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VALUE ENGINEERING AND EXPERIENCE CURVE PREDICTIONS

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INTRODUCTION

This booklet illustrates some situations in which experience curve techniques may be applied as an aid in analyzing VECP's. It is assumed by the author that personnel applying these techniques will be sufficiently familiar with experience curve application and theory to be able to apply the solutions and/or methods in this book to their own particular problems.

Certain things should be remembered as one reads this booklet. The experience curve theory used is the unit experience curve theory. This theory maintains that unit cost decreases as quantities double, resulting in the notion that cumulative units plotted against cost per unit on log-log paper gives a straight line. This is in contrast to the theory that cumulative average cost plotted against cumulative units on log-log paper is a straight line. The former theory is known as the Crawford theory, and the latter is the Wright theory. The Crawford theory has gained prominence in recent years.

This booklet deals with general situations which one might incur in dealing with value engineering problems. Most of these are cases with which the author has come in contact. It is hoped that the method used in these particular cases will indicate methods that might be used in similar situations.

The method of dealing with the experience curve techniques and value engineering problems in this book will be to state a problem in terms of specific figures and give a sample solution using these figures. It should be pointed out that the solutions worked out in this book are done using tables developed by this organization. The formal equations and theory used for the solutions are given in a separate section from the examples. The solutions in this book are directed toward obtaining the total savings and the average savings per unit for some given quantity as the result of a value engineering change made at some point in production. The total savings and the average savings per unit are important figures in calculating the worth of a change and the contractor's share of savings as a result of the change.

Also, it should be pointed out that non-recurring costs such as tooling costs are treated as separate quantities in the examples. In no case are non-recurring costs spread over the curve. In each case the effect of these costs should be considered after the experience curve analysis of recurring cost has been performed.

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zation of the cost reduction proposal on future purchases of the item."

Thus, the ASPR attempts to define the unit cost reduction which will be used in calculating the contractor's share of savings. For most production contracts early in the production of an item the substitution clause is used. Thus, when a VECP is submitted the contracting officer must estimate the average unit cost reduction resulting from utilization of the value engineering change on future procurements of the item. The experience curve can be a valuable tool for making this estimation.

In order to use experience curve techniques one must have some knowledge of the contractor's production slope. Quite often this can be obtained easily. The contractor sometimes submits experience curves or his production slope in his bid or during negotiations. Sometimes it is possible to estimate a contractor's slope from his work on a similar item or from the industry average slope on a similar item. Of course, the best method is to obtain data on the contractor's past performance, if available, and construct his experience curve. Also, in some cases experience curves or production slopes may be known for major components. Thus, if a VECP involves mainly one major component, the slope for that component might be used in evaluating the VECP. Possibly, individual slopes might be obtained for fabrication, assembly, etc. and when a VECP mainly involves one of these processes the particular curve involved could be used in the analysis.

Many value engineering changes involve the elimination of a process, or an assembly or fabrication feature. If these value engineering changes had not been made, the cost which was eliminated corresponding to each of these would have decreased in accordance with experience curve theory. The process, assembly, or fabrication procedure might have been improved upon. The cost associated with the unneeded part or design feature might have been reduced due to the solution of an engineering or technical problem. Various components might have been subcontracted out to contractors who could do the job at a lower cost. Improvements in design features might have been made. Laborers would have become more efficient in the performance of their jobs. All of these things are the factors which determine a contractor's production or experience curve. Thus, the cost which was eliminated by a value engineering change would have decreased some as production continued even if the value engineering change had not been made. The savings per unit resulting from the value engineering change will decrease at the same rate that the eliminated cost would have decreased. Hence, if a contractor or an industry is exhibiting an 85% slope of production, we may evaluate the savings resulting from certain value engineering changes on an 85% slope in an attempt to estimate what the projected savings over a period of time will be. It is important to remember that a savings of $10.00 on the 25th unit produced is not a savings of $10.00 on the 1,000th unit.

To illustrate what can happen if this fact is overlooked, consider the following example. (The results of the experience curve analysis will be given but the procedure will not be explained.) A contractor has the first production contract on an item, and from previous experience on similar items he estimates his production slope to be 73%. His contract is for 100 units and contains a value engineering incentive clause which gives him 50% of the savings on the instant contract as a result of value engineering changes and 30% of the savings on future procurements within a three year period. Furthermore, it is estimated that within the contractor's sharing period approximately 2,400 additional units will be procured.

At the 10th unit the contractor submits a VECP which reduces the cost per unit for the remaining 90 units of the instant contract by $500. The contracting officer must estimate the savings resulting from the value engineering change not only on the instant contract but on future production

THE PROBLEM

In spite of the increased emphasis on value engineering, there are many people who question its worth. The problem is that it is difficult to estimate the amount of money a value engineering change actually saves as production continues, and, as a result, it is difficult to arrive at the amount of money the contractor should receive for making the value engineering change. The experience curve can be a very useful tool for solving this problem. It will give the total savings and the average unit cost reduction over any specific quantity as the result of the value engineering change.

The need for a method of estimating the total savings and the average savings per unit over a specific quantity of units to be produced in the future arises from certain clauses in the Armed Services Procurement Regulation. ASPR, 1-1703.2, states that one of three basic plans of sharing savings with the contractor will be used. These are:

(1) Contractor participation in cost savings under the instant contract only,

(2) Contractor participation in cost savings under the instant contract plus royalty payments on actual future procurements within a stated period.

(3) Contractor participation in cost savings under the instant contract plus estimated savings on additional quantities expected to be procured subsequently, the estimated additional quantities being stated in the instant contract.

There is usually no difficulty with the first plan because it is fairly easy to calculate the savings on the instant contract. Plans (2) and (3) present some problems, however. Under plan (2) at the time the VECP is negotiated, the contracting officer must make a determination of the average unit cost reduction under the instant contract and of the average unit cost reduction over future production within a specific royalty period. This determination is made only once, and the contractor's incentive is calculated based on the unit cost reductions decided upon. The third plan calls for a lump sum payment to be made to the contractor at the time the VECP is negotiated which includes the contractor's share of savings under the instant contract and his share of savings on estimated future procurements within some sharing period. The estimated quantity to be procured during the sharing period is stated in the contract.

Essentially, both methods are alike except that in plan (2) the contractor receives his share of savings on future procurements in royalty payments which are made as future quantities are delivered. In plan (3) the contractor receives all of his share of the estimated savings in one lump sum payment at the time the VECP is negotiated. Under both plans the contracting officer must make an estimate of future savings as a result of the value engineering change at the time he negotiates the VECP.

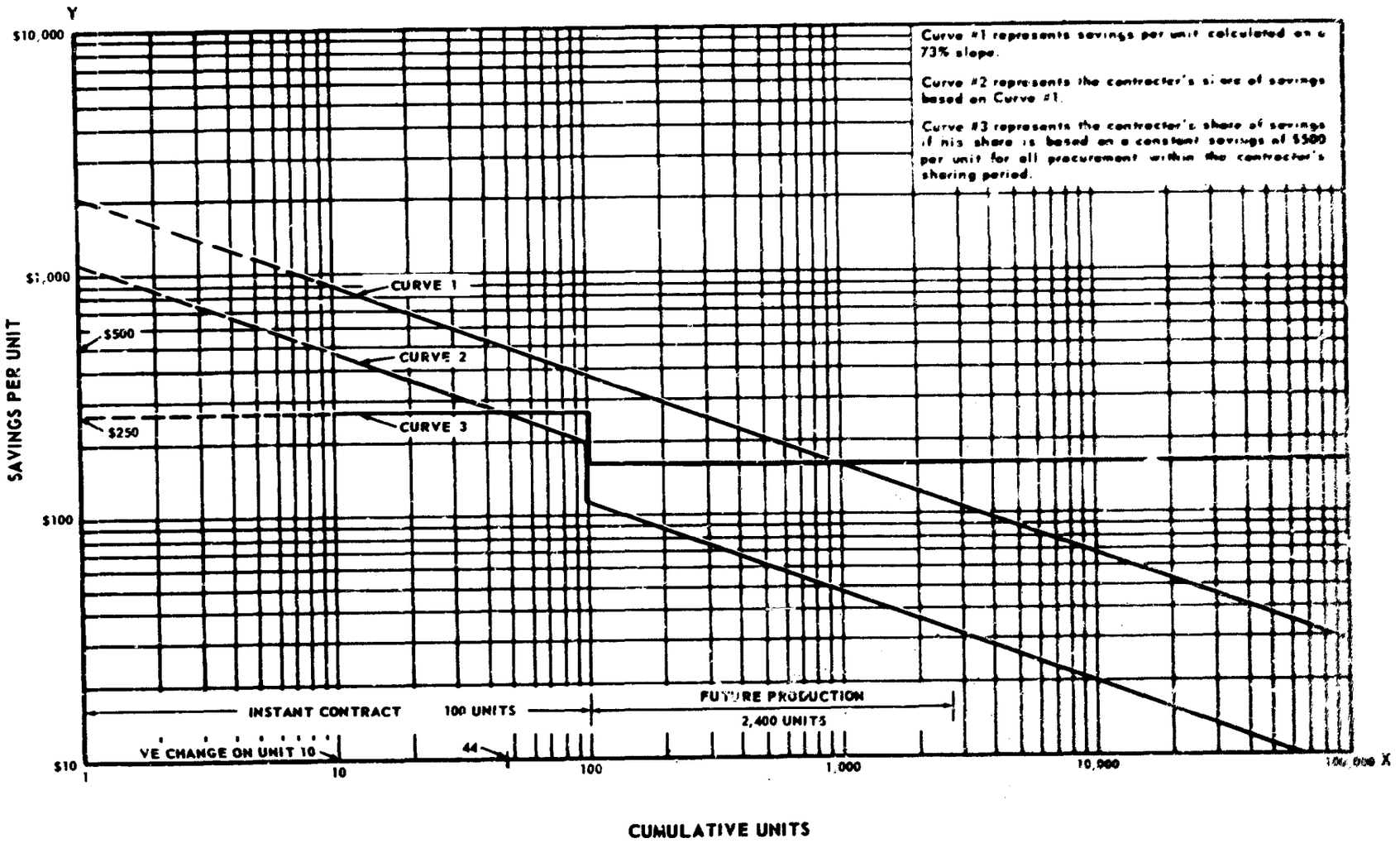
Another part of the ASPR dealing with unit cost reduction under future production is ASPR, 1-1707.2 (j) (1) (i). This clause states that:

(i) "The unit cost reduction under this contract will be what it would have been had the cost reduction proposal been utilized on all units under this contract; . . ."

The ASPR continues as follows:

"Whenever in the judgement of the contracting officer, the unit costs under the instant contract will not be fairly representative of unit costs under future contracts (as will generally be the case with developmental contracts and may be the case with initial production contracts), paragraph (j) of the foregoing clause should be modified by . . . changing the text of (i) in subparagraph (j) (1) to read as follows:

(i) "The unit cost reduction will be the average amount of the decrease in unit cost of performance which the contracting officer estimates will result from the utili-


Y
$10,000
$1,000
$500
$250
$100
$10
SAVINGS PER UNIT
CURVE 1
CURVE 2
CURVE 3
Curve #1 represents savings per unit calculated on a 73% slope.
Curve #2 represents the contractor's share of savings based on Curve #1.
Curve #3 represents the contractor's share of savings if his share is based on a constant savings of $500 per unit for all procurement within the contractor's sharing period.
INSTANT CONTRACT
100 UNITS
FUTURE PRODUCTION
2,400 UNITS
VE CHANGE ON UNIT 10
44
1
10
100
1,000
10,000
100,000 X
CUMULATIVE UNITS

within the contractor's sharing period also. Suppose that the $500 per unit savings on the instant contract is taken as a constant savings per unit over all production within the sharing period (i.e., over the entire 2,500 units to be procured within the sharing period). Then, the contractor's share of savings is calculated below:

50% of ($500 × 90 units)	=	$ 22,500
30% of ($500 × 2,400 units)	=	360,000
contractor's total share	=	$382,500

Thus, the contractor's total share would be $382,500.

An experience curve analysis of the VECP, however, gives quite different results and exposes an alarming possibility. Use of the experience curve shows that the contractor's total share of savings should be $113,306 which is less than a third of the $382,500 obtained above. But what is even more important is that the experience curve analysis shows that the total savings resulting from the value engineering change within the sharing period is $347.688. Therefore, if the contractor is paid $382,500 for making the change, he will receive more money than the value engineering change is actually saving during the sharing period. The $382,500 figure was obtained using a unit cost reduction of $500 as the average unit cost reduction over future production as well as the instant contract. But the experience curve analysis gives an average unit cost reduction over future production within the royalty period of $126.12. See graph which follows. This example illustrates the need for some tool such as the experience curve to aid the contracting officer in estimating the worth of a VECP and the contractor's share of savings. This booklet explains how to apply the experience curve to various situations which arise.

Before discussing particular applications of the experience curve in analyzing VECP's, a few comments should be made concerning the experience curve. The experience curve is only a tool to be used as an aid in evaluating VECP's. Experience and management principles must still be used in this analysis. Also, it must be remembered that the experience curve an-

THE EXPERIENCE CURVE (Theory)

Before one can read and understand the examples to follow, he should become acquainted with some of the terms and theory pertaining to experience curve methods. Some of the equations which can be used in the absence of the appropriate tables will be illustrated, and then the methods of obtaining certain quantities used throughout the following examples will be explained.

The basic concept of experience curve theory is that the cost (or man-hours) of producing a certain item decreases by a constant percentage as the quantities of the item produced double. For example, the cost of the second unit produced is a certain percentage of the cost of the first unit. The cost of the fourth unit is the same percent of the cost of the second unit; etc. This is expressed by an equation of the form, $Y = AX^B$, where A is the cost (or man-hours) of the first unit produced and B is a constant which is determined by the percent of cost reduction as quantities produced double. X is the particular unit whose cost (or man-hours) we are attempting to predict, and Y is the cost (or man-hours) associated with that unit. The equation, $Y = AX^B$, can be transformed into the equation, $\text{Log } Y = \text{Log } A + B \text{ Log } X$, by taking the logarithm of both sides. The straight line on Log-Log paper resulting from the theory and the logarithmic equation are the tools most frequently used for predicting and extrapolating cost of future units of production.

When it is said that a contractor is producing on a 90% slope, it is meant that the cost reduction is 10% as quantities double. For example, the cost of the second unit is 90% of the cost of the first unit; the cost of the fourth unit is 90% of the cost of the second; etc. The value of B in the two equations above may be found from the following equation:

$$B = \frac{\text{Log (Slope)} - 2}{.301030}$$

The value of B for various slopes from 50% to 99% is given in Table I in Volumes I and II of the *Experience Curve Tables* published by this organization.

The cost of any unit may be found if the cost of the first unit is known and the slope of production is known by using the equation, $\text{Log } Y + \text{Log } A + B \cdot \text{Log } X$. Conversely, if the cost of a particular unit is known and the slope is known, the cost of the first unit may be found by rearranging the equation to obtain the following form: $\text{Log } A = \text{Log } Y - B \text{ Log } X$. If the tables mentioned above are available, the work involved in solving the above equations is avoided.

Most of the time instead of having a particular unit's cost, the cost of a lot or a specific quantity of units is known. Then the problem is that of choosing some unit in the lot to represent the entire lot. This unit is the algebraic lot midpoint. The algebraic lot midpoint of a lot is that unit in the lot whose cost is most nearly the average cost per unit for the lot. In other words, the cost of the algebraic lot midpoint times the number of units in the lot yields the total cost of the lot. The algebraic lot midpoint of a lot is rarely the arithmetic midpoint of the lot, and for different slopes the algebraic lot midpoint will be different for the same lots. For example, the algebraic lot midpoint for the lot running from unit 501 to unit 700 on a 90% slope is not the same as on an 80% slope. The algebraic lot midpoint can be obtained by using the *Experience Curve Tables* mentioned above, by using a table called *Pamper* (easiest method), or by the use of the following equation:

$$K = \left[\frac{L \cdot (1 + B)}{N_1^{1+B} - N_2^{1+B}} \right]^{1/B}$$

Where
- K = the algebraic lot midpoint
- N_2 = the first unit in lot minus ½
- N_1 = last unit in lot plus ½
- L = number of units in the lot
- B = constant (defined above)

The solution of the equation is complicated and, if pos-

alysis can be only as good as the data put into it. The experience curve analysis takes a legitimate savings at some point in production and projects this savings over future production.

There are types of value engineering problems which cannot be solved by the use of experience curve techniques. For instance, sometimes a change is made in an item which does not reduce the cost of producing the item but reduces the cost of using or maintaining the item once it is in the field. This type of change cannot be handled very well by experience curve techniques. Another type of change which is not discussed is one in which there is a reduction in non-recurring cost such as tooling but an increase in recurring cost (with no change in slope). No matter how large the reduction in non-recurring cost is, the increase in recurring cost will eventually counterbalance any savings made.

In the problem already discussed it was mentioned that a production slope is needed in order to perform an experience curve analysis. The slope used in the analysis might be the contractor's overall production slope. It might be a major component production slope if enough data is available to obtain a curve for major components. If individual curves have been developed for assembly, fabrication, etc., one of these curves might be used if a particular VECP involved mainly one of these areas. Sometimes the industry average slope for production of the item might be used in the analysis.

In at least one situation the industry average slope might be the best one to use. When an experience curve analysis is performed on a VECP, the projected savings over future production is that savings which will occur as the result of the value engineering change if future production continues on approximately the same slope as the one used in the analysis. Obviosuly, future production of the item might be performed by several different contractors, all of whom are producing on different slopes. Thus, the average slope for the industry might depict savings as a result of the value engineering change over future production more accurately than using any one contractor's slope in the analysis of the VECP. In many cases it happens that most of the contractors producing a certain type of item all have similar production slopes, so that the results of an experience curve analysis using any one contractor's production slope will not be very different from the actual savings.

In general, experience curve analyses of VECP's are more useful and more applicable to production contracts on new items or on contracts for items of which only few have been produced previously. Early in the production of any item is the period when most cost reductions are made. One would expect a greater difference in the cost to produce the first unit and the cost to produce the 100,000th unit than the cost to produce the 100,000th unit and the cost to produce the 200,000th unit. Thus, the experience curve would be more useful in projecting savings as the result of a value engineering change made near the beginning of production than it would be for projecting savings as the result of a value engineering change made after 100,000 units have been produced.

When a contractor's slope is known, the work involved in analyzing any VECP is reduced to ten or fifteen minutes when the tables are used. The tables and a publication on the experience curve can be obtained from the Defense Documentation Center. The address and appropriate documentation numbers are given in Appendix A at the end of this publication.

I. Given an 80% slope, the corresponding value of B may be found from the tables already mentioned or from the equation as follows:

$$B = \frac{\text{Log } (80) - 2.}{.301030} = \frac{1.903090 - 2.000000}{.301030}$$

$$B = -0.321928$$

II. Given an 80% slope and a first unit cost of $1,000, find the cost of the 5,000th unit.

$$X = 5{,}000$$
$$A = 1{,}000$$
$$B = -0.321928 \text{ (from above)}$$
$$\text{Log } Y = \text{Log } A + B \text{ Log } X$$
$$\text{Log } Y = \text{Log } \$1{,}000 - .321928 \text{ (Log } 5{,}000)$$
$$\text{Log } Y = 3 - .321928 \text{ (}3.698970)$$
$$\text{Log } Y = 3 - 1.190802 = 1.809198$$
$$Y = \$64.446 \text{ or } \$64.45$$

Therefore, the 5,000th unit costs $64.45.

Using the *Experience Curve Tables* mentioned above to solve the same problem, one would find the pages pertaining to an 80% slope. The unit factor for unit 5,000 would be located. For unit 5,000 the unit factor is .06444624.

$$Y = \$1{,}000. \times \text{(Unit factor for unit } 5{,}000)$$
$$Y = \$1{,}000. \times (.06444624) = \$64.45$$

III. Given an 80% slope and a cost of $100 for unit 1,000 find the cost of the first unit.

$$B = -0.321928 \text{ (from above)}$$
$$X = 1{,}000$$
$$Y = \$100$$
$$\text{Log } A = \text{Log } Y - B \cdot \text{Log } X$$
$$\text{Log } A = \text{Log } \$100 - (-.321928) \text{ Log } 1{,}000$$
$$\text{Log } A = 2 + .321928 \ (3)$$
$$\text{Log } A = 2 + .965784$$
$$\text{Log } A = 2.965784$$
$$A = \$924.24$$

Therefore, the cost of the first unit is $924.24.

Using the *Experience Curve Tables* the same result can be obtained by finding the pages for an 80% slope and locating the unit factor for unit 1,000. The unit factor for unit 1,000 is 0.10819712.

$$A = Y \div \text{(Unit factor for } 1{,}000)$$
$$A = \$100 \div 0.10819712$$
$$A = \$924.24$$

IV. Given an 80% slope and a lot running from unit 901 to unit 3,632, find the algebraic lot midpoint.

$$\text{Slope} = 80\%$$
$$B = -.322 \text{ (from above)}$$
$$1 + B = .678$$
$$L = 2{,}732$$
$$N_1 = 3{,}632 + .5 = 3{,}632.5$$
$$N_2 = 901 - .5 = 905.5$$

$$K = \left[\frac{L \cdot (1 + B)}{N_1^{1+B} - N_2^{1+B}}\right]^{-1/B}$$

$$K = \left[\frac{2{,}732 \ (.678)}{(3{,}632.5)^{.678} - (900.5)^{.678}}\right]^{-1/B}$$

$$K = \left[\frac{1852.296}{\text{AL}\,[(.678)\ (\text{Log } 3632.5)] - \text{AL}\,[(.678)\ (\text{Log } 900.5)]}\right]^{-1/B}$$

$$K = \left[\frac{1852.296}{\text{AL}\,[(.678)\ (3.560206)] - \text{AL}\,[(.678)\ (2.954484)]}\right]^{-1/B}$$

$$K = \left[\frac{1852.296}{\text{AL}\,(2.413820) - \text{AL}\,(2.003140)}\right]^{-1/B}$$

$$K = \left[\frac{1852.296}{259.3105 - 100.7255}\right]^{-1/B} = \left[\frac{1852.296}{158.585}\right]^{-1/B}$$

sible, one of the tables above should be used. Also, the production slope or an estimate of it is needed since B appears in the equation for K.

Illustrations of the above equations, their application, and a discussion of Experience Curve tables and Pamper tables are given below.

The Experience Curve Tables consist of factors which enable one to easily obtain the cost of man-hours associated with any unit of production if he knows the cost or man-hours associated with the first unit and the production slope. They also contain factors which will yield the cumulative total cost and the cumulative average cost (or man-hours) if the cost (or man-hours) associated with the first unit is known. The problem of finding the cost of a unit is reduced to looking up a factor corresponding to the unit and the particular production slope involved. This factor is multiplied by the cost of the first unit produced to obtain the cost of the unit we are interested in. Of course, the tables can be used to do the opposite also. If we know the cost of a unit and desire to know the cost of the first unit, we can look up the factor for the unit and divide it into the cost of the unit. This will give the corresponding cost of the first unit. Once we have this, the corresponding cost of any unit may be found. The tables can be used in the same manner for finding man-hours and savings. Also, Experience Curve Tables can be used for finding algebraic lot midpoints, but these can be obtained more quickly by using Pamper tables.

Pamper tables (Practical Application of Midpoints for Exponential Regression) reduce the work of calculating an algebraic lot midpoint to that of looking up a factor, multiplying it by the number of units in the lot, and adding the result to the first unit in the lot. In order to use the Pamper tables one needs only to know the production slope. The results obtained by using Pamper tables will be an estimate of the algebraic lot midpoint but will be close enough to the true value for all practical purposes.

EXPERIENCE CURVE ANALYSIS OF A TYPICAL VECP

The Armed Services Procurement Regulation, 1-1703.2, states that one of three basic plans of sharing savings with the contractor will be used. These are:

(1) Contractor participation in cost savings under the instant contract only,

(2) Contractor participation in cost savings under the instant contract plus royalty payments on actual future procurements within a stated period,

(3) Contractor participation in cost savings under the instant contract plus estimated savings on additional quantities expected to be procured subsequently, the estimated additional quantities being stated in the instant contract.

For various situations one of these plans may be appropriate when another is not. However, in the following example the experience curve analysis for each plan will be illustrated without regard as to whether that plan would ordinarily be used or not.

A contractor has the first production contract on a new item. His slope of production is estimated to be approximately 83%. The contract calls for production of 20,000 units and contains a value engineering incentive clause. After he has already produced 5,000 units, the contractor submits a Value Engineering Change Proposal which effects a unit cost reduction for the remaining 15,000 units under the instant contract of $5.00 per unit. Assume there is no implementation cost or other non-recurring cost.

Using the contractor's estimated slope of production, we may construct a unit savings curve to represent the savings per unit on future production and the theoretical savings per unit on previous units which would have occurred if the value engineering change had been made earlier in production. (See the following graph.) This can be done by letting the $5.00 per unit savings represent the savings on the algebraic lot midpoint[2] of a lot from 5,001 to 20,000. Using PAMPER Tables (or the formula illustrated in Example IV of the section on theory) this algebraic lot midpoint can be found to be the 11,450th unit. Using Experience Curve Tables (or the formula in Example III in the section on theory) the theoretical savings on the first unit produced corresponding to a savings of $5.00 on the 11,450th unit can be found to be $61.67. Now using the Experience Curve Tables (or the formula illustrated in Example II in the section on theory) we can find the savings on any particular unit as a result of the value engineering change.

Case (1) Contractor participation in cost savings under the instant contract only.

Suppose that the value engineering incentive clause in the contract gives the contractor 45% of the savings on the instant contract resulting from the change. From above we know that the savings on the instant contract is $5.00 per unit for the remaining 15,000 units. Therefore, the contractor's share of savings is:

$$45\% \text{ of } (\$5.00 \times 15{,}000) = \$33{,}750.$$

Case (2) Contractor participation in cost savings under the instant contract plus royalty payments on actual future procurements within a stated period.

Suppose that the value engineering incentive clause in the contract gives the contractor 35% of the savings on the instant contract and 25% of the savings on future production within a three year period. Furthermore, suppose that within the three year royalty period it is estimated that an additional 80,000 units will be produced. We desire to calculate a unit cost reduction to use in calculating the contractor's share of savings over future production. Obviously, if production con-

[2] The savings on the algebraic lot midpoint of a lot when multiplied by the number of units in the lot gives the total savings on the lot.

$$K = (11.68015)^{1/.322} = AL[1/.322 \text{ (Log } 11.68015)]$$

$$K = AL\left[\frac{1.067448}{.322}\right] = AL(3.315055)$$

$$K = 2{,}066$$

Therefore, the algebraic lot midpoint is unit 2,066.

If *PAMPER* is used, the page with factors applying to an 80% slope is found. The factor for a lot running from unit 901 to unit 3,632 is found to be .42167. This factor is multiplied by the number of units in the lot, and the result is added to the first unit in the lot.

$$(.42167) \times 2{,}732 = 1{,}152$$
$$+ \quad 901 \text{ (1st unit)}$$
$$2{,}053 = K$$

Although there is a difference of 13 units in the *Pamper* value and that calculated using the equation, this difference is in error by less than 1%. In most experience curve problems this error is negligible.

The *Experience Curve Tables* can also be used to calculate algebraic lot midpoints, and the results are a little more accurate than the results obtained using *Pamper* tables. The work involved in using either table is much less than the work required for the manual calculation.

Most of the applications of experience curve techniques to value engineering problems involve being able to find algebraic lot midpoints, being able to find the cost of the first unit, and being able to find the cost of various units of production. All of the calculations needed to do these things have been illustrated above. Although all the work may be done without the tables mentioned above, it would be impractical to attempt to apply experience curve techniques to many problems without using them (due mostly to the lengthy calculations needed for obtaining algebraic lot midpoints). There is much more that could be said about the theory and application. The things mentioned above are the points considered important for the understanding of the following examples.

MINOR VALUE ENGINEERING CHANGES

Minor value engineering changes are changes which reduce the cost per unit by only a small amount in comparison to the total cost of the item. These changes do not appreciably affect the contractor's slope of production, and often there are many submitted on a contract. Although they have been designated as minor in this discussion, the total savings which results from them is not minor! Because they are more common and somewhat easier to handle than major changes, the case of the minor change will be discussed first. Some of the results obtained for minor changes can be used in the case of major changes.

Cases in which the value engineering change is implemented on the first unit produced and cases in which the value engineering change is implemented after production has started will be considered. Although it may at first seem odd to have a value engineering change implemented on the first unit produced, this has occurred and, in fact, the notion of pre-bid value engineering has been tried. (Contractors were invited to submit Value Engineering Change Proposals with their proposals. The contract was then awarded with the Value Engineering Change Proposal incorporated.)[1]

Often many minor Value Engineering Change Proposals are submitted, all of which will be made at nearly the same point in production. An example is included which illustrates that these may be handled as a group instead of handling each Value Engineering Change Proposal individually. After performing the experience curve analysis on the Value Engineering Change Proposals as a group, results may be obtained for each individual Value Engineering Change Proposal.

[1] COST REDUCTION DIGEST, August 11, 1965, "Stretching the Procurement Dollar at the Federal Aviation Agency."

tinues on approximately an 83% slope during the three year royalty period, the average savings per unit over that period will be considerably less than $5.00 per unit (the average savings per unit for the remaining 15,000 units on the instant contract).

The average savings per unit as a result of the value engineering change on the additional 80,000 units to be produced within the royalty period can be calculated as follows. The algebraic lot midpoint of a lot from 20,001 to 100,000 can be found to be unit 53,592. The savings on this unit corresponding to a savings of $5.00 on unit 11,450 can be found to be $3.30. This is the average savings per unit for the additional 80,000 units to be produced within the royalty period. The contractor's total share of savings on both the instant contract and on future production during the royalty period can be calculated as follows:

35% of ($5.00 × 15,000) = 35% of $75,000 = $26,250.

Thus, the savings on the instant contract is $75,000, and the contractor's share of this savings is $26,250.

25% of ($3.30 × 80,000) = 25% of $264,000 = $66,000.

The savings on anticipated future production within the royalty period is $264,000, and the contractor's share of this is anticipated to be $66,000.

The total savings is $75,000 + $264,000 = $339,000. The total share which the contractor receives is $26,250 + $66,000 = $92,250.

The contractor's share of savings can be calculated using a unit cost reduction of $5.00 per unit for the instant contract and $3.30 per unit for the additional 80,000 units to be produced within the royalty period.

Case (3) Contractor participation in cost savings under the instant contract plus estimated savings on additional quantities expected to be procured subsequently, the estimated additional quantities being stated in the instant contract.

In this case the contractor is paid a lump sum at the time the Value Engineering Change Proposal is approved which represents his share of the savings on the instant contract and of the savings on future production within the sharing period. As in the previous case, suppose that it is estimated that 80,000 additional units will be produced within the contractor's sharing period. We have actually already solved this case in the discussion of the previous one. The total savings there was found to be $339,000, and the contractor's share was found to be $92,250. Thus, the lump sum payment made to the contractor at the time the change is approved would be $92,250. This would be his share of savings on the instant contract and future production within the sharing period.

It might be instructive to point out an important fact at this point. If one unit cost reduction were desired which could be used to calculate the contractor's share of savings on both the instant contract and future production, the average savings per unit could not be used. To illustrate this, consider the following. Suppose that we desire a unit cost reduction such that 35% of that reduction times 15,000 units plus 25% of that reduction times 80,000 units will give $92,250, the contractor's total share of savings. Let X be the desired unit cost reduction. Then:

$$35\% \text{ of } (15{,}000x) + 25\% \text{ of } (80{,}000x) = \$92{,}250$$

or

$$5{,}250x + 20{,}00x = \$92{,}250$$

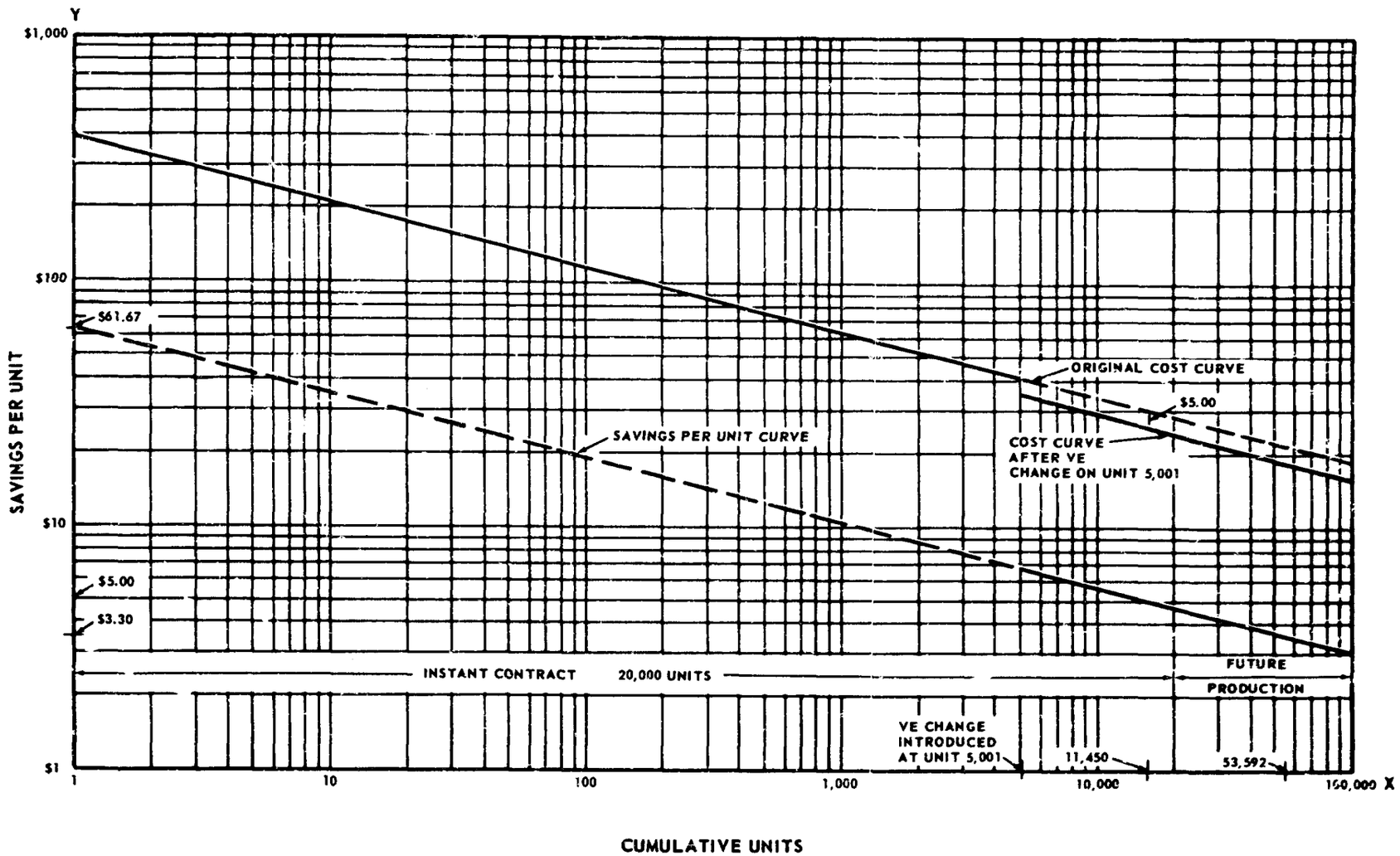
$$25{,}250x = \$92{,}250$$

$$x = \$3.65$$

Thus, $3.65 is the unit cost reduction desired. However, it is not the average savings per unit which is the total savings divided by the number of units to be produced within the sharing period.

$$\$339{,}000 \div 95{,}000 = \$3.57$$

Thus, $3.57 is the average savings per unit for 95,000 units as a result of the change.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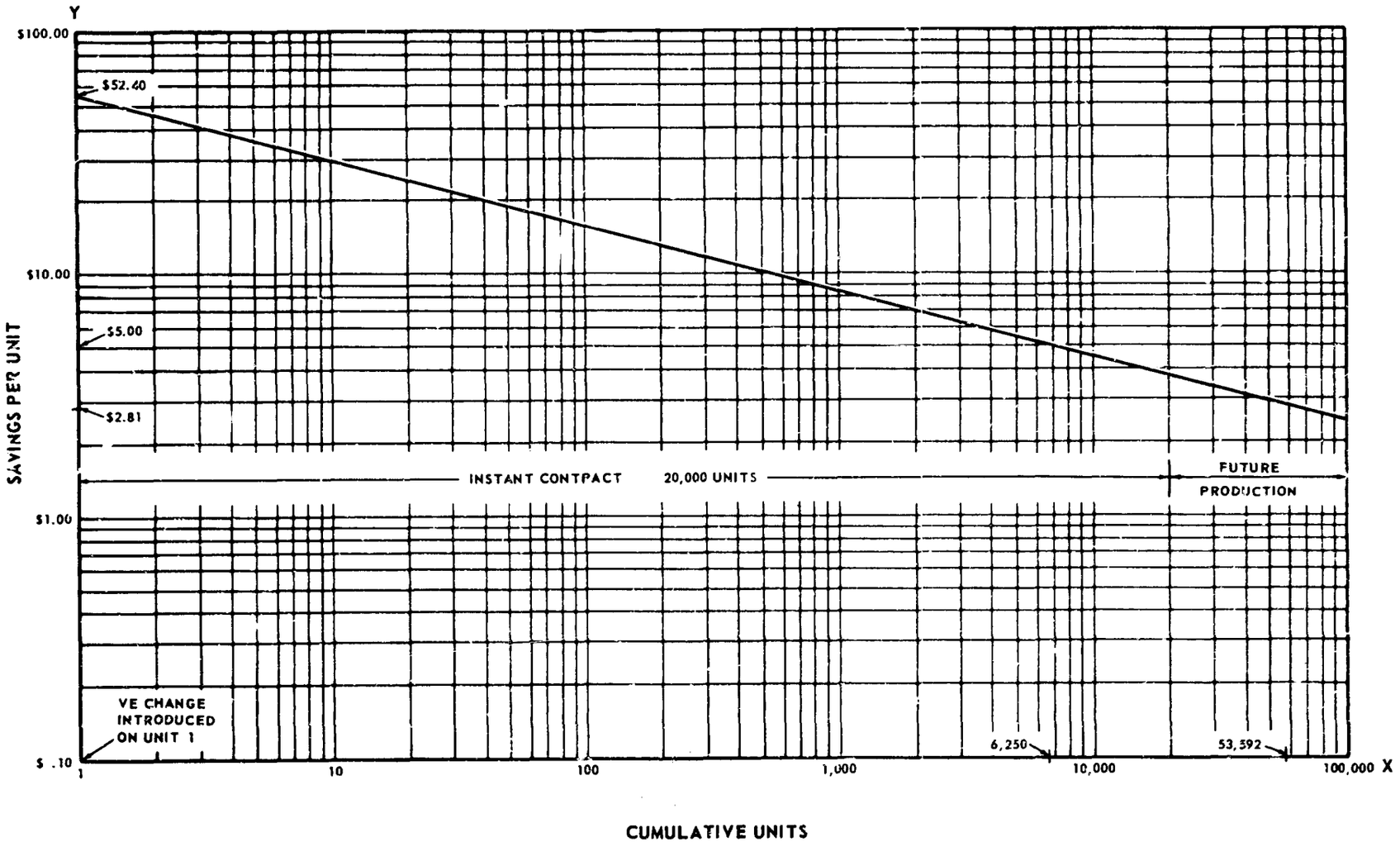
CUMULATIVE UNITS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SAVINGS PER UNIT
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INTRODUCED
ON UNIT 1
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53,592
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X
CUMULATIVE UNITS

A VALUE ENGINEERING CHANGE IMPLEMENTED ON THE FIRST UNIT PRODUCED

Consider an example similar to the preceding one except that in this case the contractor introduces the change at the first unit produced. The contractor has a first production contract for 20,000 units of a newly developed item. His production slope is estimated to be 83%. The contractor submits a Value Engineering Change Proposal which reduces the cost per unit for the *entire instant contract* by $5.00.

The main difference in the solution to this problem and the previous one is that in this case the $5.00 savings per unit must be considered the savings on the algebraic lot midpoint of a lot from unit 1 to unit 20,000. This can be found to be unit 6,250. The savings on the first unit produced corresponding to a savings of $5.00 on the 6,250th unit can be found to be $52.40. Now the savings on any unit as a result of the value engineering change can be found. The method of determining the contractor's share of savings for the three different sharing plans is the same as in the preceding example.

Case (1) Contractor participation in cost savings under the instant contract only.

Suppose the value engineering incentive clause in the contract gives the contractor 35% of the savings on the instant contract. Since $5.00 is the average savings per unit for the instant contract, the total savings is:

$$\$5.00 \times 20{,}000 = \$100{,}000.$$

The contractor's share of savings is:

$$35\% \text{ of } (\$5.00 \times 20{,}000) = 35\% \text{ of } \$100{,}000 = \$35{,}000.$$

Case (2) Contractor participation in cost savings under the instant contract — plus royalty payments on actual future procurements within a stated period.

Suppose the value engineering incentive clause in the contract gives the contractor 35% of the savings under the instant contract and 25% of the savings on future production within a royalty period of three years. Furthermore, suppose that it is estimated that an additional 80,000 units will be produced within the three year period.

The algebraic lot midpoint of a lot from 20,001 to 100,000 (the additional 80,000 units) is unit 53,592. The savings on this unit as a result of the value engineering change is $2.81. This is the average savings per unit over the additional 80,000 units to be produced within the royalty period.

Therefore, the contractor's share of savings can be found as follows:

$$35\% \text{ of } (5.00 \times 20{,}000) = 35\% \text{ of } \$100{,}000 = \$35{,}000.$$

The savings on the instant contract is $100,000 and the contractor's share is $35,000.

$$25\% \text{ of } (\$2.81 \times 80{,}000) = 25\% \text{ of } \$224{,}800 = \$56{,}200.$$

The savings on the additional 80,000 units is $224,800 and the contractor's share is $56,200.

The total savings occurring over the 100,000 units to be produced on the instant contract and future production is $100,000 + $224,800 = $324,800. The contractor's total share of savings is $35,000 + $56,200 = $91,200.

Therefore, the contractor's share of savings can be calculated using a unit cost reduction of $5.00 for the instant contract and $2.81 for the additional 80,000 units to be produced within the royalty period.

Case (3) Contractor participation in cost savings under the instant contract plus estimated savings on additional quantities expected to be procured subsequently, the estimated additional quantities being stated in the instant contract.

Suppose the value engineering incentive clause in the contract gives the contractor 35% of the savings under the instant contract and 25% of the savings on future production within a sharing period of three years. Furthermore, suppose that an additional 80,000 units will be procured within the sharing period.

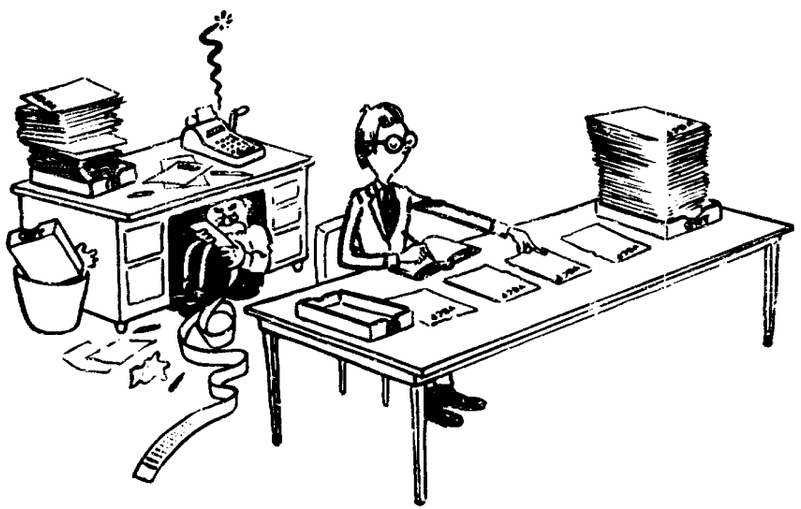
ANALYSIS OF SEVERAL VECP's HANDLED AS ONE

If many VECP's on the same contract are on hand to be evaluated, a shortcut may be taken provided that all the value engineering changes will be made on approximately the same unit of production if approved. All the VECP's can be combined into one and the experience curve analysis performed one time. After the experience curve analysis has been performed for all the VECP's grouped together, results for each individual VECP such as the unit cost reduction as a result of each may be obtained by a very simple method.

For example suppose that a contractor is producing on an 85% slope and has a contract for 25,000 units. The value engineering incentive clause in the contract calls for the contractor to receive 30% of the savings on the instant contract, and 20% of the savings on future production within a sharing period in which an additional 75,000 units will be produced. The contractor submits five Value Enginering Change Proposals to be introduced at the 5,001st unit for the following amounts:

VECP	Savings per unit for remaining 20,000 units
1	$3.00
2	1.75
3	5.00
4	2.00
5	7.50
Total	$19.25

As can be seen, the Value Engineering Change Prosposals total a savings per unit of $19.25 over the remaining 20,000 units. If all five are approved, the savings of $19.25 on the remaining 20,000 units can be taken as the savings on the algebraic lot midpoint of the lot from unit 5,001 to unit 25,000. This unit is the 13,444th unit. The savings on the first unit corresponding to a savings of $19.25 on the 13,444th unit is $178.82. The savings on any unit as a result of the change can now be found.



This problem has already been solved in the discussion of Case (2) above. The total savings was found to be $324,800. The contractor's total share was found to be $91,200. If one unit cost reduction figure is needed which can be used to calculate a total share of $91,200 for the contractor, the following equation can be solved. Let X be the figure. Then:

$$35\% \text{ of } (20{,}000x) + 25\% \text{ of } (80{,}000x) = \$91{,}200.$$

or

$$7{,}000x + 20{,}000x = \$91{,}200$$
$$27{,}000x = \$91{,}200$$
$$x = \$3.38$$

$3.38 is not the average savings per unit; however, that figure is $3.25.

PROCEDURAL SUMMARY

The preceding two examples discuss in detail the two cases which arise most frequently. Solutions are discussed in both cases for all three sharing plans mentioned in the ASPR. In the following discussions the same procedures are used in the experience curve analyses, but reference will not be made to any specific sharing plan since the application to each has been demonstrated.

The steps in calculating the total savings and the average savings per unit over future production within the contractor's sharing period are given below.

1. Calculate the algebraic lot midpoint of the lot consisting of the remaining units on the instant contract after the value engineering change is made.
2. Let the average savings per unit for the remaining portion of the instant contract which results from the VECP be the savings on this unit.
3. Calculate the corresponding theoretical savings on the first unit.
4. Calculate the algebraic lot midpoint of the lot formed by the estimated quantity to be procured in future buys within the contractor's sharing period.
5. Calculate the corresponding theoretical savings on the unit found in step four.
6. Multiply the result of step five by the estimated quantity to be procured within the contractor's sharing period.

The result of step six is the total savings resulting from the value engineering change over the estimated future procurements within the contractor's sharing period.

The result of step six when added to the savings on the instant contract as a result of the value engineering change yields the total savings which occurs on both the instant contract and future procurements within the sharing period.

The average savings per unit over the additional 75,000 units to be produced within the sharing period can be found by calculating the algebraic lot midpoint of a lot from 25,001 to 100,000. This can be found to be the 57,394th unit. The savings on this unit as a result of the change can be found to be $13.70. This is the average savings per unit over the additional 75,000 units as a result of the change. Thus, the contractor's share of the savings on these units is:

20% of (75,000 × $13.75) = $1,027,500 = $205,500.

The contractor's share of savings on the instant contract is:

30% of (20,000 × $19.25) = 30% of $385,000 = $115,500.

These figures pertain to all five VECP's taken together.

If the same figures are needed for VECP #1, the following calculation may be performed:

$3.00 is 15.58% of $19.25. Hence, 15.58% of any figure for all five VECP's taken together will give the corresponding figure for VECP #1. *e.g.* 15.58% of $13.70 = $2.13. Therefore, $2.13 is the average savings per unit over the additional 75,000 units as a result of VECP #1 for $3.00 on the instant contract.

Thus, the contractor's share of the savings on the additional 75,000 units to be produced within the sharing period with respect to VECP #1 only is:

20% of (75,000 × $2.13) = $31,950.

The contractor's share of the savings on the instant contract as a result of VECP #1 is:

30% of (20,000 × $3.00) = $18,000.

Thus, the total share the contractor receives of the savings due to VECP #1 is $31,950 + $18,000 = $49,950. The same result could be obtained by taking 15.58% of $321,000 which is the total share of savings the contractor receives for all five VECP's taken together.

15.58% of $321,000 = $50,012.

The same results can be obtained for VECP numbers 2, 3, 4, and 5 in a similar manner.

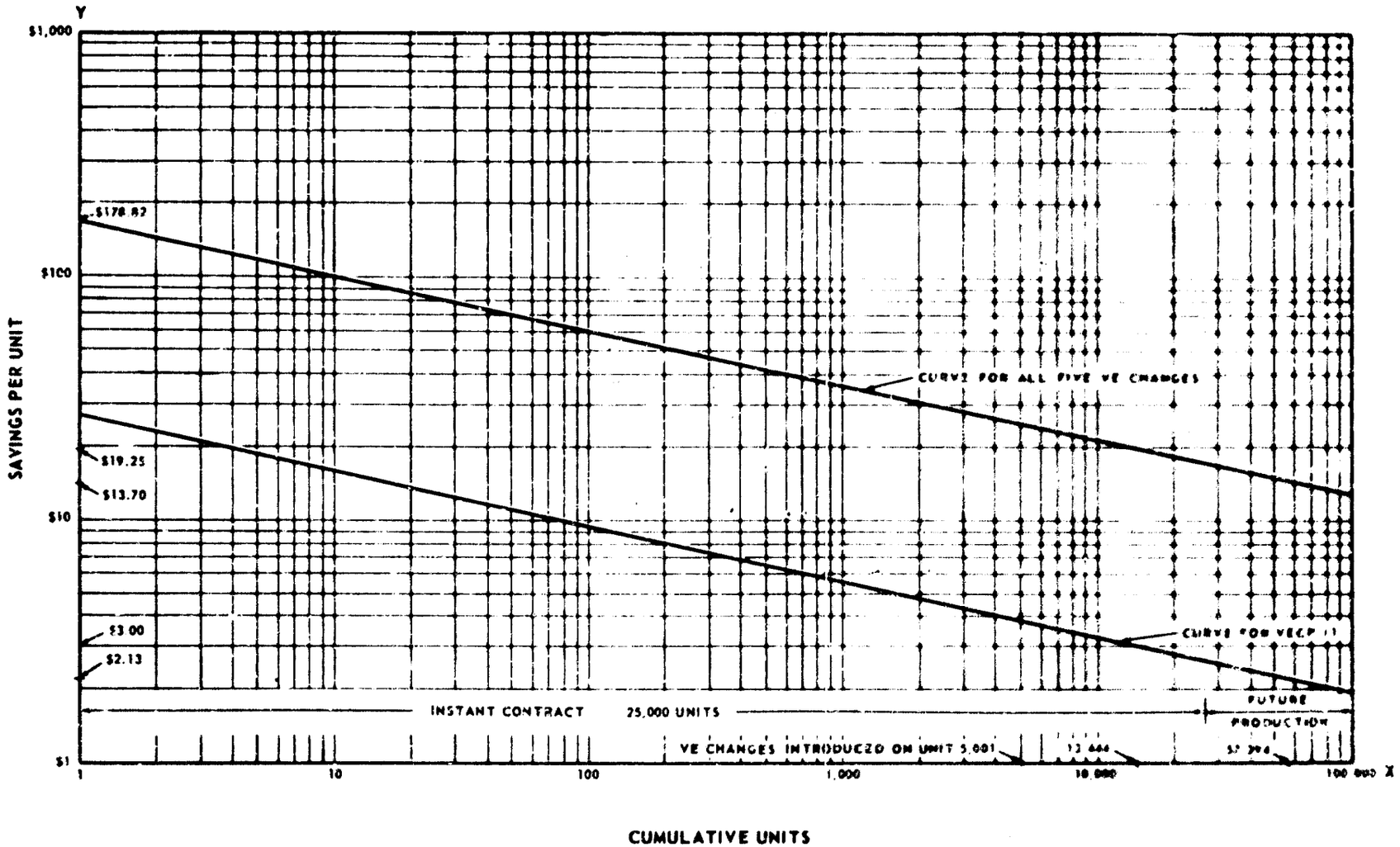
MAJOR VALUE ENGINEERING CHANGES

Major value engineering changes differ from minor changes in one or both of two ways. A major value engineering change may reduce the cost per unit of production by a significant amount, may cause the slope of production to change significantly, or may do both. If it only reduces cost but does not change the contractor's slope of production it may be handled exactly like minor value engineering change. However, if the value engineering change causes the slope to change, a new technique must be used. In this case we do not work with a savings curve as we did in dealing with minor changes. We work with the contractor's experience curve (i.e. the contractor's cost curve). The main difference in the two methods is that in working with the minor change problems we need not deal with (or even know) the cost of the item or component with which we are dealing. In working with the major change problem in which the slope changes, we do need to know the cost of the item. (i.e., We need to know the contractor's cost curve.) However, in dealing with a major engineering change of any sort which affects the cost of an item by a significant amount, we would probably know more about the cost than in the minor change problem.

Two cases follow—one in which the recurring cost reduces but the slope changes to a flatter slope, and one in which the recurring cost is at first greater but the slope is steeper. The procedure is similar for both cases.

The case of a major value engineering change with a decrease in recurring cost but a change to a flatter slope.

This problem arises when a contractor is producing an item on a certain slope and then at some unit of production submits a Value Engineering Change Proposal which reduces the recurring cost but in doing this changes the slope of production. If the recurring cost is reduced and the slope changes to a steeper slope, there is no problem because the value engineering change can only result in total cost reduction. How-


Y
$1,000
$100
$10
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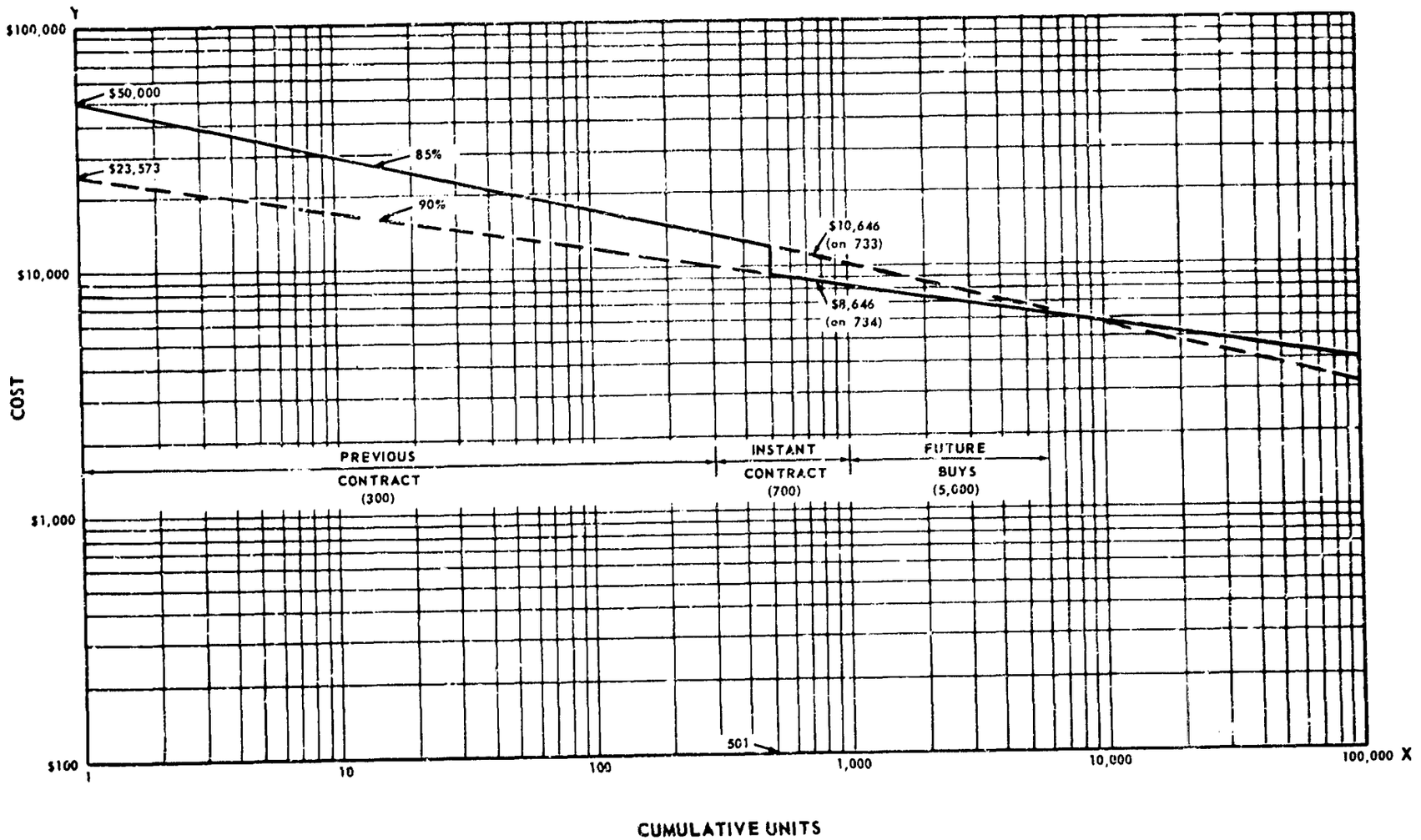
SAVINGS PER UNIT
$178.82
$19.25
$13.70
$3.00
$2.13
CURVE FOR ALL FIVE VE CHANGES
INSTANT CONTRACT
25,000 UNITS
FUTURE
PRODUCTION
VE CHANGES INTRODUCED ON UNIT 5,001
1
10
100
1,000
X
CUMULATIVE UNITS


Y
$100,000
$50,000
85%
$23,573
90%
$10,646
(on 733)
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COST
PREVIOUS
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CUMULATIVE UNITS

ever, if there is a reduction in recurring cost and the slope changes to a flatter slope, there is the possibility, depending upon the number of units to be produced, that the value engineering change may not save money. The case of a reduction in recurring cost and a flatter slope might result from a change in the item being produced which eliminates some part of the manufacturing process that had been done by hand. This would result in a flatter slope.

Consider the case of a contractor who is producing an item which had a first unit cost of $50,000 on an 85% slope and has a contract for 700 units of the item. Futhermore, suppose this is the 2nd buy following a first buy of 300 units made earlier. In the contract there is a value engineering incentive clause which gives the contractor 30% of the savings on the instant contract and 20% of the savings on future buys resulting from value engineering changes. At his 201st unit the contractor submits a Value Engineering Change Proposal which will reduce the cost of the remaining 500 units of the instant contract by $2,000 per unit. But the value engineering change will also cause his production slope to change from 85% to 90%. It is estimated that 5,000 more units will be produced on future buys. The problem is to decide whether to approve the change, and if it is approved, to calculate the contractor's share of savings. See the following graph.

The contractor claims a savings of $2,000 per unit for the remaining 500 units of his contract. Since 300 units had been produced before his contract started, his contract constitutes a lot running from unit 301 to 1,000. A savings on the remaining 500 units of the instant contract of $2,000 each implies a savings of $1,000,000 on the instant contract. This means that the difference in cost of the algebraic lot midpoint of the lot from 501 to 1,000 on the 85% curve and of the algebraic lot midpoint on the 90% curve must be $2,000. (These two points are not necessarily the same for two different slopes.) The algebraic lot midpoint on an 85% slope of a lot from 501 to 1,000 is the 733rd unit. The cost of this unit on an 85% slope is $10,646. The algebraic lot midpoint of the same lot on a 90% slope is the 734th unit. Thus, the cost of this unit is $8,646 ($2,000 less than the midpoint on an 85%). The cost of the 1st unit on a 90% slope corresponding to a cost of $8,646 on the 734th unit is $23,573.

The algebraic lot midpoint of a lot running from unit 501 to 6,000 (the total quantity to be produced) on an 85% slope is the 2,639th unit, and its cost is $7,884. Therefore, if the value engineering change is not approved, the total cost of the remaining 5,500 units to be produced is:

$$5{,}500 \times \$7{,}884 = \$43{,}362{,}000$$

The algebraic lot midpoint of a lot running from unit 501 to 6,000 on a 90% slope is the 2,685th unit, and its cost (if the value engineering change is approved) is $7,099. Therefore, if the value engineering change is approved the total cost of the remaining 5,500 units to be produced is:

$$5{,}500 \times \$7{,}099 = \$39{,}044{,}500$$

Therefore, the total cost of all remaining production (5,500 units) will be less if the value engineering change is approved. The savings will be:

$$\$43{,}362{,}000 - \$39{,}044{,}500 = \$4{,}317{,}500$$

However, suppose that instead of 5,000 units 29,000 more units will be produced. This will bring total production to 30,000 instead of 6,000. The algebraic lot midpoint of the lot from 501 to 30,000 on an 85% slope is the 10,803rd unit, and its cost is $5,666. Therefore, if the value engineering change is not approved, the cost of production for the remaining 29,500 units will be:

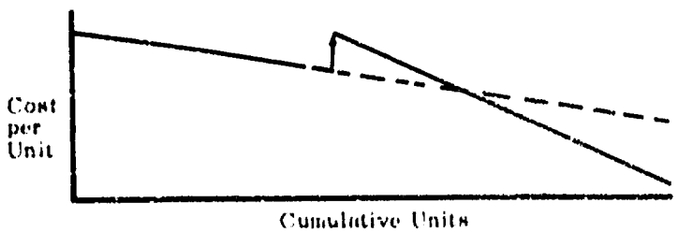
$$29{,}500 \times \$5{,}666 = \$167{,}147{,}000$$

The algebraic lot midpoint of a lot from 501 to 30,000 on a 90% slope is the 11,172nd unit, and its cost (if the value

30% of (500 × $838.52) = $125,778
20% of (5,000 × $838.52) = $838,520
Total = $964,298

which is the same share that was calculated above. The effects of an increase in non-recurring cost such as tooling, etc. can be examined after the experience curve analysis of the change in recurring cost. Obviously, an increase in tooling would be deducted from the total savings calculated above in examining the worth of the change.

A problem similar to the problem above is one in which a value engineering change increases the recurring cost but changes the slope of production to a steeper slope. The problem is to determine whether the total cost after making the change is less than if the change were not made. This is depicted graphically below.



This problem is handled exactly in the same manner as the previous problem. However, the results for this problem turn out to be the opposite of the results in that problem. In this problem we find that as the quantity to be produced after the value engineering change is made increases, the savings resulting from the change increases. In the previous problem as the quantity to be produced after the change increased, the savings resulting from the change decreased. In this problem as in the above problem the effect of an increase in non-recurring cost can be handled after the experience curve analysis of total savings resulting from decrease in recurring cost.

THE EFFECT OF NON-RECURRING COSTS

So far, non-recurring costs have not been discussed. For the purpose of this discussion, a non-recurring cost is any cost which is incurred only one time. An increase or decrease in tooling cost would be a non-recurring cost according to the foregoing definition. The cost of installing a new process within a plant might be called a non-recurring cost. When a decrease in non-recurring cost accompanies a Value Engineering Change proposal, the contractor usually receives incentive pay on the savings due to the reduction in non-recurring cost on only the instant contract. Therefore, the contractor's share of savings on the instant contract would be his percent of the savings on recurring costs added to his percent of the savings on non-recurring cost, but his share of savings on future production would be the proper percent of only the savings on recurring cost. When an increase in non-recurring cost accompanies a Value Engineering Change Proposal, the experience curve analysis is performed on the recurring cost portion of the Value Engineering Change Proposal, and the effect of the increase in non-recurring cost on the end result of the analysis is taken into account afterwards.

As an example, consider the case of a contractor with a contract for 10,000 units of an item. It has been found that the contractor producing the item in the past produced on approximately an 84% slope, and it is estimated that the present contract will have approximately the same slope. On past contracts 20,000 items have been produced. The present contract contains a value engineering incentive clause which gives the contractor 30% of all savings on the instant contract and 20% of all savings on future production within a specific sharing period. It is estimated that 30,000 additional units will be produced during the contractor's sharing period. After he has produced 1,000 units, the contractor submits a Value Enginering Change Proposal which will reduce the cost per unit for the rest of the contract by $2.00 per unit. How-

engineering change is approved) will be $5,716. Therefore, if the value engineering change is approved, the cost of the remaining 29,500 units will be:

$$29{,}500 \times \$5{,}716 = \$168{,}622{,}000.$$

Thus, if 29,000 additional units were to be procured on future buys, the value engineering change would not be approved since the total cost of production over the remaining 29,500 units would be greater than if the value engineering change were not made. The difference is:

$$\$168{,}622{,}000 - \$167{,}147{,}000 = \$1{,}475{,}000.$$

From the above example it is obvious that the number of units to be produced on the new slope has a great influence on the worth of the value engineering change.

Returning to the original example in which 5,000 more units would be produced, we proceed in calculating the contractor's share of savings. Above it has been mentioned that the savings on the instant contract is $1,000,000. (i.e., $2,000 per unit for 500 units.)

The contractor's share is 30%. Therefore, his share on the instant contract is:

$$30\% \text{ of } \$1{,}000{,}000 = \$300{,}000$$

The algebraic lot midpoint on a 90% slope of a lot from 1,001 to 6,000 is the 3,104th unit. The cost of this unit is $6,944. The algebraic lot midpoint on an 85% slope of the same lot is the 3,073rd unit. The cost of this unit would be $7,608. Therefore, the savings on future buys (units 1,001 to 6,000) is: 5,000 units × ($7,608 − $6,944) = $3,320,000. The contractor's share of this savings is 20%. Therefore, he receives:

$$20\% \text{ of } \$3{,}320{,}000 = \$654{,}000$$

The contractor's total share of savings resulting from the value engineering change is:

$$\$3000{,}000 + \$664{,}000 = \$964{,}300.$$

The average unit cost reduction which may be used to calculate the contractor's share of savings on the instant contract is $2,000 per unit. (i.e., 30% of ($2,000 × 500) = 30% of $1,000,000 = $300,000.)

The average unit cost reduction for the additional 5,000 units to be produced within the contractor's sharing period is the difference in cost of the two algebraic lot midpoints for units 1,001 to 6,000 on the 85% and 90% slopes. From above we know that this was:

$$\$7{,}608 - \$6{,}944 = \$664.$$

Thus, $664 is the unit cost reduction on future production which can be used to calculate the contractor's share of future production.

For example: 20% of ($664 × 5,000) = 20% of $3,320,000 = $654,000.

If one unit cost reduction figure is desired which can be used to obtain the contractor's total share of savings on both the instant contract and future buys ($964,300), the following equation may be solved. Let X be the desired figure.

$$\$964{,}300 = 30\% \text{ of } (500x) + 20\% \text{ of } (5000x)$$
$$\$964{,}300 = 150x + 1000x$$
$$\$964{,}300 = 1150x$$
$$\$838.52 = x$$

$838.52 is *not* the average savings per unit over the remaining 5,500 units to be produced. It is the one figure (savings per unit) which can be used to calculate the contractor's share of savings on both the instant contract and on future buys so that over 5,500 units the contractor receives the amount he should receive for making the value engineering change and no more. In other words if the contractor's share of savings on both the instant contract and future buys is calculated using $838.52 per unit savings, the same share will go to the contractor as was obtained in the separate calculations for the instant contract and future buys. His share is:

THE EFFECT OF NEGOTIATIONS

An interesting and useful fact about experience curve analyses will be discussed here. In the foregoing examples we have worked with the VECP as the contractor has submitted it. If the VECP stated a savings of $5.00 per unit for the remaining units under the instant contract, we based our experience curve analysis on the $5.00 unit cost reduction quoted in the VECP. However, the amounts submitted in a VECP are subject to negotiation at the time the VECP is approved and a supplemental agreement is added to the original contract. Therefore, although the experience curve analysis is based on a unit cost reduction of $5.00 for the instant contract, the unit cost reduction actually appearing on the supplemental agreement may be less. However, in order to calculate the contractor's share of savings and the total savings based on the new unit cost reduction figure in the supplemental agreement, it is not necessary to perform another experience curve analysis. For example, in the first problem discussed under minor value engineering changes the VECP claimed to effect an average unit cost reduction of $5.00 per unit for the remaining portion of the instant contract. Based on that figure an experience curve analysis of the VECP yielded $3.30 per unit as the average unit cost reduction over future production within the sharing period and a total share of savings on both the instant contract and future production for the contractor amounting to $92,250. If the original $5.00 unit cost reduction figure is changed to $4.00 as the result of negotiations, the new average unit cost reduction over future production and contractor's total share of savings can be obtained easily by using ratio and proportion: Let X be the average unit cost reduction over future production within the contractor's sharing period. Then X is to $4.00 as $3.30 is to $5.00. Stated more mathematically, we have:

$$\frac{X}{\$4.00} = \frac{\$3.30}{\$5.00}$$

$$X = \frac{(\$3.30)\ (\$4.00)}{\$5.00}$$

$$X = \$2.64$$

Therefore, $2.64 is the average unit cost reduction over future production within the contractor's sharing period corresponding to an average unit cost reduction of $4.00 per unit on the instant contract.

The contractor's total share of savings over both the instant contract and future production corresponding to a savings of $4.00 per unit on the instant contract can be obtained in a similar manner. Let X represent the contractor's share. Then:

$$\frac{X}{\$4.00} = \frac{\$92,250}{\$\ 5.00}$$

or

$$X = \$74,360$$

Therefore, $74,360 is the contractor's total share of savings on both the instant contract and future production corresponding to an average unit cost reduction of $4.00 on the instant contract.

Hence, no matter what the unit cost reduction submitted on a VECP changes to as a result of negotiations, the experience curve analysis need be performed only once. The ratio and proportion method illustrated above is good as long as the quantities involved and the production slope are the same.

ever, there is an increase in tooling cost amounting to $25,000 accompanying the Value Engineering Change Proposal.

The experience curve analysis is performed exactly as in the preceding example. The $2.00 per unit savings is considered to be the savings on the algebraic lot midpoint of the remaining units to be produced under the instant contract. The 20,000 units which have already been produced before this contract must also be taken into account. Therefore, the algebraic lot midpoint of the remaining units on the instant contract is the algebraic lot midpoint of a lot running from 21,001 to 30,000. This is the 25,311th unit. The theoretical savings on the first unit produced (i.e., unit #1 on the first production contract) corresponding to a savings of $2.00 on the 25,311th unit is $25.62.

The savings and the contractor's share of savings on the instant contract (not considering the increase in tooling cost) is calculated as follows:

30% of (9,000 × $2.00) = 30% of $18,000 = $5,400

The total savings on the instant contract is $18,000. The contractor's share of this savings is $5,400.

The algebraic lot midpoint of the lot running from 30,001 to 60,000 is unit 43,929. The savings on this unit is $1.74. The savings on future production within the sharing period and the contractor's share is calculated as follows:

20% of (30,000 × $1.74) = 20% of $52,200 = $10,440.

The savings is $52,200, and the contractor's share of this is $10,440.

Therefore, the total savings within the contractor's sharing period (not taking into account the increase in tooling cost) is:

$18,000 + $52,200 = $70,200.

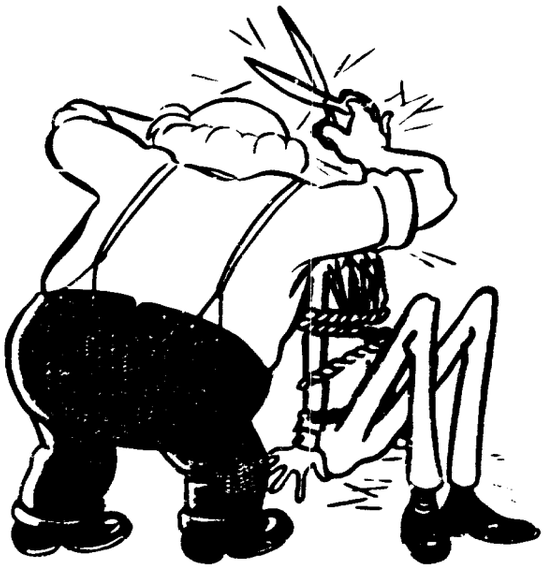
The contractor's total share of this savings is:

$5,400 + $10,440 = $15,840.

Taking the $25,000 increase in tooling into account, it is obvious that the savings of $18,000 on the instant contract as a result of the value engineering change will not counterbalance the increase in tooling cost. However, the total savings of $70,200 which occurs within the contractor's sharing period is larger than the contractor's total share, $15,840, plus the increase in tooling, $25,000. The net savings which occurs within the contractor's sharing period as a result of the change is:

$70,200 − ($15,840 + $25,000) = $29,360.

Even if the savings resulting from the value engineering change within the sharing period did not compensate for the increase in tooling cost, the Value Engineering Change Proposal could still be considered if it were known that more units would be produced beyond the contractor's sharing period.



APPENDIX A – REFERENCED MATERIALS

The Experience Curve Tables, Pamper Tables, and a book on the experience curve titled Alpha and Omega and the Experience Curve may be obtained by writing to the Defense Documentation Center. The appropriate address and documentation numbers are given below.

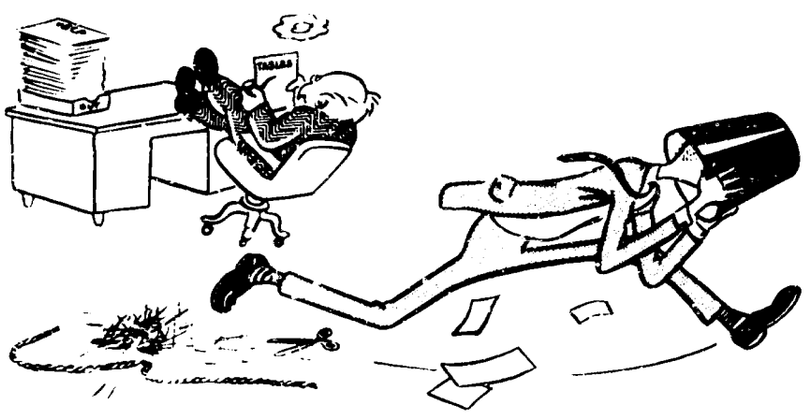
Headquarters, Defense Documentation Center
Cameron Station
Alexandria, Virginia

Experience Curve Tables	
Volume I	AD-612803
Volume II	AD-612804
Pamper Tables	AD-612802
Alpha and Omega and the Experience Curve	AD-617133

WHEN THE ESTIMATED QUANTITY TO BE PROCURED CHANGES

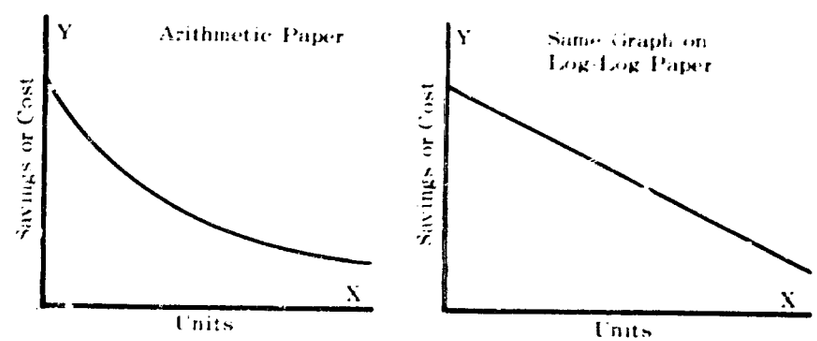
Any experience curve analysis of a VECP is based on an estimated quantity of units to be produced. If an experience curve analysis is performed on the basis that a certain number of units will be procured within the sharing period and this number is changed after the analysis has been performed, the amount the contractor receives as his share of the savings will be either too great or too small. (Note: The average unit cost reduction on future production must be determined at the time the change is approved and usually cannot be redetermined.)

For example, in the previous problem the experience curve analysis was performed on the basis that 30,000 additional units would be procured within the contractor's sharing period. The average savings per unit as a result of the value engineering change over the additional 30,000 units was found to be $1.74. Suppose that later the quantity to be procured changes to 50,000 units. If an experience curve analysis were performed on the basis that 50,000 units were to be procured, the average savings per unit as a result of the change over the additional 50,000 units could be found to be $1.66. Therefore,



the average unit cost reduction over the additional quantity to be produced within the sharing period differs by $.08 per unit from the original figure that was calculated. Over 50,000 units this amounts to $4,000. Thus, if the royalty payment sharing plan were being used, the contractor would receive approximately $4,000 too much as a result of the increase in the additional quantity to be procured from 30,000 to 50,000 units. However, if the additional quantity had reduced from 30,000 to 20,000, the contractor would have received less than he should have.

The amount of change in average unit cost reduction that occurs when the additional quantity to be procured within the sharing period changes depends upon the number of units already produced. Remember that the experience curve is an exponential curve on arithmetic graph paper. (See the diagrams below.)



Therefore, if few units have been produced (i.e., we are not far out on the X axis), there will be a great change in average savings or average unit cost reduction for a small increase in quantity of units to be produced. But if many units have already been produced (i.e., we are far out the X axis) there will be only a small change in average savings per unit for a change in the quantity to be produced.

APPENDIX B – DEFINITIONS

1. Algebraic Lot Midpoint: The unit which best represents a lot in that the cost or man-hours of that unit is approximately equal to the average cost or man-hours per unit for the lot. The cost or man hours of the algebraic lot midpoint multiplied by the number of units in the lot yields the total cost or man hours of the lot.

2. Experience Curve: A curve (depicting cost or man-hours per unit) obtained from a least squares fit to a set of data. The experience curve falls under two variable non-linear correlation problems in statistics.

3. Future Production: Contracts which will be negotiated, follow-on procurements.

4. Instant Contract: The contract under which production is presently being performed.

5. Percent Slope: The difference between 100% and the percent of decrease in cost or man-hours of successively doubled units.

   e.g., If the cost per unit of production decreased by 10% between the fifth and tenth units of production and decreased again by 10% between the tenth and twentieth units and continued in this manner, the slope of production would be 90%.

6. Royalty Payment: A payment (on a specific quantity of units) made to the contractor representing his share of the savings resulting from use of a VECP that he submitted.

7. Sharing Period: A specific quantity of units or a specific period of time in which the contractor shares on all savings resulting from VECP's he has submitted.

8. VECP: Value Engineering Change Proposal, a cost reduction proposal submitted by a contractor which requires a change in contractual specifications or drawings.