HOW MANY PARTS TO MAKE AT ONCE

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Interest on capital tied up in wages, material and overhead sets a maximum limit to the quantity of parts which can be profitably manufactured at one time; "set-up" costs on the job fix the minimum. Experience has shown one manager a way to determine the economical size of lots.

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Every manufacturer is confronted with the problem of finding the most economical quantity to manufacture in putting through an order. This is a general problem and admits of a general solution, and, however much it may be advisable to exercise judgment in a particular case, such exercise of judgment will be assisted by a knowledge of the general solution.

The writer has seen the practical workings of a first class stock system and does not wish to be understood as claiming that any mere mathematical formula should be depended upon entirely for determining the amount of stock that should be carried or put through on an order. This is a matter that calls, in each case, for a trained judgment, for which there is no substitute. There are many other factors of even more importance than those given in this discussion.

But in deciding on the best size of order, the man responsible should consider all the factors that are mentioned. While it is perfectly possible to estimate closely enough what effect these factors will have, the chances are many mistakes costing money will be made. Hence, using the formula as a check, is at least warranted. Given the theoretically correct result, it is easy to apply such correction factors as may be deemed necessary.

In determining the economical size of lot the following factors are involved:

Unit Cost (C). This is the cost in dollars per unit of output under continuous production, without considering the set-up or getting-ready expense, or the cost of carrying the stock after it is made.

Set-up Cost (S). This involves more than the cost of getting the materials and tools ready to start work on an order. It involves also, the cost of handling the order in the office and throughout the factory. This cost is often neglected in considering the question.

Most managers, indeed, have a rather hazy idea as to just what this cost amounts to. If such is the case an investigation will show that the cost of handling, checking, indexing and superintending an order in the offices and shops is a considerable item and may, in a large factory, exceed one dollar per order. The set-up cost proper is generally understood. Indeed, shop foremen in general appreciate only too well what the cost of set-up means on small orders, and so, if left to themselves, will almost invariably put their work through in large quantities to keep down this item. So doing, however, affects unfavorably the next factor.

Interest and Depreciation on Stock (I). Large orders in the shop mean large deliveries to the storeroom, and large deliveries mean carrying a large stock. Carrying a large stock means a lot of money tied up and a heavy depreciation. It will here be assumed that a charge of ten per cent on stock is a fair one to cover both interest and depreciation. It is probable that double this would be fairer in many instances.

Movement (M). It is evident that the greater the movement of the stock the larger can be the quantities manufactured on an order. This, then, is a vital factor.

Manufacturing Interval (T). This is the time required to make up and deliver to the storeroom an order, and, while it seldom is a vital factor, it is of value in the discussion.

There is another factor, X, the unknown size of order which will be most economical. Thus summarizing, there are the following factors in the problem:

M equals the number of units used per month (movement).
C equals the quantity cost of a unit in dollars or the unit cost.
S equals the set-up cost of an order in dollars.
T equals the manufacturing interval in months.
I equals the unit charge for interest and depreciation on stock.
X equals the unknown size of order, or lot size, which is most economical.

The manufacturing interval is useful only in that it enables us to find the safe stock minimum, or smallest quantity the storekeeper may allow his stock to fall to before he must enter an order for more.

At first sight this minimum quantity would seem to influence the amount of stock and therefore the interest charges. It does nothing of the kind, however, and it will be found that the stock consists of additions in lots of X and a gradual exhaustion of the stock to nothing. The stock minimum simply serves to notify the storekeeper when to enter an order for new stock, so that he will use up his stock clean before deliveries on the new order are made and, at the same time, never be without stock for any considerable interval.

The average stock, if the movement is regular, it will be evident, is $X/2$. If the movement is irregular, and it generally is, there is introduced an additional complication. This, however, can generally be neglected or applied as a correction factor to the final result. The average stock being $X/2$, the value of this stock will evidently be C times this, or $CX/2$ (value of average stock on hand).

This is the quantity cost only. To it must be added the set-up cost for the average stock. Since the set-up cost per order is S, and the average stock is half the size of an order, the set-up cost of the average stock will be $S/2$. The total value of the average stock will then be $1/2(CX+S)$. The annual interest and depreciation cost at ten percent will be one-tenth this or $1/20(CX+S)$.

Now since M units per month are used, this will be $12M$ units per year, and this interest charge must be divided by the number of pieces used in a year to get the interest charge in dollars per unit, which gives

$$\frac{1}{240M}(CX+S)=I$$

The total set-up cost for X units being S dollars, the set-up cost per unit must be S/X. This now gives, as the whole cost of a unit, the interest charge per piece plus the set-up cost per piece plus the unit cost per piece, or

$$\frac{1}{240M}(CX+s)+\frac{S}{X}+C$$

Let this summation equal Y.

The problem then is the old one of finding the value for X that will give the minimum value to Y. As the solution of this problem involves higher mathematics, suffice it to say that the value for X that will give the minimum value to Y, reduces to

$$\sqrt{\frac{240MS}{C}}$$

Now $240S/C$ may be calculated at once and the square root taken. Call this result K, because it will be a constant for any case. Then $X=K\sqrt{M}$.

Now let an actual example be taken and see what the results will be. Suppose that an article has a movement, M, of 1,000 units per month with a set up cost of two dollars and a unit cost of ten cents. Applying the formula, it is found that the theoretical economical size of lot is 2,190 units. This shows the set-up cost to be about 0.1 cent and the interest charges about the same amount.

Referring to the Figure I a curve will be seen representing the cost per piece of set-up for various manufacturing quantities and an interest and depreciation charge under the same conditions. The sum of these two is marked the total cost, although

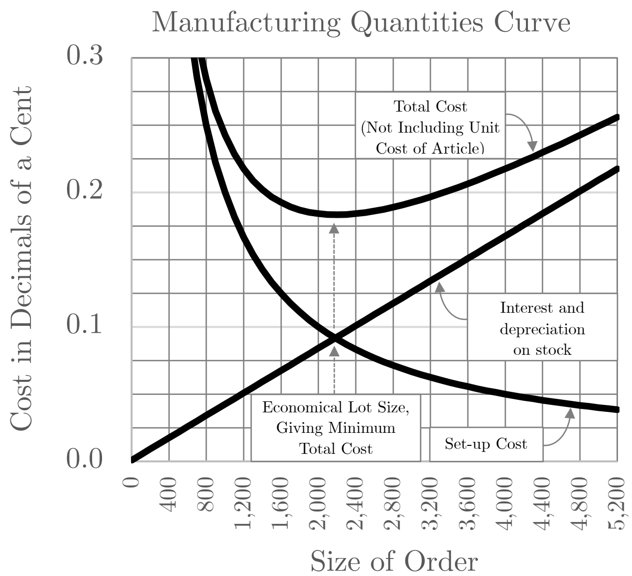


Figure I. An increase in the size of the order results in an increased interest charge and a decreased set-up cost. The curves show this graphically and indicate a minimum total cost in this case at 2,200 units.

it does not include the unit cost of ten cents, which is not added because assumed constant.

It should be noted that this so-called total cost can vary between wide limits only when the manufacturing quantity is selected with very poor judgment. For example, in the case given, the least total cost possible will be about 0.188 cents at 2,190 units on an order. This quantity can vary from 1,000 to 5,000, and the additional cost will be only about 0.05 cent. This on an article costing ten cents, is a very small percentage. While this is true for the values given it is not universally true, and thus it is seen that the general law can be applied with some profit to the specific problems of manufacture.

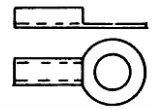
Some actual examples of costs may be illuminating. Take, for example, the copper connector shown in Figure II. Here is an article that is being used at the rate of 1,230 pieces a month, with a unit cost of $0.0135 per piece, and a set-up cost of $2.15. This latter cost includes the clerical work, superintendence, and so on, as well as the actual cost of getting ready in the shop.

It is found by applying the formula that the correct manufacturing quantity is 6,850 pieces. The different values of the cost are shown in the curves on the diagram. It will be noted that the loss is much greater if too small a quantity is put through, than it is for too large a one. For example, if this article were made in 2,200 lots, $0.001 would have to be added to the original cost of $0.0135, which would involve a loss of $0.00028. On the other hand, if they were put through in lots of 10,000, which is about as far the other way, there would be a loss of only about one eighth of this amount. Or, in percentages, in the first case there would be incurred an unnecessary expense of about two per cent on the original cost, while in the latter case the loss would have been only about one quarter of one per cent. It should be noted that in this case this article would be put through in lots that would last for nearly six months.

Take, as a further example, the stud shown on Figure III. Here is a piece that is used in lots of thirty. It is an expensive piece and costs in quantity $5.65. The set-up cost is $1.85. The correct quantity is 48.5 or, say, 49. Here the least overhead for set-up and interest charges would be $0.076 per piece. Making the article in lots of twenty, there would be about the same unnecessary loss as when they were made in lots of 100, or about three cents each. This is not a large amount, but at the rate of consumption given, it will involve a loss of $10.80 a year, which is avoidable and, therefore, worth considering. So it is seen, the more valuable the article, the more "worth while" it is to apply the formula.

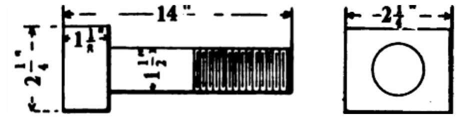
There are not many men who understand the theory underlying the economic size of lots, and so a knowledge of it should be of considerable value. For example, having once determined that it is wise to put in orders for lots of one hundred, based on a certain consumption, it is of value to know that this consumption must increase four fold to warrant doubling the manufacturing quantities. It is further gratifying to know that the effect on profits from an error is so small as shown by the curves.

In conclusion, it may be well to say that the method given is not rigorously accurate, for many minor factors have purposely been left out of the consideration. It may be objected that interest and depreciation should be figured, not only on original cost, but also on the set-up cost, since that has to be incurred before the parts can be stocked. Such refinements, however, while interesting, are too fine spun to be practical. The general theory as developed here is reasonably correct and will be found to give good results.



Article = A Small Connector
Material = Copper

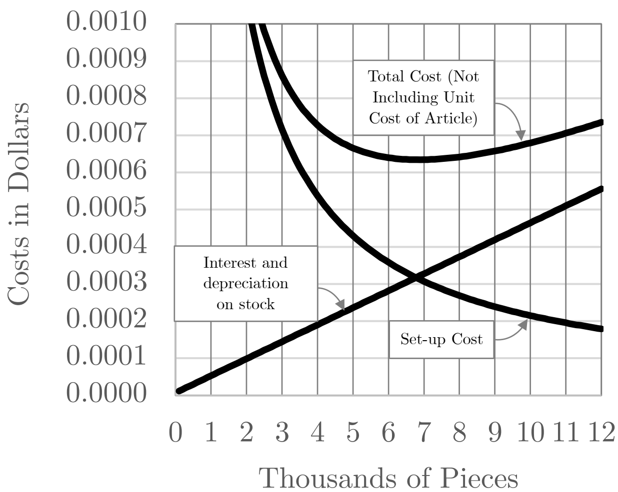
Monthly Quantity = M= 1,230
Cost per Piece = C = $0.0135
Set-up Cost = S = $2.15
Mfg. Quantity = X ≈ 6,850

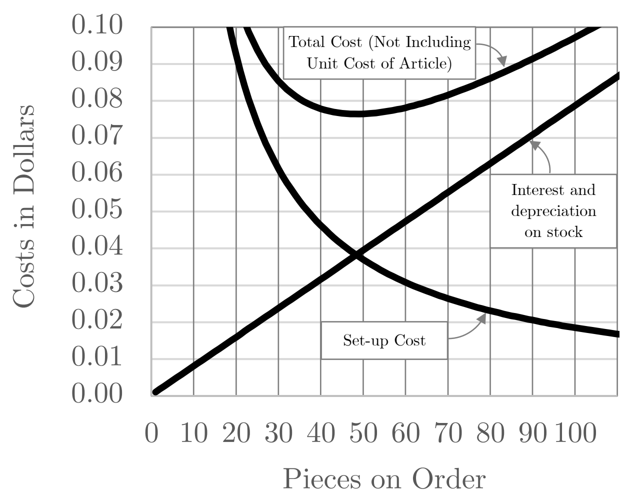


Article = A Stud
Material = Copper

Quantity per Month = M = 30
Cost per Piece = C = 5.65 Dollars
Set-up Cost = S = 1.85 Dollars
Manufacturing Quantity = x ≈ 48.5

$$= \sqrt{\frac{240 \times 30 \times 1.85}{5.65}}$$





Figures II and III: In each of these diagrams is shown the effect of the size of the lot on the set-up and interest charges per unit. The set-up cost curves slope downward with increased size of the order while the interest curves slant upward. The sum of the two elements gives total costs the curve of which is the upper one and shows a minimum opposite where the two lower curves cross.