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H. L. Ducker

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By H. L. Ducker

The prime objective of the ordinary manufacturing industry is to produce a definite marketable product by the combination of raw material, labor and machine processes. In the process types of industry the product may be a uniform article such as cotton yarn; or under what is known as the special-order type of industry it may be machined steel products, each a special job in itself.

In such circumstances it is not difficult to charge the material and labor to the product, and the burden usually presents no insurmountable difficulty, because all costs must be borne by the articles produced. But it often happens, especially in the process-type of manufacturing industry, that all of the raw material is not found in the finished product but is lost in the processing in the form of waste, scrap or the like.

This residue, having gone part way through the process, may be somewhat different from the original raw material. This is designated by some writers as a by-product. It is evident that this residue or waste, or whatever it may be called, is not a desired end of the industry but arises incidentally and unavoidably in the manufacturer's regular output. In some cases this residue has no value but requires an additional cost for its disposal; in other cases it can be used as fuel or can be sold at a nominal figure or in some other way disposed of with a slight advantage to the concern.

Cases arise, however, in which it is necessary to put the residue through additional manufacturing processes to make it marketable to avoid a dead loss or the necessity of paying for removal from the premises. When additional labor or machine processes or further ingredients are expended upon this residue to make it salable, it is clear that the manufacturer has broadened the scope of his industry over what would have been necessary to produce the original article of production.

The effect of this residue upon the costs of the original product, whether sold as it arises or made into a new product, and the proper method of recording the financial aspects of it form some of the most interesting if not the most complicated phases of cost accounting. In view of the fact that this feature is found in so large a proportion of the large process industries to-day, the subject has more than a passing interest to cost accountants and producers as well.

Before launching into the subject itself a few words about terminology might be of value. Unfortunately, in this as in other branches of accountancy, there can hardly be said to exist an accepted uniform terminology. Some writers draw a distinction between waste, scrap, spoilage and by-products, while others assert that they are the same. Still others draw a distinction between scrap and waste on the one hand and by-products on the other. The definition of a by-product is not treated alike by any two writers upon cost-accounting subjects.

While little would be gained by attempting to decide which writer's terminology is more accurate, it will aid in the study of a subject for the reader to know what meaning a writer intends to convey in the terminology used by him in the exposition of his subject. With the end in view of assisting the reader, and without any thought of introducing a new terminology or of supporting or opposing the terminology of any other writers, the following terms as used in this article and the meaning associated with them in presenting this subject, are set forth as a sort of foreword to what follows.

By-product will be considered to be any salable or usable product produced as merely incident and in addition to the main product without the necessity for any other further manufacturing processes. Used in this sense it closely corresponds with the terms scrap and waste as used by many cost writers; in fact it includes both of these as the terms are ordinarily used—the waste of a cotton mill is a by-product, and so is the scrap metal of a foundry.

Co-product is a salable product made in a factory by adding to one or more of its by-products, labor, material or machine processes to convert the by-product into an article having a greater market value—that is, the manufacturer is engaged in producing his main product and also in making a minor product out of some of the by-product produced in manufacturing the major product.

Joint Products are manufactured articles which are produced simultaneously by a uniform process or series of processes; and each one has more than a nominal market value in the form in which produced.

By-products—Methods of Costing

The treatment of costs in by-product industries is by no means uniform. A number of different methods are in use but only the three more common ones will be discussed.

The first method can hardly be called a method at all. The net receipts from the sales of the by-product are totaled and are added to net operating profit under the "miscellaneous income" group. None of this amount is treated as a reduction of cost of regular product. The advocates of this method contend that the by-products are mere incidents in the production of the regular product and that if anything can be realized from the sale of such by-products it is miscellaneous income—not a reduction of cost of manufacture. The effect of such treatment is to charge the regular product with all costs of producing it, without any offset for values received from the by-products. The by-products are assumed not to have cost anything and receipts from the net sales of such by-products are considered all gain. The simplicity of this method is its greatest recommendation. If the amount realized by the sale of the by-products is relatively small as compared to the regular product, this method would have slight effect upon costs.

The second method differs from the first in only one respect. Costs of wrapping or packing the by-product and selling costs are deducted from the net receipts from its sale and the remainder is added to "miscellaneous income." No cost for either labor or material is added to the cost of the by-product and no credit is made to the manufacturing cost of the regular product for any portion of the amount realized from the by-product. This method is little better than the first and the added work of keeping the shipping and selling costs does not avoid the inaccuracy of the costs of the regular product.

The third method attempts to establish what portion of total manufacturing cost goes into the by-product, or what arbitrary value should be assigned to it for the portion of costs found in it. Under one method the value of the raw material in it is computed and considered its cost. In this case, the manufacturing costs are credited with this amount and this amount is debited to the by-product account. Marketing and selling expenses may or may not be added to the cost of the by-product. The difference between these costs and the net receipts from the sales of by-products is considered as miscellaneous income, or miscellaneous expense, as the case may be.

In some cases the total market value of the by-product is credited to the cost of manufacturing regular product and no profit is shown from the sale of the by-products. The theory back

of this method is that the market price prevails at average cost represented in the by-product. Other industries establish a standard value for the by-product based on the average selling price over a long period of time and credit manufacturing costs with by-products produced at this rate.

It can be easily seen that if the by-product market fluctuates sharply the crediting of its market price to manufacturing cost tends to obscure the true cost and also to conceal variations in the cost of making regular product. If the price is held at a standard figure, a profit is apt to be shown on the by-product and the main product will be over or under-costed.

Assume that the manufacturing costs of a company for a month are $60,000 before making any adjustment for by-products. During this period 100 pounds of one class of by-product are produced.

(a) An arbitrary value of five cents a pound is assigned to the by-product:

By-product	$5.00	
Manufacturing expense		$5.00
By-product	1.00	
Selling expenses		1.00
Cash (accts. rec.)	6.25	
By-product		6.25
By-products	.25	
P & L (miscellaneous)		.25

(b) Total receipts from net sales of by-products are credited to cost of manufacture.

By-product	$6.25	
Manufacturing expense		$6.25
Cash (or accts. rec.)	6.25	
By-products		6.25

Co-products—Methods of Costing

Where a plant puts its by-products through processes to make co-products, the correct costing of the output presents some real problems. In this, as in the case of by-products, several methods of costing are in use among the numerous concerns producing co-products.

One method makes no charge to the co-product for the by-product or waste material and hence no credit to the manufacturing cost of the major product. The co-product is charged with labor, processing costs and any added materials necessary to convert it into the salable co-product. It is also charged with its portion of the selling cost. The difference between the receipts from the net sales of this co-product and the processing and selling costs is considered a miscellaneous profit or loss, as the case may be. This may be illustrated by the following journal entries:

Co-product A	xx	
Labor		xx
Material		xx
Overhead		xx
Co-product A	xx	
Selling expense		xx
Cash (accts. rec.)	xx	
Co-product A		xx
Co-product A	xx	
P & L (miscellaneous income)		xx

This method is used where the by-product is only a minor factor in quantity and value and where the subsequent processing and selling costs are small enough to have no important effect upon the "profit ability" of the industry as a whole. In these cases the volume and profit of the main product sales are sufficient to insure the success of the industry, and the profit on the co-product is considered as a fortunate source of miscellaneous income.

Under another method some value is fixed for the by-product going into the co-product which is the first charge to the latter and is credited in like amount to the manufacturing cost of the main product. The by-product value may be determined by some of the methods already described for establishing the values of the by-products sold in that form or the value may be determined by working backward from the selling price or a stated standard figure of value.

Suppose that co-product A produced during a certain month is all sold for $100. The selling costs charged to it were $10; the labor in processing the by-product from which it was made was $15, and other manufacturing charges amounted to $5. Ten per cent. of the selling price is estimated to be profit. To find the

value of the by-product used in producing co-product A, as the basis for the credit to the manufacturing costs of the main product, the following calculation can be made:

Selling price yield of co-product		$100
Deduct estimated profit of 10%		10
		$90
Deduct: Selling expenses	$10	
Labor	15	
Other manufacturing charges	5	30
Value of by-product produced by main process		$60

The journal entry charging the co-product and crediting the main product would be:

Co-product A	$60	
Manufacturing costs (main product)		$60

In opposition to this method it is argued that by-products produced in one period are usually not finally made into a by-product until a subsequent period and that, if the sales are credited to the manufacturing costs in the month when the sales are made, a period which did not produce the by-products will receive credit for them.

This argument may be answered in two ways: First, a record of the quantity of by-products produced each month can be kept and from the average market price of the co-product the by-product unit value can be determined by working backward from this figure. The quantity produced multiplied by the unit values will determine the credit to the manufacturing cost of the main product for the same period. Second, if the operations are fairly uniform and prices are not subject to violent fluctuations, the results from period to period will be about the same, and if the amount of the credit to the manufacturing cost of the main product is uniform, it does not make any difference whether the credit is from by-products produced in some prior month or not.

Joint products—cost problems

Joint products are produced when a manufacturer by a single process or uniform series of processes produces a product of two or more kinds, sizes or grades, all of which are of relative importance and value. The process or series of processes must be applied up to the point at which the identity of the products becomes established in order that the products be strictly "joint". An example is the chemical industry where certain chemicals are

mixed and put through a series of processes until two or more new chemicals are produced. Up to the point where the identity of the new products is established the operations are joint—they apply as much to the production of one of the products as to the other.

If the products are in fact joint products, the operations are joint and the costs can only be applied to each product upon some arbitrary basis. One of the most common methods is to average the costs on the basis of units of each produced. For example, at a joint cost of $120 two products are produced as follows: A, 180 pounds; B, 60 pounds. The total production is 240 pounds, the total cost $120. Therefore, the average cost is $150 a pound and the total cost of A is $90 while that of B is $30.

It is obvious that this method can give satisfactory results only under ideal conditions. If the relative quantity of each product were nearly the same and if the market values were at almost the same level, the average method would have no bad results. But let us assume in the case cited that the output of A was 220 pounds and the output of B was 20 pounds, total cost remaining the same, but that B could sell for $3.00 a pound while all that could be realized in a competitive market on A is fifty cents a pound.

By the method already shown, costs of A and B would be:

A—220 pounds 220/240 of $120=$110
B— 20 pounds 20/240 of $120=$10
110÷220=$.50 cost of A
10÷ 20=$.50 cost of B

Since A is sold for fifty cents a pound, it is being sold at manufacturing cost, while on B a gross profit of $2.50 a pound is realized.

Another method of costing joint production is to split the cost between the products in the same proportion as the yield realized from selling values. This method is in quite common usage and works well where the market is wholly competitive and prices are not controlled by the producers. The theory back of this method is that what the product will yield determines its value as a product and this value should then be the basis of the amount of the cost which that product must absorb.

Reverting to our illustration, we have 220 pounds of A at 50 cents and 20 pounds of B at $3.00 a pound. Let it be assumed that the expenses per pound of selling and marketing the product

are equal so that no consideration need be taken of this point. The $120 cost would be pro-rated between A and B as follows:

	Produced	*Unit selling price*	*Total value*	*Relative value*
A.....	220	$ .50	$110.00	64.7%
B.....	20	3.00	60.00	35.3%
	240		$170.00	100 %

A—64.7% of $120 = $77.64 unit cost of A = $ .3529
B—35.3% of $120 = $42.36 unit cost of B = 2.1185

$120.00

One method of pro-rating the joint cost between the products is on the basis of theoretical production. A modification of this method is used in certain portions of some textile industries. A simple illustration of the principle involved is here presented:

Assume that a concern produces two grades of product, A and B, in a single process. The theoretical production for a period should be 400,000 units of A and 480,000 units of B.

Actual production for the same length of time is 450,000 units of A and 300,000 units of B. The total production cost is $1,680,000.

If the theoretical production of the two grades were equal, each would bear half of the cost of production per unit. But more of B than of A is produced. Costs per unit are inversely proportionate to quantity and hence grade B should bear a smaller portion of production cost per unit than A.

480,000 ÷ 400,000 = 1.20 production ratio
450,000 × 1.20 = 540,000 A on the basis of B
300,000 × 1.00 = 300,000 B

840,000 production on basis of B

750,000 actual unit production
1,680,000 ÷ 840,000 = $2.00 unit cost of production, basis of B
2.00 × 120 = $2.40 unit cost of producing A

Joint-product and Co-product Operations

Many industries combine the joint-product and co-product features in their operations. For instance the joint operations may produce three products, X, Y and Z. Product X and Y may be salable as they are produced and each may command a good price. Z, however, possesses a better market after it is further processed and made into product M.

The cost features can best be shown by using an illustration. Suppose that the total product consists in weight of 40% of X, 40% of Y, and 20% of Z, all produced jointly by a uniform series of operations, the total cost of which is $5,000 in a certain month. Z is converted into product M by additional processing costs of $300. The combined production of X, Y, and Z is 10,000 pounds. No loss or gain in weight occurs in any of the production. Average market value per pound of each product is as follows: X, $1.00; Y, $1.25; and M, $.90. Selling and administrative expenses are uniform for all products, being ten cents a pound.

The solution as applied in some industries would be:

Product		*Output*	*Market*	*Total*
X.....	40%—	4,000	1.00	$4,000
Y.....	40%—	4,000	1.25	5,000
Z.....	20%—	2,000	.90	1,800
	100%	10,000		$10,800

Co-product M—		
2,000 pounds—market value $.90 total.....		$1,800
Deduct:		
Selling and admin. exp. @ $.10 per pound.....	$200	
Cost of converting Z to M.....	300	500
Relative yield value of Z.....		$1,300

X—Yield value (1.00—.10 selling cost) 4,000 × .90 = $3,600
Y— " " (1.25—.10 " " 4,000 × 1.15 = 4,600
Z— " " 1,300
$9,500

Cost of X 3600/9500 of 5,000 = $1,894.74 unit cost $.4737
" " Y 4600/9500 of 5,000 = 2,421.06 unit cost .6053
" " Z 1300/9500 of 5,000 = 684.20
$5,000.00

Unit cost of Z = (684.20+300) ÷ 2,000 = $.4921 per pound

A survey of this method shows that it equitably spreads the costs over the output. M is considered to have borne its share of joint costs in proportion to its yield value after deducting selling and subsequent costs. The yield values of X and Y are determined by deducting from the market value the selling and administrative costs. X, Y and Z all having been placed on the same basis, the joint costs are pro-rated to them proportionately.

After determining the proportion of the joint cost to be allotted to Z there must be added to it the cost of converting it into co-product M, giving a final unit cost of $.4921 a pound.

The illustrations used have been purposely made simple in order not to obscure the principles in a maze of figures. In such industries as artificial-gas production, petroleum refining and meat packing, the cost procedure appears extremely complicated, but a careful study of the methods used in each case will show that the same simple fundamental principles will appear back of each mass of figures.