUIRED

1. Tabulate the conversion costs of each operation, the total units produced, and the conversion cost per unit.
  2. Calculate the total costs and the total cost per window of work order 626 and work order 750.
- 20-17 Operation costing, journal entries.** The Omaha Desk Company specializes in making desks of varying shapes, materials, and sizes. It has a cutting operation, an assembly operation, and a staining operation. Some goods are sold unstained, so they do not go through the staining operation. Consider the following data for November:



Direct materials requisitioned by cutting	\$200,000
Direct materials requisitioned by staining	20,000
Conversion costs of all operations (actual)	190,000
Conversion costs allocated:	
Cutting	50,000
Assembly	110,000
Staining	30,000

#### REQUIRED

Prepare the appropriate journal entries. Assume that there is no beginning or ending work in process and that all goods are transferred to Finished Goods. The total manufacturing costs of the products not undergoing staining were \$60,000.

**H 20-18 Operation costing.** The Pafko Company, a small manufacturer, makes a variety of tool boxes. The company's manufacturing operations and their costs for November were

	Cutting	Assembly	Finishing	Total
Direct manufacturing labor	\$2,600	\$16,500	\$4,800	\$23,900
Manufacturing overhead	<u>3,000</u>	<u>22,900</u>	<u>3,300</u>	<u>29,200</u>
	<u>\$5,600</u>	<u>\$39,400</u>	<u>\$8,100</u>	<u>\$53,100</u>

Three styles of boxes were produced in November. The quantities and direct materials costs were

Style	Quantity	Direct Materials
Standard	1,200	\$18,000
Home	600	6,660
Industrial	200	<u>5,400</u>
		<u>\$30,060</u>

The company uses actual costing. It tracks direct materials to each style of box. It combines direct manufacturing labor and manufacturing overhead and allocates the conversion costs on the basis of all product units passing through an operation. All product units are assumed to receive an identical amount of time and effort in each operation. The Industrial style, however, does not go through the finishing operation.

#### REQUIRED

1. Tabulate the conversion costs of each operation, the total units produced, and the conversion costs per unit for November.
2. Calculate the total costs and the cost per unit of each style of box produced in November. Be sure to account for all the total costs.

**20-19 Journal entries (continuation of 20-18).**

#### REQUIRED

Prepare summary journal entries for each operation. For simplicity, assume that all direct materials are introduced at the beginning of the cutting operation. Also, assume that all units were transferred to finished goods when completed and that there was no beginning or ending work in process. Prepare one summary entry for all conversion costs incurred, but prepare a separate entry for allocating conversion costs in each operation.

**H 20-20 Operation costing.** The Penske Company manufactures a variety of plastic products. The company has an extrusion operation and subsequent operations to form, trim, and finish parts such as buckets, covers, and automotive interior components. Plastic sheets are produced by the extrusion operation. Many of these sheets are sold as finished goods directly to other manufacturers.



Additional direct materials (chemicals and coloring) are added in the finishing operation.

The company's manufacturing costs assigned to products for October were

	Extrude	Form	Trim	Finish	Totals
Direct materials	\$650,000	\$ 0	\$ 0	\$ 80,000	\$ 730,000
Direct manufacturing labor	55,000	30,000	20,000	40,000	145,000
Manufacturing overhead	270,000	90,000	40,000	60,000	460,000
	<u>\$975,000</u>	<u>\$120,000</u>	<u>\$60,000</u>	<u>\$180,000</u>	<u>\$1,335,000</u>

In addition to plastic sheets, two types of automotive products (firewalls and dashboards) were produced:

	Units	Plastic Sheet Direct Materials	Additional Direct Materials
Plastic sheets, sold after extrusion	10,000	\$500,000	\$ 0
Firewalls, sold after trimming	1,000	50,000	0
Dashboards, sold after finishing	2,000	100,000	80,000
	<u>13,000</u>	<u>\$650,000</u>	<u>\$80,000</u>

For simplicity, assume that all of the items and units produced received the same steps within each operation.

#### REQUIRED

1. Tabulate the conversion costs of each operation, the total units produced, and the conversion costs per unit for October.
2. Tabulate the total costs, the units produced, and the costs per unit. Be sure to account for all the total costs for October.

**20-21 Backflush journal entries and JIT production.** The Lee Company has a plant that manufactures transistor radios. The production time is only a few minutes per unit. The company uses a just-in-time production system and a backflush costing system with two trigger points for journal entries:

- ◆ Purchase of direct (raw) materials
- ◆ Completion of good finished units of product

There are no beginning inventories. The following data pertain to April manufacturing:

Direct (raw) materials purchased	\$ 8,800,000
Direct (raw) materials used	8,500,000
Conversion costs incurred	4,220,000
Allocation of conversion costs	4,000,000
Costs transferred to finished goods	12,500,000
Cost of goods sold	11,900,000

#### REQUIRED

1. Prepare summary journal entries for April (without disposing of under- or overallocated conversion costs). Assume no direct materials variances.
2. Post the entries in requirement 1 to T-accounts for applicable Inventory Control, Conversion Costs Control, Conversion Costs Allocated, and Cost of Goods Sold.
3. Under an ideal JIT production system, how would the amounts in your journal entries differ from those in requirement 1?

**20-22 Backflush costing and JIT production.** The Acton Corporation manufactures electrical meters. For August, there were no beginning inventories of direct (raw) materials and no beginning and ending work in process. Acton uses a JIT production system and backflush costing with two trigger points for making entries in the accounting system:



- ◆ Purchase of direct materials debited to Inventory: Raw and In-Process Control
- ◆ Completion of good finished units of product debited to Finished Goods Control at standard costs

Acton's August standard costs per unit are direct materials, \$25; conversion costs, \$20. The following data apply to August manufacturing:

Direct (raw) materials purchased	\$550,000
Conversion costs incurred	\$440,000
Number of finished units manufactured	21,000
Number of finished units sold	20,000

#### REQUIRED

1. Prepare summary journal entries for August (without disposing of under- or overallocated conversion costs). Assume no direct materials variances.
2. Post the entries in requirement 1 to T-accounts for applicable Inventory Control, Conversion Costs Control, Conversion Costs Allocated, and Cost of Goods Sold.

**20-23 Backflush, second trigger is sale.** Assume the same facts as in 20-22. Assume that the second trigger point for the Acton Corporation is the sale—rather than the production—of finished units. Also, the Inventory Control account is confined solely to direct materials, whether these materials are in a storeroom, in work in process, or in finished goods. No conversion costs are inventoried. They are allocated at standard cost to the units sold. Any under- or overallocated conversion costs are written off monthly to Cost of Goods Sold.

#### REQUIRED

1. Prepare summary journal entries for August, including the disposition of under- or overallocated conversion costs. Assume no direct materials variances.
2. Post the entries in requirement 1 to T-accounts for applicable Inventory Control, Conversion Costs Control, Conversion Costs Allocated, and Cost of Goods Sold.

**20-24 Backflush, one trigger point.** Assume the same facts as in 20-22. Now assume that there is only one trigger point, the completion of good finished units of product, which are debited to Finished Goods Control at standard costs. Any under- or overallocated conversion costs are written off monthly to cost of goods sold.

#### REQUIRED

1. Prepare summary journal entries for August, including the disposition of under- or overallocated conversion costs. Assume no direct materials variances.
2. Post the entries in requirement 1 to T-accounts for applicable Inventory Control, Conversion Costs Control, Conversion Costs Allocated, and Cost of Goods Sold.

### PROBLEMS

- ✓ **20-25 Operation costing, equivalent units.** (CMA, adapted) Gregg Industries manufactures a variety of plastic products, including a series of molded chairs. The three models of molded chairs, which are all variations of the same design, are Standard (can be stacked), Deluxe (with arms), and Executive (with arms and padding). The company uses batch manufacturing and has an operation-costing system.

Gregg has an extrusion operation and subsequent operations to form, trim, and finish the chairs. Plastic sheets are produced by the extrusion operation, some of which are sold directly to other manufacturers. During the forming operation, the remaining plastic sheets are molded into chair seats



and the legs are added. The Standard model is sold after this operation. During the trim operation, the arms are added to the Deluxe and Executive models and the chair edges are smoothed. Only the Executive model enters the finish operation, where the padding is added. All of the units produced receive the same steps within each operation.

The May production run had a total manufacturing cost of \$898,000. The units of production and direct materials costs incurred are as follows:

	Units Produced	Extrusion Materials	Form Materials	Trim Materials	Finish Materials
Plastic sheets	5,000	\$ 60,000	\$ 0	\$ 0	\$ 0
Standard model	6,000	72,000	24,000	0	0
Deluxe model	3,000	36,000	12,000	9,000	0
Executive model	2,000	24,000	8,000	6,000	12,000
	<u>16,000</u>	<u>\$192,000</u>	<u>\$44,000</u>	<u>\$15,000</u>	<u>\$12,000</u>

Manufacturing costs of production assigned during the month of May were

	Extrusion Operation	Form Operation	Trim Operation	Finish Operation
Direct manufacturing labor	\$152,000	\$60,000	\$30,000	\$18,000
Manufacturing overhead	<u>240,000</u>	<u>72,000</u>	<u>39,000</u>	<u>24,000</u>
	<u>\$392,000</u>	<u>\$132,000</u>	<u>\$69,000</u>	<u>\$42,000</u>

#### REQUIRED

- For each product produced by Gregg Industries during the month of May, determine (a) the unit cost, and (b) the total cost. Be sure to account for all costs incurred during the month, and support your answer with appropriate calculations.
- Without considering your answer in requirement 1, assume that 1,000 units of the Deluxe model produced during May remained in work-in-process at the end of the month. These units were 100% complete as to materials costs and 60% complete in the trim operation. Determine the cost of the 1,000 units of the Deluxe model in the work-in-process inventory at the end of May.

#### 20-26 Operation costing with ending work in process and journal entries.

The Galvez Company produces two models of video recorders. The deluxe units undergo two operations. The superdeluxe units undergo three operations. Consider the following:

	Production Order	
	For 1,000 Deluxe Units	For 500 Superdeluxe Units
Direct materials (actual costs)	\$50,000	\$54,000
Conversion costs allocated:		
Operation 1	20,000	10,000
Operation 2	?	?
Operation 3	—	5,000
Total manufacturing costs	?	?

#### REQUIRED

- Operation 2 is highly automated. The budgeted conversion costs for 19\_7 were \$100,000 direct manufacturing labor and \$440,000 manufac-



turing overhead. The budgeted production for 19\_7 was 180,000 units. Each product unit receives the same conversion costs per unit in operation 2. Compute the total costs of processing the deluxe products and superdeluxe products in operation 2.

2. Compute the total manufacturing costs and the unit costs of the deluxe and superdeluxe products.
3. Prepare journal entries that track the costs of all 1,000 deluxe units through operations to Finished Goods.
4. Suppose that at the end of the year, 500 deluxe units were in process through operation 1 only and 300 superdeluxe units were in process through operation 2 only, but complete with respect to direct materials and conversion costs. Compute the cost of the ending work-in-process inventory. Assume that no direct materials are charged in operation 2 but that \$4,000 of additional direct materials are to be charged to the 500 units processed in operation 3. (Ignore end-of-year variances.)

**20-27 Operation costing, service sector, equivalent units.** Union Bank uses an operation-costing system to determine the cost of opening two types of accounts (a checking account, and a checking account with an overdraft facility) and the cost of adding an overdraft facility to an existing checking account. Checking accounts are opened at the branch; overdraft facilities are approved by the Credit Department. Information for the month of March is as follows:

	Branch Costs	Credit Department Costs
Total service costs allocated to the account-opening and overdraft activity	\$7,200	\$14,850

In March, the bank signed up 600 checking account customers and 200 checking account customers with an overdraft facility. Furthermore, 100 customers added an overdraft facility to their existing checking accounts. All branch transactions related to opening accounts are assumed to receive an identical amount of time and effort. Similarly, the time and effort in the Credit Department to set up each overdraft facility are assumed to be the same.

#### REQUIRED

1. Calculate the total costs and the unit cost in March for opening a checking account, opening a checking account with an overdraft facility, or adding an overdraft facility to an existing checking account.
2. Suppose that at the end of March, the Credit Department had not completed setting up 40 of the 100 overdraft facilities for existing customers. Credit processing was 25% complete with respect to these 40 customers. There was no work pending in the Credit Department at the beginning of March, and the department had set up overdraft facilities for all other customers who wanted overdraft facilities during March. Calculate the total costs and the unit cost in March of opening a checking account, opening a checking account with an overdraft facility, and adding an overdraft facility to an existing checking account.

**20-28 Backflush costing and JIT production.** The Ronowski Company produces telephones. For June, there were no beginning inventories of raw materials and no beginning and ending work in process. Ronowski uses a JIT production system and backflush costing with two trigger points for making entries in its accounting system:

- ◆ Purchase of direct (raw) materials
- ◆ Completion of good finished units of product

Ronowski's June standard cost per unit of telephone product is direct materials, \$26; conversion costs, \$15. There are two inventory accounts:

- ◆ Inventory: Raw and In-Process Control
- ◆ Finished Goods Control



The following data apply to June manufacturing:

Raw materials purchased	\$5,300,000
Conversion costs incurred	\$3,080,000
Number of finished units manufactured	200,000
Number of finished units sold	192,000

**REQUIRED**

1. Prepare summary journal entries for June (without disposing of under- or overallocated conversion costs). Assume no direct materials variances.
2. Post the entries in requirement 1 to T-accounts for applicable Inventory Control, Conversion Costs Control, Conversion Costs Allocated, and Cost of Goods Sold.

✓ **20-29 Backflush, second trigger is sale.** Assume the same facts as in 20-28. Assume that the second trigger point for the Ronowski Company is the sale—rather than the production—of finished units. Also, the inventory account is confined solely to direct materials, whether they would be in a storeroom, in work in process, or in finished goods.

No conversion costs are inventoried. They are allocated at standard cost to the units sold. Any under- or overallocated conversion costs are written off monthly to Cost of Goods Sold.

**REQUIRED**

1. Prepare summary journal entries for June, including the disposition of under- or overallocated conversion costs. Assume no direct materials variances.
2. Post the entries in requirement 1 to T-accounts for applicable Inventory Control, Conversion Costs Control, Conversion Costs Allocated, and Cost of Goods Sold. Explain the composition of the ending balance of Inventory Control.
3. Suppose conversion costs were sufficiently material in amount to be included in Inventory Control. Using a backflush system, show how your journal entries would be changed in requirement 1. Explain briefly.

**20-30 Backflush, one trigger point.** Assume the same facts as in 20-28. Now assume that there is only one trigger point, the completion of good finished units of product, which are debited to Finished Goods Control at standard costs. Any under- or overallocated conversion costs are written off monthly to Cost of Goods Sold.

**REQUIRED**

1. Prepare summary journal entries for June, including the disposition of under- or overallocated conversion costs. Assume no direct materials variances.
2. Post the entries in requirement 1 to T-accounts for applicable Inventory Control, Conversion Costs Control, Conversion Costs Allocated, and Cost of Goods Sold. Explain the composition of the ending balance of Inventory Control.
3. If you did Problem 20-28, compare and explain any differences between the results here and those in Problem 20-28.

**20-31 Accounting for variances (continuation of 20-28).** Suppose the same quantity of raw materials had additional costs as follows:

Price variance	\$30,000 U
Efficiency variance	70,000 U

**REQUIRED**

1. Prepare summary journal entries (without explanations) to record the raw material variances.
2. Assume that under- or overallocated conversion costs are written off monthly to Cost of Goods Sold. Prepare the pertinent summary journal entry.



**20-32 Just-in-time systems, ethics.** Gail Daly, the plant manager at Daisy Electricals calls Linda Anwar, the plant controller, into her office. She had just finished reviewing Anwar's report on the financial benefits from implementing JIT. The report described the following annual benefits and costs.

	First Year After Implementation	Subsequent Years
Annual expected benefits from:		
Lower investment in inventories	\$290,000	\$350,000
Reductions in setup costs	110,000	150,000
Reduction in costs of waste, spoilage, and rework	200,000	250,000
Operating income from higher revenues as a result of responding faster to customers	180,000	300,000
Annual expected costs of implementing JIT	950,000	750,000

"We have been working on getting organized for JIT for almost a year now. Some of the financial benefits you have computed seem optimistic to me. I don't think we are quite there yet, but if you continue to use the financial numbers you have, we would be forced to implement JIT sooner than we should. Please look over the numbers and see what you can do. I think some of the numbers are rather soft anyway. I also understand that plant profitability might take a hit in the year JIT is first implemented. I retire next year and I don't want to go out with a losing record." Anwar is quite certain that her numbers are correct. She is also aware that Daly would lose most of her performance bonuses if plant earnings decrease next year. It does not seem fair to her that Daly should be penalized in the short term for what is in the long-run interest of the company.

#### REQUIRED

1. On the basis of Anwar's report, calculate the effect of JIT implementation on plant profitability in the first year after implementation and in subsequent years. On the basis of Anwar's report, should Daisy implement JIT?
2. Is Daly correct in characterizing some of the financial benefits as "soft." Which items do you think she is referring to? If the benefits you identify as "soft" are not realized, should Daisy implement JIT?
3. Is Daly being unfairly penalized if she implements JIT? What should Daly do? What should Anwar do?

#### COLLABORATIVE LEARNING PROBLEM

**20-33 Backflushing.** The following conversation occurred between Brian Richardson, plant manager at Glendale Engineering and Charles Cheng, plant controller. Glendale manufactures automotive component parts such as gears and crankshafts for automobile manufacturers. Richardson has been very enthusiastic about implementing JIT and about simplifying and streamlining the production and other business processes.

Richardson: "Charles, I would like to substantially simplify our accounting in the new JIT environment. Can't we just record one accounting entry at the time we ship products to our customers? I don't want to have our staff spending time tracking inventory from one stage to the next, when we have as little inventory as we do."

Cheng: "Brian, I think you are right about simplifying the accounting, but we still have a fair amount of raw material and finished goods inventory that varies from period to period depending on the demand for specific products. Doing away with all inventory accounting may be a problem."



Richardson: "Well, you know my desire to simplify, simplify, simplify. I know that there are some costs of oversimplifying, but I believe that, in the long run, simplification pays big dividends. Why don't you and your staff study the issues involved, and I will put it on the agenda for our next senior plant management meeting."

#### INSTRUCTIONS

Form groups of two or more students to complete the following requirements.

#### REQUIRED

1. What backflush costing method would you recommend that Cheng adopt? Remember Richardson's desire to simplify the accounting as much as possible. Develop support for your recommendation.
2. Think about the three examples of backflush costing described in this chapter. These examples differ with respect to the number and types of trigger points used. Suppose your goal of implementing backflush costing is to simplify the accounting, but only if it closely matches the sequential tracking approach. Which backflush costing method would you propose if
  - a. Glendale had no raw materials or work-in-process inventories but did have finished goods inventory?
  - b. Glendale had no work-in-process or finished goods inventories but did have raw material inventory?
  - c. Glendale had no raw material, work-in-process, or finished goods inventories?
3. Backflush costing has its critics. In an article in the magazine *Management Accounting*, entitled "Beware the New Accounting Myths," R. Calvasina, E. Calvasina, and G. Calvasina state:

The periodic (backflush) system has never been reflective of the reporting needs of a manufacturing system. In the highly standardized operating environments of the present JIT era, the appropriate system to be used is a perpetual accounting system based on an up-to-date, realistic set of standard costs. For management accountants to backflush on an actual cost basis is to return to the days of the outdoor privy.

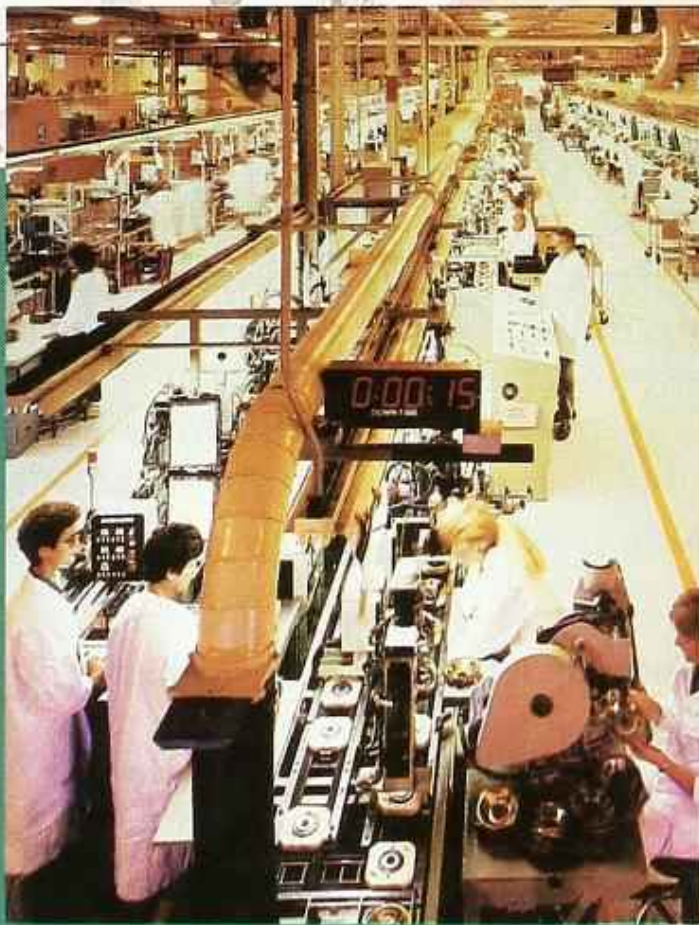
Comment on this statement.



# 21

## CHAPTER

# INVENTORY MANAGEMENT AND JUST-IN-TIME



Manufacturers are demanding more-frequent deliveries with shorter purchase-order lead times from their suppliers. To better service the companies who use their automotive products, Harman-Motive has invested in new information systems and technology. Better coordination and faster response times are helping Harman-Motive and its customers to reduce inventory levels.

### LEARNING OBJECTIVES

After studying this chapter, you should be able to

1. Explain why cost management of materials is pivotal in many organizations
2. Identify five categories of costs associated with goods for sale
3. Explain the economic order quantity (EOQ) decision model and how it balances ordering costs and carrying costs
4. Explain the reorder point and safety stocks
5. Discuss why EOQ models are rarely sensitive to minor variations in cost predictions
6. Describe the potential conflicts that can arise between EOQ decision models and models used for performance evaluation
7. Compare EOQ and just-in-time (JIT) purchasing models
8. Determine the relevant benefits and relevant costs in JIT purchasing
9. Identify relevant benefits and relevant costs in JIT production
10. Describe measures for evaluating JIT production performance



## OBJECTIVE 1

Explain why cost management of materials is pivotal in many organizations

**Inventory management** encompasses the planning, organizing, and control activities that focus on the flow of materials and inventory into, through, and from the organization. Many decisions fall under the inventory management umbrella. When is the best time to purchase materials or merchandise? How should purchasing arrangements be structured? Which is the best way to handle materials or merchandise inventories, once they are received?

Managing inventories and materials is important because, on average, the costs of materials account for more than 50% of total costs in manufacturing companies and over 70% of total costs in retail companies. Managers respond to the high costs of materials and inventory in several ways. In the last chapter, we saw managers adopting JIT systems to reduce inventory. Managers also focus on reducing the purchasing costs of materials. The 1990s have seen General Motors (GM) demand double-digit percentage price cuts from its suppliers. General Electric (GE) recently announced Target 10, an initiative that aims to cut GE's costs of purchases by 10%. To achieve these goals, GM and GE have offered to assist suppliers in reducing costs, and those suppliers who fail to cooperate will probably lose business.

Accounting information can play a key role in inventory management. This chapter illustrates the importance of accounting information in two areas:

1. The management of goods for sale in retail organizations
2. The management of materials, work in process, and finished goods in organizations with manufacturing operations

Inventory management is of little concern in service companies since these companies hold minimal materials and inventory.

## MANAGING GOODS FOR SALE IN RETAIL ORGANIZATIONS

Cost of goods sold measures the costs of inventory sold, including the costs of purchasing and managing inventory. Cost of goods sold constitutes the largest single cost item for most retailers. For example, Kroger, a grocery retail store, reported the following breakdown of operations for 1994:

Sales		100.0%
Deduct costs:		
Cost of goods sold	75.8%	
Selling, general and administration costs	19.7	
Other costs, interest, and taxes	3.3	
Total costs		98.8
Net income		1.2%

The paper-thin net income percentage for Kroger, like other retail grocery stores, means that better decisions regarding the purchasing and managing of goods for sale can cause dramatic percentage increases in net income.

### Costs Associated with Goods for Sale

The following cost categories are important when managing inventories and goods for sale.

1. **Purchasing costs:** **Purchasing costs** consist of the costs of goods acquired from suppliers including incoming freight or transportation costs. These costs usually make up the largest single cost category of goods for sale. Discounts for different purchase-order sizes and supplier credit terms affect purchasing costs.
2. **Ordering costs:** **Ordering costs** consist of the costs of preparing and issuing a purchase order. Related to the number of purchase orders processed are special processing, receiving, inspection, and payment costs.
3. **Carrying costs:** **Carrying costs** arise when a business holds inventories of goods for sale. These costs include the opportunity cost of the investment tied up in inven-

## OBJECTIVE 2

Identify five categories of costs associated with goods for sale



tory (see Chapter 11, pp. 395–396) and the costs associated with storage, such as storage-space rental and insurance, obsolescence and spoilage.

4. *Stockout costs:* A **stockout** occurs when a company runs out of a particular item for which there is customer demand. A company may respond to the shortfall or stockout by expediting an order from a supplier. Expediting costs of a stockout include the additional ordering costs plus any associated transportation costs. Alternatively, the company may lose a sale due to the stockout. In this case, stockout costs include the lost contribution margin on the sale plus any contribution margin lost on future sales hurt by customer ill-will caused by the stockout.

5. *Quality costs:* The *quality* of a product or service is its conformance with a preannounced or prespecified standard. As described in Chapter 19, four categories of costs of quality are often distinguished: (a) prevention costs, (b) appraisal costs, (c) internal failure costs, and (d) external failure costs.

The descriptions of the cost categories indicate that some of the relevant costs for making inventory decisions and managing goods for sale are not available in existing accounting systems. Opportunity costs, which are not typically recorded in accounting systems, are an important component in several of these cost categories.

The inclusion of costs from all five categories makes cost of goods sold substantial.<sup>1</sup> Advances in information-gathering technology, however, are attempting to increase the reliability and timeliness of inventory data and reduce costs in these five categories. For example, electronic data interchange (EDI) links a company to its suppliers via computers. An order is often initiated by a single keystroke, increasing timeliness and reducing costs of ordering. Similarly, barcoding technology allows a scanner to capture purchases and sales of individual units. This creates an instantaneous record of inventory movements and helps in the management of purchasing, carrying, and stockout costs.

## Economic-Order-Quantity Decision Model

The first major decision in managing goods for sale is deciding how much of a given product to order. The **economic order quantity (EOQ)** decision model calculates the optimal quantity of inventory to order. The simplest version of this model incorporates only ordering costs and carrying costs into the calculation. It assumes the following:

1. The same fixed quantity is ordered at each reorder point.
2. Demand, ordering costs, and carrying costs are certain. The **purchase-order lead time**—the time between the placement of an order and its delivery—is also certain.
3. Purchasing costs per unit are unaffected by the quantity ordered. This assumption makes purchasing costs irrelevant to determining EOQ, because purchasing costs of all units acquired will be the same, whatever the order size in which the units are ordered.
4. No stockouts occur. One justification for this assumption is that the costs of a stockout are prohibitively high. We assume that to avoid these potential costs, management always maintains adequate inventory so that no stockout can occur.
5. In deciding the size of the purchase order, management considers the costs of quality only to the extent that these costs affect ordering costs or carrying costs.

Given these assumptions, EOQ analysis ignores purchasing costs, stockout costs, and quality costs. To determine EOQ, we minimize the relevant ordering and carrying costs (those ordering and carrying costs that are affected by the quantity of inventory ordered):

$$\text{Total relevant costs} = \text{Total relevant ordering costs} + \text{Total relevant carrying costs}$$

<sup>1</sup>In some cases, inventory “shrinkage” from shoplifting and employee theft can also add to cost of goods sold.

### OBJECTIVE 3

Explain the economic order quantity (EOQ) decision model and how it balances ordering costs and carrying costs



**EXAMPLE:** Video Galore sells packages of blank video tapes to its customers; it also rents out tapes of movies and sporting events. It purchases packages of video tapes from Sontek at \$14 a package. Sontek pays all incoming freight. No incoming inspection is necessary, as Sontek has a superb reputation for delivering quality merchandise. Annual demand is 13,000 packages, at a rate of 250 packages per week. Video Galore requires a 15% annual return on investment. The purchase-order lead time is 2 weeks. The following cost data are available:

Relevant ordering costs per purchase order		\$200.00
Relevant carrying costs per package per year:		
Required annual return on investment, 15% × \$14	\$2.10	
Relevant insurance, materials handling, breakage, etc., per year	<u>3.10</u>	5.20

What is the economic order quantity of packages of video tapes?

The formula underlying the EOQ model is

$$EOQ = \sqrt{\frac{2DP}{C}}$$

where

EOQ = Economic order quantity

$D$  = Demand in units for a specified time period (1 year in this example)

$P$  = Relevant ordering costs per purchase order

$C$  = Relevant carrying costs of 1 unit in stock for the time period used for  $D$  (1 year in this example)

The formula indicates that EOQ increases with demand and ordering costs and decreases with carrying costs.

We can use this formula to determine the EOQ for Video Galore as follows:

$$EOQ = \sqrt{\frac{2 \times 13,000 \times \$200}{\$5.20}} = \sqrt{1,000,000} = 1,000 \text{ packages}$$

Therefore, Video Galore should order 1,000 tape packages each time to minimize total ordering and carrying costs.

The total annual relevant costs (TRC) for any order quantity  $Q$  can be calculated using the following formula:

$$\begin{aligned} TRC &= \text{Total annual relevant ordering costs} + \text{Total annual relevant carrying costs} \\ &= \frac{\text{Number of purchase orders per year}}{\text{Number of purchase orders per year}} \times \frac{\text{Relevant ordering costs per purchase order}}{\text{Relevant ordering costs per purchase order}} + \frac{\text{Average inventory in units}}{\text{Average inventory in units}} \times \frac{\text{Annual relevant carrying costs of 1 unit for a year}}{\text{Annual relevant carrying costs of 1 unit for a year}} \\ &= \left(\frac{D}{Q}\right) \times P + \left(\frac{Q}{2}\right) \times C = \frac{DP}{Q} + \frac{QC}{2} \end{aligned}$$

(Note that in this formula,  $Q$  can be any order quantity, not just the EOQ.)

When  $Q = 1,000$  units,

$$\begin{aligned} TRC &= \frac{13,000 \times \$200}{1,000} + \frac{1,000 \times \$5.20}{2} \\ &= \$2,600 + \$2,600 = \$5,200 \end{aligned}$$

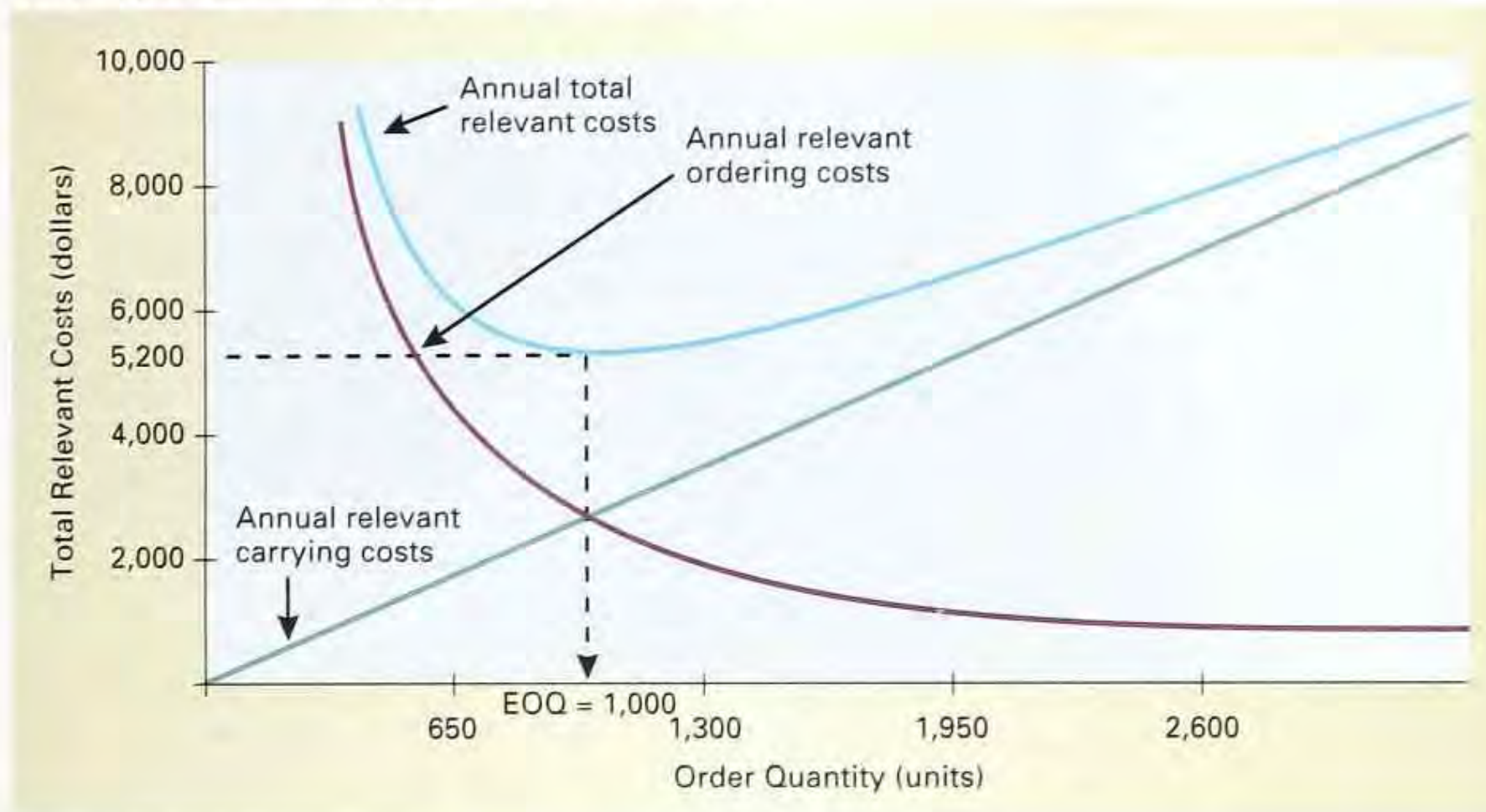
The number of deliveries each time period (in our example, 1 year) is

$$\frac{D}{EOQ} = \frac{13,000}{1,000} = 13 \text{ deliveries}$$

Exhibit 21-1 shows a graph analysis of the total annual relevant costs of ordering ( $DP/Q$ ) and carrying inventory ( $QC/2$ ) under various order sizes ( $Q$ ), and illus-



EXHIBIT 21-1  
Ordering Costs and Carrying Costs for Video Galore



trates the trade-off between the two types of costs. The larger the order quantity, the higher the annual relevant carrying costs, but the lower the annual relevant ordering costs. *The total annual relevant costs are at a minimum where total relevant ordering costs and total relevant carrying costs are equal* (in the Video Galore example, each equals \$2,600).

### When to Order, Assuming Certainty

The second major decision in dealing with cost of goods for sale is when to order. The **reorder point** is the quantity level of the inventory on hand that triggers a new order. The reorder point is simplest to compute when both demand and lead time are certain:

$$\text{Reorder point} = \frac{\text{Number of units sold}}{\text{per unit of time}} \times \text{Purchase-order lead time}$$

Consider our Video Galore example. We choose a week as the unit of time:

Economic order quantity	1,000 packages
Number of units sold per week	250 packages
Purchase-order lead time	2 weeks

Thus,

$$\begin{aligned} \text{Reorder point} &= \frac{\text{Number of units sold}}{\text{per unit of time}} \times \text{Purchase-order lead time} \\ &= 250 \times 2 = 500 \text{ packages} \end{aligned}$$

So, Video Galore will order 1,000 packages of tapes each time its inventory stock falls to 500 packages.

The graph in Exhibit 21-2 presents the behavior of the inventory level of tape packages, assuming demand occurs uniformly throughout each week.<sup>2</sup> If the purchase-order lead time is 2 weeks, a new order will be placed when the inventory level reaches 500 tape packages so that the 1,000 packages ordered are received at the time inventory reaches zero.

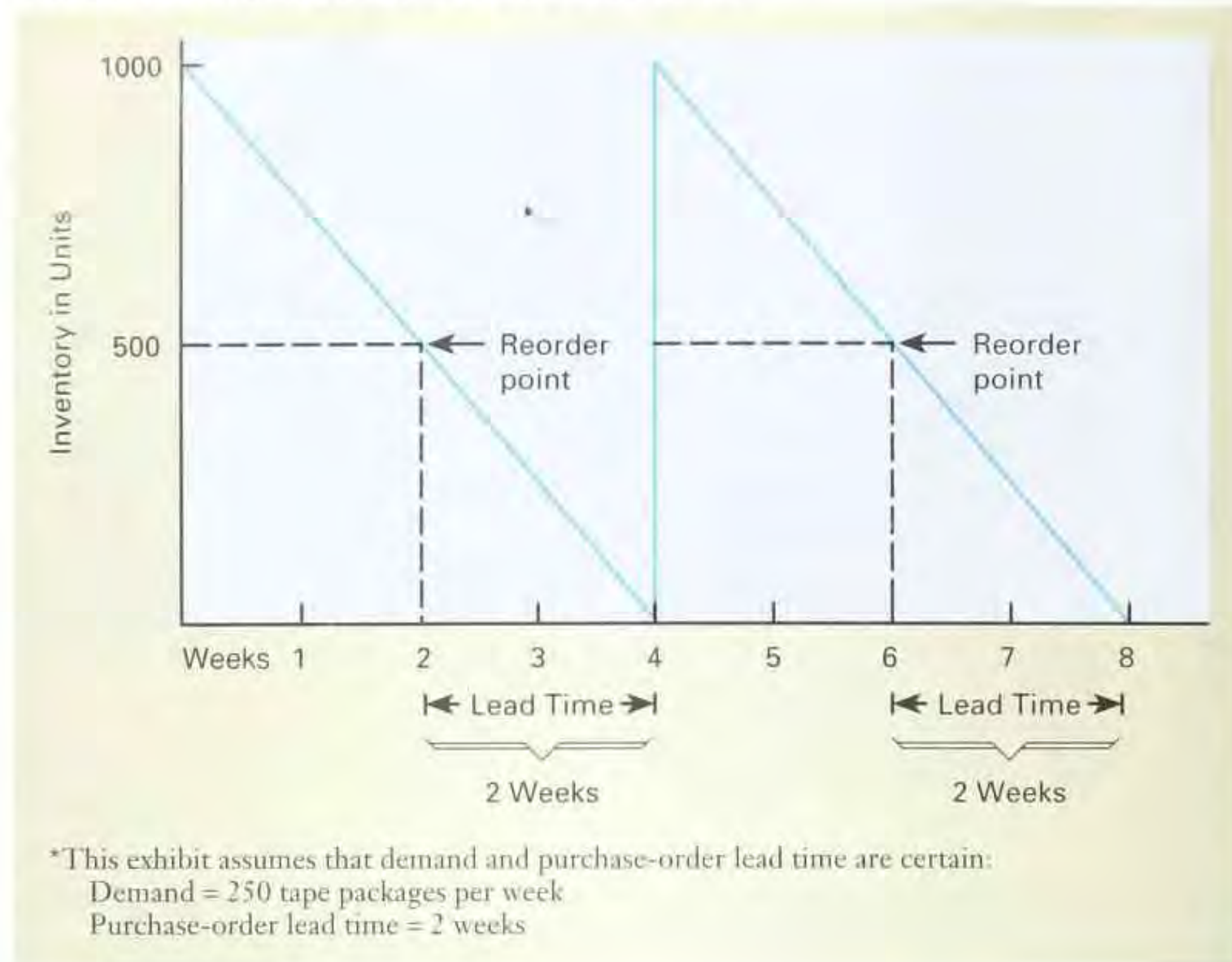
<sup>2</sup>This handy formula does not apply when the receipt of the order fails to increase inventory to the reorder-point quantity (for example, when the lead time is 3 weeks and the order is a 1-week supply). In these cases, orders will overlap.

#### OBJECTIVE 4

Explain the reorder point and safety stocks



EXHIBIT 21-2  
Inventory Level of Tape Packages for Video Galore\*



## Safety Stock

So far, we have assumed that demand and purchase-order lead time are certain. When retailers are uncertain about the demand, the lead time, or the quantity that suppliers can provide, they often hold safety stock. **Safety stock** is inventory held at all times regardless of inventory ordered using EOQ. It is used as a buffer against unexpected increases in demand or lead time and unavailability of stock from suppliers. In our Video Galore example, expected demand is 250 packages per week, but the company's managers feel that a maximum demand of 400 packages per week may occur. If Video Galore's managers decide that the costs of stockout are prohibitive, they may decide to hold safety stock of 300 packages. This amount is the maximum excess demand of 150 packages per week for the 2 weeks of purchase-order lead time. The computation of safety stock hinges on demand forecasts. Managers will have some notion—usually based on experience—of the range of weekly demand.

A frequency distribution based on prior daily or weekly levels of demand provides data for computing the associated costs of maintaining safety stock. Assume that one of seven different levels of demand will occur over the 2-week purchase-order lead time at Video Galore.

Total Demand for 2 Weeks	Units						
	200	300	400	500	600	700	800
Probability (sums to 1.00)	0.06	0.09	0.20	0.30	0.20	0.09	0.06

We see that 500 is the most likely level of demand for two weeks because it is assigned the highest probability of occurrence. We also see that there is a 0.35 probability that demand will be between 600, 700, or 800 packages ( $0.20 + 0.09 + 0.06 = 0.35$ ).

If a customer calls Video Galore to buy video tapes, and the store has none in stock, it can "rush" them to the customer at a cost to Video Galore of \$4 per pack-



age. The relevant stockout costs in this case are \$4 per package. The optimal safety stock level is the quantity of safety stock that minimizes the sum of the relevant annual stockout and carrying costs. Recall that the relevant carrying costs for Video Galore are \$5.20 per unit per year.

Exhibit 21-3 presents the total annual relevant stockout and carrying costs when the reorder point is 500 units. We need only consider safety stock levels of 0, 100, 200 and 300 units, since demand will exceed the 500 units of stock available at reordering by 0 if demand is 500, by 100 if demand is 600, by 200 if demand is 700, and by 300 if demand is 800.<sup>3</sup> The total annual relevant stockout and carrying costs would be minimized at \$1,352, when a safety stock of 200 packages is maintained. Think of the 200 units of safety stock as extra stock that Video Galore maintains. For example, Video Galore's total inventory of tapes at the time of reordering its EOQ of 1,000 units would be 700 units (the reorder point of 500 units plus the safety stock of 200 units).

Sontek does a similar analysis. Sontek too maintains safety stocks to meet unexpected demands from its customers. The net result is high levels of inventory in the supply chain consisting of the manufacturer and retailer. To reduce these inventories, companies are forming strategic partnerships. For example, Video Galore could contract with Sontek to manage Video Galore's inventory of tapes. Sontek could then better coordinate the flow of goods in the entire supply chain. For instance, Sontek could reduce its own inventory holdings when Video Galore is holding high quantities of inventory, and vice versa. Companies such as 3M, Procter & Gamble and Scott Paper have signed such agreements with WalMart, the largest retail company in the United States.

## CHALLENGES IN ESTIMATING INVENTORY-RELATED COSTS AND THEIR EFFECTS

### Considerations in Obtaining Estimates of Relevant Costs

Obtaining accurate estimates of the cost parameters used in the EOQ decision model is a challenging task. For example, the relevant annual carrying costs of inventory consist of *incremental* or *outlay costs* plus the *opportunity cost of capital*.

What are the relevant incremental costs of carrying inventory? Only those costs that vary with the quantity of inventory held—for example, insurance, property taxes, costs of obsolescence, and costs of breakage. Consider the salaries paid to clerks, storekeepers, and materials handlers. These costs are irrelevant if they are unaffected by changes in inventory levels. Suppose, however, that as inventories decrease, these salary costs also decrease as the clerks, storekeepers, and materials handlers are transferred to other activities or laid off. In this case, the salaries paid to these persons are relevant incremental costs of carrying inventory. Similarly, the costs of storage space owned that cannot be used for other profitable purposes as inventories decrease are irrelevant. But if the space has other profitable uses, or if rental cost is tied to the amount of space occupied, storage costs are relevant incremental costs of carrying inventory.

What is the relevant opportunity cost of capital? It is the return forgone by investing capital in inventory rather than elsewhere. It is calculated as the required rate of return multiplied by those costs per unit that vary with the number of units purchased and that are incurred at the time the units are received. (Examples of these costs per unit are purchase price, incoming freight, and incoming inspection.) Opportunity costs are not computed on investments, say, in buildings, if these

<sup>3</sup>If Video Galore is better (worse) off holding 100 units of safety stock rather than 0, it would prefer holding 100 (0) units rather than any number between 1 and 99 units. If Video Galore is better (worse) off holding 200 units of safety stock rather than 100, it would prefer holding 200 (100) units rather than any number between 101 and 199. If Video Galore is better (worse) off holding 300 units of safety stock rather than 200, it would prefer holding 300 (200) units rather than any number between 201 and 299. You can verify these statements by substituting different values of safety stock for 0, 100, 200, and 300 in Exhibit 21-3.