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# ESTIMATING THE COST OF WORK

WITH SPECIAL REFERENCE TO UNSTANDARDIZED OPERATIONS, AS IN JOBBING SHOPS OR REPAIR WORK

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# PREFACE

This incomplete discussion upon the systematic collection and use of unit costs for ordinary estimating purposes has been compiled partly from memoranda issued from time to time within the past four years by the author to the members of the hull Estimating and Planning Staff at certain Navy Yards, as a part of their instruction and training.

On account of the satisfactory results obtained by the use of these notes, incomplete as they are, I have been persuaded rather than to wait several years longer for more complete data from which to prepare a scientific discussion of the problems of the average estimator, to venture at this time to contribute my mite to the cause of standardization of labor. I do this in the belief that my efforts will be supported and far surpassed by many others of kindred faith, and that at some distant day the art of Estimating the Cost of all classes of work will approach becoming a science.

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# INTRODUCTION

## What Is an Estimate?

The word "estimate" is used in several different senses, and in dealing with the cost of work it is necessary to confine our discussion principally to one specific definition or meaning. Those who require or seek estimates of cost need them for a variety of reasons or purposes, and these various purposes correspond with the kind of estimate required, for example:

*To estimate* may mean: To make a "rough" approximation of probable cost. This is the only kind of estimate possible when the specifications are not exact as to the extent and nature of the work which is contemplated. Such estimates as this are required by Congress upon which to base most of the appropriations. Such an estimate is required for large projects or for contemplated work not definitely decided upon, where the approximate outlay may determine whether the project can be financed properly, and whether it is worth while to go to the expense of making more detailed investigation and of making accurate estimates.

*To estimate* may mean: To fix the value by comparison and experience; to calculate; and usually to make this calculation by utilizing all available comparative data. If an estimate is made for a prospective customer, it is usually in the form of a "bid," submitted on a regular form of proposal; and if the estimate is accepted and approved, it becomes the contract price. This form of estimate must be made and checked with great care; and it will be of advantage to be able to submit an estimate of this kind without undue delay. Hence both accuracy and promptness are desirable. Such estimates or "bids" are made by adding to the estimated *cost of production* a sum for marketing the product and for *profit.*

The term "estimated cost of work" will be used to indicate the probable actual cost or outlay to the contractor, which is required for a specified production. Profit and selling expense will not be included. Total cost is composed of labor, material, and incidental expense. Attention will be especially devoted to estimating the *labor.* Estimating the cost of material presents no difficulty to the experienced estimator after a complete list of the material required is prepared. The "incidental" expense can be allowed for by a number of different methods, depending upon the degree of accuracy desired, and upon the kind of cost-keeping system in effect in the plant. The practical application of these methods to estimating the incidental or overhead expense will be discussed briefly.

In estimating or calculating probable costs (which must be done by comparison and experience), the estimator is bound to use some *standard* of comparison, not a fixed or immutable standard, but nevertheless a standard or guide; whether such standard is the written record of actual previous costs of identical or similar products, or whether such standard exists only in the mind or imagination of the estimator.

## What Is a Standard?

Funk & Wagnalls' Standard Dictionary says a standard is: "Any type, model, example, or authority with which comparison may be made; any fact, thing or circumstance forming a basis for adjustment and regulation; a criterion of excellence."

In the art of estimating, it is only in determining what costs *should be,* if we eliminate preventable waste (or, using Mr. Emerson's term, it is only in "predetermining costs"), that we establish a standard which is "a criterion of excellence." In estimating what costs *will actually be,* we use for a standard of comparison the type or example of past performance which represents the *average* cost of work, under standard conditions. By thus using a *standard* estimate for each unit (whether the unit chosen be an object or an operation), based on the cost of a standard number of units under certain conditions taken as standard, the estimator can proceed methodically to classify and study all cost data and estimates with reference to such standard.

By this means, each and every cost or estimate can be compared to some standard cost or estimate; and data gradually collected by which the best possible estimates can be skillfully made for any item of work that may arise.

The pursuit of this practical application of data and knowledge by estimators, and the devising of rules which govern the average costs of all units, dependent on the variables of (1) Number of units, (2) Size of unit, (3) Classification number, will become an *art* instead of a haphazard guessing process.

# ESTIMATING THE COST OF WORK

## THE ART OF ESTIMATING

THE usual methods of estimating are many and diversified. Large volumes have been written on the subject; many books for each class of building work, but very few books for repair work. All these works are valuable and should be read and studied before the ambitious estimator or task-setter undertakes to systematize his data and to benefit by the methods set forth briefly in this modest volume. A partial list of such books will be found in the Appendix.

A thorough technical knowledge of his own business is assumed of all who will be interested enough to read this volume, and a knowledge and experience in planning work in more or less detail, including making itemized Bills of Material. The accuracy and rapidity with which a good estimator can prepare estimates depend upon the accuracy and thoroughness of the *data* which the *records* for the particular plant furnish, and upon the convenience and handiness of the data arranged, tabulated or plotted in compact form, properly indexed and classified.

This volume primarily attempts to state the result of the author's experience in connection with preparing and checking estimates for all kinds of ship construction and repair work, and the collection and classifying of all kinds of actual cost extending over a period of ten years; embracing work in both Government and private plants, and including costs of ordinary day work, piece work and premium systems of pay.

The actual figures given are not intended to be accurate for any individual plant other than the particular shops or plants from which the data were obtained. But by reference to the scale of wages in appendix the estimates can be reduced to the hourly basis to compare with other plants. That is, the main point to emphasize is that *each plant* must collect *its own data;* and the writer believes that the analysis, arrangement and concise record of such data along the outlines indicated will materially assist estimators or task-setters, or superintendents, in preparing accurate estimates for new work or repair work with facility, and estimates will be in a convenient shape for comparison with actual costs, as well as form the preliminary basis for a piece-work or bonus system.

## GENERAL METHODS BY CURVES OR GRAPHS

ALL estimating data of value can, as a rule, be reduced to curves, thus placing in compact form on one sheet of paper as much information as several pages of figures would take up. Curves also show many important facts and observations which are not so readily impressed on the attention as other methods. This particularly applies to the separation of estimates for labor into the two main elements: (1) Cost of preparation for doing work (i. e., aside from the actual operation of the machine or workmen in "producing"), including travel to work, setting up, removal, etc., (2) Cost of operation.

The simplest form of curve, which fits a very great variety of operations and jobs, shows the number of units performed as abscissæ and the cost (or number of hours' work) as ordinates. Such a curve is shown on page 5.

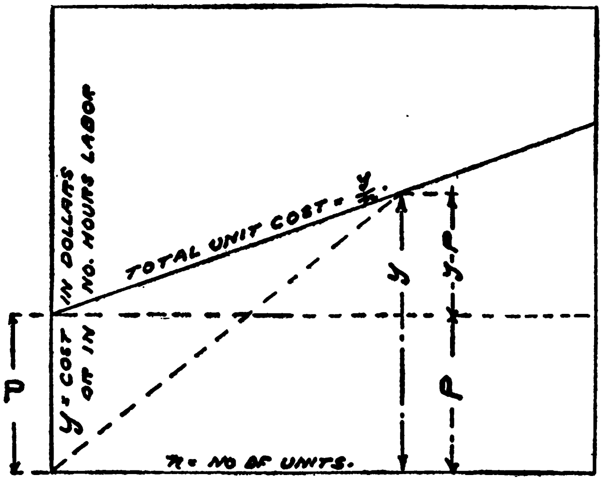



FIG. 1. SIMPLE GRAPHIC EXPRESSION OF COST DATA

The ordinate at the origin is the cost of Preparation (P). This forms a very considerable part of the total labor cost. For a day's work it often amounts to over half the total labor cost. Hence its importance in estimating the cost of work must not be overlooked.

The above straight-line curve represents fairly well the cost of *simple* operations in repetition manufacturing work, e. g., where the "operating cost" of machining, aside from "preparation cost," increases *directly* as the number of pieces manufactured. This condition, however, seldom obtains, for many practical reasons mentioned later, and the form of the actual curve for recorded costs will, in most cases, be somewhat as shown in the curve below, which may be compared with the straight-line curve on the preceding page:

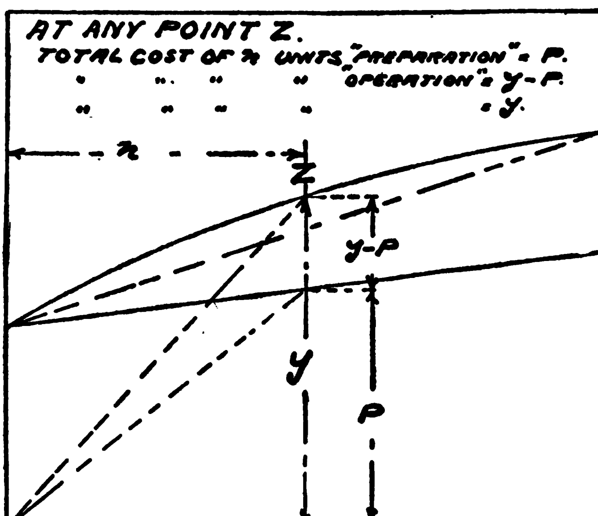



FIG. 2. USUAL FORM OF CURVE OF ACTUAL UNIT COSTS:

UNIT COST OF PREPARATION = $\frac{P}{n}$

UNIT COST OF OPERATION = $\frac{y-P}{n}$

UNIT COST OF TOTAL = $\frac{y}{n}$

## Practical Meaning of the Curves

These simple curves merely show graphically what every one knows, but which is so frequently not allowed for properly or correctly by most estimators, namely: That the unit cost depends absolutely upon the number of units performed one after the other (up to a certain practical limit). Up to this number there is a determinable relation between unit cost and number of units; and this relation can be expressed mathematically. This is true not only of manufactured articles, as explained by Mr. Van Deventer in an article in the *American Machinist* of December 25, 1913, called "Minimum Costs on Small and Variable Lots"—but it also holds good for all manner of operations. The investigation of this relation for all classes of work constitutes an important function for all estimators. By plotting fair curves, from actual cost records, showing graphically the number of units in each operation of a certain class as abscissa and the total cost of the operation as ordinate, we get at once the estimated cost of any desired number of units. We do not have to even bother about estimating the unit cost.

Let us give a simple example, taking the case of riveting, in ship work. In estimating the cost of driving odd or scattered rivets, it has usually been customary to "guess" at a unit price, or to estimate roughly, from unrecorded experience. This should not be necessary. Suppose we want to estimate the cost of driving 25 ¾-inch rivets in the inner bottom of a ship, by day work. Our records show for this class of work that day work costs average twice as much as piece-work. We look at the piece-work schedule price per 100 rivets, Class 4, size 6, and find the piece-work cost would be $2.50 per 100, or 2½ cents each. The allowance for "preparation" for the first rivet is $0.32. From the curve for riveting, or by simple calculation, or from the Table of Scattered Riveting we get the estimated cost of $0.86 for 25 ¾-inch rivets, class 4. This table was prepared from the curve. Trial by the three methods will show that using the curve is the easiest method. The estimate for day work will be twice the piece-work estimate, or $1.72. Use $1.70.

The piece-work prices which appear later as Estimating data were set with this principle in mind; and for a small number of units, or "scattered work," which comprises such a high proportion of repair work, an allowance was made for "preparation," up to about four hours' average output at ordinary day work.

## NEW CONSTRUCTION WORK

FOR manufacturing work or new construction, the records of total costs of *objects* are, of course, the most reliable and valuable data for estimating on identical objects. In case of minor differences in design, allowances can readily be made for corresponding differences in cost. When it comes to an entirely different design, however, estimates must be based on the elements or divisions of work which go to make up the total costs of objects. For example, in ship construction, the usual divisions comprise Steel Hull proper, Hull fittings, Boilers, Engines, Auxiliary machinery, Piping systems, Plumbing work, Woodwork, Painting, Equipment, etc. And these are still further subdivided. For example, ordinary steel in Hull proper into (a) Shell plating, (b) Framing, (c) Bulkheads, (d) Decks, (e) Bridges, (f) Foundations for machinery, (g) Inclosures, (h) Metal masts and spars, (k) Rivets, (l) Nonconducting sheathing and ceiling.

These elements are estimated for separately, usually on the *per pound* basis, by comparing actual records of cost per pound for previous vessels built at the plant, where such records are available, provided they are accurate. Frequently cost records are less accurate than careful estimates. In many cases, however, such comparisons are not accurate, due to different design and arrangement of any previous vessel, and we can either allow for these differences more or less by offhand judgment, or we can separate these groups or items still further, until we arrive finally at a fair means of comparison with previous costs of small units. These methods of estimating on new work are very reliable where previous costs are accurate and comparable with the new conditions, and where no appreciable changes or improvements in methods of doing work have taken place since the previous work was completed.

There are, of course, many other units of comparison besides the pound or ton, for all classes of new work; such as the square foot, the square, the running foot, the cubic yard, the number of units (as number of rivets, number of holes punched, etc.). That is to say, units of length, area, volume, or weight.

The final or ultimate separation into units comparable with previous work may result in comparison of prime elements or "operations," that is, the successive steps required to construct each part of the whole; such as laying off, marking, punching, shearing, machining, assembling, erecting, riveting, calking and testing. It is with this final method of analysis into prime elements that we have to deal in the case of *repair work,* in most cases, for the reason that we seldom have two repair or alteration jobs of identical nature and scope.

### Repair Work

There are many difficulties, seemingly unsurmountable, in the way of accurately estimating on repair work, especially ship repair work. Previous records of *total* costs are seldom of much assistance, as identical repair jobs seldom recur, and conditions are never the same. Total costs of similar jobs, however, serve as a guide or check on the detail estimate. They should not be accepted without careful analysis and comparison as to the character of work, and conditions under which performed.

Among the difficulties that attend estimating on repair work may be mentioned the following:

1. Extent and nature of repairs unknown in detail until the work is under way; that is, before estimate is made.

2. Accessibility of the work, whether in the shop or in the field; work may be overhead, or in closed-in or cramped places.

3. Complexity and difficulty of the work compared to some assumed *standard* condition; work may be on plain plates or shapes, or on curved or irregular surfaces, or on beveled shapes.

4. Continuity or contiguity of the units which comprise the operation, the amount of shifting of tools or position of the workmen which is required.

5. Physical or natural conditions surrounding the work, such as weather, light and heat; also the possibility of efficient supervision, considering the locality of the work and number of men employed to advantage at one time and place.

As to the first-named difficulty, namely, lack of definite specifications because impossible to make them, it may be said that this makes an accurate estimate impossible; in fact, no *real estimate* can be made, but only a rough guess. In such cases, it is a pure waste of time trying to guess accurately, and it would be better in all such cases not to make an estimate at all until the work of dismantling or overhauling was under way sufficiently to determine exactly what repairs had to be done. If a "bid" *must* be submitted on this class of work, it will be the best practice to bid on actual cost plus a fixed profit (either a lump sum profit or a percentage of cost).

The other difficulties enumerated above of estimating on repair work may be called conditions of a variable nature, and as such may be classified to cover all manner of repair jobs sufficiently for ordinary estimating purposes. The accuracy of such estimates will be dependent upon: (1) The thoroughness with which the detailed observations of similar operations under various conditions have been obtained and recorded. (2) The skill and judgment of the estimators in classifying various conditions, and in assigning the particular operation being estimated upon into the right class. (3) The skill of workmen employed, system of pay in use, and methods of organization used in the shop; that is to say, dependent upon the efficiency of labor: and (4) The judgment of the estimators, based upon proper records of past work of a similar nature, in making allowances for wholly unforeseen contingencies or extra minor work not planned for originally. This latter factor may in ordinary ship repair work run as high as 20 per cent of the total labor cost for some classes of work. For small jobs, the factor will naturally be much larger than for large jobs. On the average, counting all manner of alteration and repair jobs, large and small, for a whole year, this factor should not exceed 10 per cent of total cost and can be estimated within 1 per cent of total cost by an experienced estimator.

## Classification of Variable Conditions

By this is meant what is commonly known as standardization of conditions, or of operations. In manufacturing work standardization has progressed to such an extent that fairly accurate estimates of cost of operations, or of a fair "time allowance" to perform an operation, can be readily made. These estimates can be based on extensive observations, motion studies, and detail cost records. In repair work, however, the problem is far more difficult; but wherever it has been studied and partially solved, the results have been so satisfactory in the way of increased efficiency, and so convincing as to the practicability of standardization of all manner of operations, that we may look some day to the serious consideration of the establishment of a Bureau of Trades under the United States Government, as proposed by Mr. Frank B. Gilbreth in "Motion Study," such Bureau to have two main tasks: (1) To subclassify the trades. (2) To standardize the trades. Mr. Gilbreth contents that

> This sub-classifying of trades according to the types and grades of motion that they use, or according to the brawn, brain, training, and skill required to make the motions, will cut down production costs. It will raise the standard of all classes. It will do away with differences between employers and employees. It will eliminate unnecessary waste. It will raise the wages of all workers. It will reduce the cost of living.

When it comes to repair work, an example of what can be done, and has been done, toward standardization is seen in the railroad repair shops of the Santa Fe, where 23,000 operations were standardized, and estimates thereby made upon which a complete bonus system was based. (See Going's "Methods of the Santa Fe.")

## Cost Data on New Construction

Before taking up the classification of elementary operations in shipwork, which we will later do from an estimator's standpoint, and make the nomenclature as simple as possible, let us first consider the main physical divisions of a vessel, and take a common classification for estimating the value of new construction by the pound. The figures on pp. 18, 19 are for direct *labor* costs only, for hull work, of several types of vessels; and they are given mainly to show how widely these unit costs vary with different types of construction, and for the different classes, or groups, of a vessel's structure. Beyond this purpose they cannot be used for anything except "rough" estimates, as each plant has to collect its own figures, and tabulate them. This may be a convenient method of tabulation, for each design of vessel built. A study of the different designs, in connection with the various unit prices thus tabulated, would enable the estimator to account for any considerable differences in unit costs due to de-

## DIRECT LABOR COSTS PER POUND IN CENTS

| Group Number | Items | I Battleship | II Destroyer | III Collier | IV Coal Barge |
|---|---|---|---|---|---|
| 7 | Ordinary steel in hull | 4.6 | 7.7 | 2.1 | 1.1 |
| | (a) Plating, outer and inner bottoms | 2.1 | 4.0 | 1.1 | 1.0 |
| | (b) Framing | 4.1 | 7.0 | 1.5 | 0.7 |
| | (c) Bulkheads | 4.7 | 8.0 | 2.2 | 1.1 |
| | (d) Decks | 3.0 | 6.0 | 1.4 | 0.6 |
| | (e) Bridges, hammock berthing and coffer-dams | 9.7 | 15.0 | 3.3 | |
| | (f) Foundations for armor, turrets and guns | 5.9 | | | |
| | (g) Work around secondary battery, etc | 15.1 | 15.0 | | |
| | (h) Foundations for machinery | 7.3 | 10.0 | 4.3 | |
| | (i) Inclosures | 10.4 | 15.0 | 2.0 | |
| | (j) Metal masts and spars | 16.0 | | 3.0 | |
| | (k) Rivets | 11.1 | 25.0 | 12.1 | 11.0 |
| 8 | Steel castings and forgings forming structural parts of hull | 5.3 | 16.1 | 1.7 | |
| 10 | Deck pillars or stanchions | 5.5 | 12.1 | 1.7 | |
| 11 | Deck planking and wood in docking and bilge keels | 6.1 | 8.0 | 4.0 | 1.1 |
| 12 | Linoleum, tiling, etc | 1.4 | 8.0 | 1.2 | |

| | | | | | |
|---|---|---|---|---|---|
| 13 | Joiner work | 30.9 | 30.0 | 8.0 | |
| 14 | Carpenter work | 11.7 | 12.0 | 5.0 | |
| 15 | Wood ladders | 39.4 | | 15.4 | |
| 16 | Wood masts and spars | 24.6 | 35.0 | 16.5 | 38.0 |
| 17 | Metal ladders | 13.1 | 25.0 | 3.8 | 4.0 |
| 18 | Paint, cement, etc | 11.5 | 13.4 | 4.9 | 2.5 |
| 19 | Turret-turning machinery, roller tracks, and rollers | 9.0 | | | |
| 20 | Fixed ammunition-hoist machinery and gear | 19.2 | 20.0 | | |
| 21 | Rudder and steering gear | 5.1 | 13.8 | 3.4 | |
| 22 | Cranes, davits, and other gear for handling boats | 11.6 | 10.0 | 8.3 | 3.0 |
| 23 | Coaling gear | 10.2 | | 10.9 | |
| 24 | Pumping and drainage, and sea connections | 33.7 | 40.0 | | |
| 25 | Plumbing work, including fresh and salt water systems | 25.5 | 25.0 | 7.9 | |
| 26 | Ventilation | 34.9 | 51.0 | 17.6 | |
| 27 | Anchor and cable gear | 6.8 | 13.3 | 4.1 | 2.3 |
| 28 | Warping and towing gear | 6.3 | 15.0 | 1.3 | 0.9 |
| 29 | Hand rails and awning stanchions, canopy frames, and hatch cranes | 28.2 | 30.0 | 17.1 | |
| 30 | Air ports, deck lights, and light boxes | 19.0 | 25.0 | 8.7 | |
| 31 | Water-tight doors | 15.2 | 44.2 | 16.8 | |
| 32 | Nonwater-tight doors | 28.7 | 18.1 | 17.2 | |
| 33 | Manhole-covers, scuttles, etc | 21.4 | 30.0 | 2.6 | 0.8 |
| 34 | Miscellaneous hull fittings | 15.3 | 25.0 | 13.3 | |

sign, and to strengthen his judgment in checking over new estimates for new work.

These labor costs per pound are for vessels built mostly by day work, and are considerably higher on the average than we would expect for work done entirely by a piecework, bonus or contract system.

The four types of vessels which are selected for comparison are all naval vessels, viz.:

(1) Battleship of the "New York" class.
(2) Torpedo-boat destroyers, 1,000 tons.
(3) Collier of the "Jupiter" class.
(4) Standard 500-ton navy coal barge.

There are several other items in ship construction for which the costs are not given, some of which are peculiar to warship construction. These items cannot be estimated by the pound with any degree of satisfaction, for example:—

Armor and armor backing.
Nickel-steel protection for hull.
Electric generating plant.
Electric wiring throughout ship.
Means of interior communication.
Installing ordnance and ordnance outfits.
Installing furniture and equipment.

In addition to these items there are certain *general items* of expense incident to building a vessel which are ordinarily charged *directly* to the cost, instead of as an overhead charge. The cost of these general items varies greatly with the organization, equipment and local conditions, and a comparison of such costs for two plants is of no great value for estimating purposes. In some systems of cost keeping a large portion of some of these items does not appear as a direct cost but as a part of the overhead or incidental charges.

These general items are classified as follows:

No. 1.—General superintendence, office expense, insurance, freight.

No. 2.—Drafting work (5 to 10 per cent of total labor).

No. 3.—Laying down in mold-loft.

No. 4.—Preparation of slip, cribbing, and scaffolding.

No. 5.—Preparation of launching ways, and launching ship.

No. 6.—Trial trip expenses, and docking.

It will be seen from the wide variations in unit costs for the groups or items above, which are in common use, that these groups are not the best that could be selected for estimating purposes. A more logical grouping for estimating or cost keeping purposes would be based upon the character of *materials* and the work upon each distinct class of material subdivided into the work by trades. . Such a classification has been used abroad, and is described at some length by Mr. L. Peskitt in a paper read before the Institution of Naval Architects at Glasgow in 1913. (See *Shipbuilding and Shipping Record* of June 26, 1913.) Mr. Peskitt outlines a method whereby the cost of steel work and such material can be determined, which is generally on the basis of weight.

He states that

> Shell and deck plating would be dealt with first, and then such other plating as occurs throughout the structure. Thereafter, and in a systematic manner, the quantities of angle sections would be taken out. An estimate would be made for the various classes of forgings and castings.................. Both in computing the cost of steel work and carpenter's wood, the cost of material is kept separate from the cost of wages.

Another way, and frequently a more accurate way, to estimate on the structural steel in hull proper, is by the total cost of processes or operations (under each subdivision or group) which can be done very readily if the jobs have been planned out in detail. For example, on standard navy coal barges, the cost of these operations at one navy yard on the shell plating group was as follows:

TWO STEEL COAL BARGES

Capacity 500 tons each

Group 7a { Shell plating, bottom and side. Weight including rivets 215,000 lb.

| OPERATION | Units | Number of units | Cost of operation | Per cent of total cost | Cost per lb. of total job (in cents) |
|---|---|---|---|---|---|
| Templating | Sq. ft.<br>Lin. ft. | 13,000<br>1,000 | $ 65<br>7 | 3.0 | .033 |
| Laying off | Sq. ft.<br>Lin. ft. | 13,000<br>1,000 | 160<br>15 | 7.2 | .080 |
| Punching | Holes | 104,000 | 200 | 8.2 | .093 |
| Shearing | Lin. ft. | 480 | 5 | 0.2 | .002 |
| Countersinking | Holes | 36,000 | 60 | 2.5 | .028 |
| Drilling | Holes | 500 | 7 | 0.3 | .003 |
| Planing | Lin. ft. | 4,000 | 40 | 1.7 | .018 |
| Erecting | Lb. | 210,000 | 140 | 5.8 | .065 |
| Bolting up | Bolts | 19,000 | 240 | 10.0 | .110 |
| Reaming | Holes | 48,400 | 220 | 9.0 | .100 |
| Riveting | Rivets | 48,400 | 1,160 | 48.0 | .540 |
| Calking | Lin. ft. | 1,300 | 15 | 0.6 | .007 |
| Smith work | Lb. | 18,000 | 85 | 3.5 | .040 |
| Total | Lb. | 215,000 | $2,419 | 100.0 | 1.125 cts. |

Each job or group of a new vessel can be estimated upon in this manner and all these estimates tabulated by jobs and by operations, all on one large sheet of paper. During the construction of the vessel, this sort of an estimate would be useful both to the contractor and to the customer (or inspector), in estimating monthly the value of the vessel as she stood on the stocks. The progress of work in tenths and in dollars could be checked off both by jobs and by operations.

## Piece-Work Prices

As a temporary standard with which to compare costs of operations in similar work, a simple set of piece-work prices will be introduced. It is hoped that if carefully studied, especially the riveting schedules and the table of allowances for "scattered" work and for non-standard conditions, they will in a measure point the way for each estimator who has no standards, to set up his own standards of comparison, taken from his own data. Some of these prices may be low or high for a particular plant, as they were of course set, in certain ship construction and repair plants, with consideration being given to the equipment and facilities, to the organization and management, and to local conditions and prevailing wages. In estimating the cost of any particular operation, we must first compare our own recorded data with these prices or costs, and get the average ratio between them. The simplicity of the classifications used (or of any other simple classifications) adds greatly to the rapidity and ease with which any ordinary estimate can be made for any number of units, however small, by using the judgment which comes from experience in classifying the conditions of the specific operation before us as to (1) accessibility, (2) complexity, (3) contiguity of the units; by assigning to the operation before us a classification or class number which will represent the combination of these three conditions; and by not forgetting to discover (by plotting our own curves from recorded data) the mathematical law which gives the relation between *number* of units and cost, for the particular operation.

Since these labor costs or prices are introduced solely as comparative estimating data, no discussion will be made of the merits or demerits of this or any other piece-work system; but only the bare figures and accompanying rules and notes will be given. It may, however, be stated that where these prices were used the good workmen made an average of 20 per cent to 60 per cent over their usual day's wages, and that the labor cost of work was reduced from 20 per cent to 60 per cent over previous work of the same kind done by day work.

## General Conditions

1. The system must be acceptable to the employee concerned.

2. When the wage earned is less than a day's wage the cause must be investigated and the day's wage paid, if found not to be the fault of the workman.

3. A scale once fixed must not be made more severe unless conditions have changed through improvement in tools, etc., and any such change must be carefully investigated by the Manager and reported to the Department with the reasons therefor.

4. Any workman desiring to do piece-work must sign a written application addressed to the Construction Officer, stating that the prices offered are satisfactory.

5. In case a workman is employed on piece-work for less than eight hours in one day, the piece prices will be paid if the total amount done by him during that day is equal to or greater than the proportionate amount of the task set.

6. For all time during the day when a man works on other work than piece-work, and for Saturday

half-holidays or other holidays, the regular per diem rates will be used.

7. Whenever it shall be necessary for a piece-worker to go over his work to make it satisfactory, he shall be checked out for such time as he is engaged in making the work satisfactory.

8. If during the remainder of the day, after having completed the work of making satisfactory piece-work done previously, he works at the rate prescribed by the task, he is to be allowed piece-work for the work he accomplishes during such remaining part of the day.

9. For example, if on the 18th, a man is engaged two hours making good piece-work done on the 17th, he shall be checked out those two hours and allowed no pay for that time. The piece-work thus made good is to be allowed him as piece-work, provided that on the 17th he accomplished the specified task. If then during the remaining 6 hours of the 18th he worked at the specified rate per hour necessary to accomplish the task in 8 hours, he is to be allowed piece-work rate for what he accomplishes during the remaining 6 hours.

## General Notes

1. The daily task for any operation, except in a few special cases, specified otherwise, may be considered as the number of units which will earn ten per cent more than regular day pay. Under favorable conditions, a first-class workman will be able to earn 50 per cent over day pay. For convenience, an output earning 57 per cent over day pay will be considered 100 per cent efficiency, so that piece-work prices will be paid for an average efficiency of 70 per cent, or more, for a pay period.

2. The prices below are intended to cover any amount of work, large or small, whether in the shops, on the ground or on ships at repair wharf or in dry dock; that is, where the distances to travel between jobs successively assigned is not great. For work at a great distance, *e. g.*, on the "Hartford," "Olympia" or vessels at torpedo-boat docks, an extra allowance for any necessary travel between jobs in excess of 300 yards will be allowed at the rate of two minutes day pay for each extra 100 yards, or fraction thereof.

3. All unit prices for an operation will be set strictly according to schedule and all proper allowances (if any) covered by schedule will be determined in writing and agreed to by the workman before the operation is started, under the personal direction of the Construction Officer and the Warrant Officer in direct charge of piece-work system.

**AS** **Assembling**

| | | |
|---|---|---|
| COAL BARGES. | Ordinary frame, complete up to main deck...... | $1.25 each |
| | Truss-frame ........... | 2.00 " |
| | W. T. bulkhead, complete up to main deck....... | 6.00 " |

This work includes the necessary assembling, bolting, reaming, fairing, etc., for riveting of the entire frame or bulkhead. All angle clips, bounding bars, stiffeners, floors, and frames to be attached and all faying surfaces to be painted.

**BO** **Bolting up**

Includes taking plate as left by erecting gang and fairing and bolting tight ready for riveters. These prices include all classes of bolting up.

| | | | |
|---|---|---|---|
| COAL BARGES. | Shell plates, inner strake.. | $1.00 | each |
| Special Prices. | Shell plates, outer strake.. | 1.50 | " |
| | Shell plates, bilge strake.. | 2.50 | " |
| | Transverse bulkhead plates......... | 0.75 | " |
| | Deck plates with seam straps........ | 1.00 | " |
| | Deck plates without seam straps..... | 0.75 | " |
| | Bolting up brackets................ | 0.05 | " |
| | Bolting up clips................... | 0.05 | " |
| | Bolting and packing bulkhead staples. | 1.00 | " |
| | Rider plates ..................... | 0.05 | " |
| | Longitudinal girder plates.......... | 1.00 | " |
| | Bolting up B. H. on ground........ | 3.00 | " |
| | Bolting up " transverse frames, on ground .................... | 2.00 | " |
| | Transverse bulkhead; bolt and pack bounding bars .................. | 1.00 | " |
| | Bulkhead stiffeners ............... | 0.10 | " |

General Prices. All bolting up straight work.

| | lbs., per sq. ft. | | | | |
|---|---|---|---|---|---|
| Weight of plates up to and including................ | 7½ | 15 | 20 | 30 | 40 |
| Bolting up, per bolt......... | .01 | .0125 | .015 | .02 | .025 |

For plates rolled or furnaced, price and a half.

## CA Calking, Pneumatic

The price for calking will include payment for all chipping necessary to fair up edges and to make good calking, assuming the average amount chipped from the edge of any metal to be less than ¼ inch. Where a greater average amount is required, it will be paid for according to the regular chipping or cutting schedule, depending upon the amount removed in addition to the regular calking price. Calking corners of angles, whether inside or outside, and with or without dutchmen, included in straight prices for calking. Joggles over laps of plates, butt straps, etc., with all dutchmen, tapered liners etc., included in the straight price for calking. Regular price only allowed for calking staples around water-tight floors, division plates, etc. Filling pieces to be allowed extra only where required throughout length of open butt. Price and a half to be allowed for all work in tanks and double bottoms when closed in.

| | Price per running ft. |
|---|---|
| Straight calking, planed or chipped...... | $.0120 |
| Straight calking, not planed or chipped.... | .0200 |
| Butt calking ........................... | .0250 |
| Crooked tool work...................... | .0250 |
| Heel of bars............................ | .0250 |
| Oil tight work.......................... | .0200 |

## CM Cementing

Portland cement in bilges and double bottoms, and under tiling:

1. (a) For average thickness below 3 inches, per cu. yd...................... $ .25
   (b) For average thickness above 3 inches, per cu. yd...................... .20
2. Cement under tiling, per sq. ft.......... .04

## CH Chipping, Pneumatic

Trimming of edges, or surfaces, of metal will be counted as chipping when the average depth of cut is not over 3/8 in. If a greater thickness of metal than 3/8 in. is to come off, cutting prices will be used. Price and a half to be allowed for all work in tanks and double bottoms when closed in.

1. Price for straight chipping ½ cent per ⅛ inch width of cut, per running foot.

2. For circular trimming, price and a half, such as manholes and lightening holes.

### CC Chipping and Calking, Pneumatic

Per 100, countersunk head rivets, and tap rivets.

| Diam. of Rivets, in. | ½ | ⅝ | ¾ | ⅞ | 1 | 1⅛ |
|---|---|---|---|---|---|---|
| Chipping and Calking | $1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 3.00 |
| Calking only | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 |

Liners and scarphs, chip and calk, each $.010

### CK Countersinking

Cents per 100 holes

| Diam. of hole, in. | ¼ | ⅜ | ½ | ⅝ | ¾ | ⅞ | 1 | 1⅛ |
|---|---|---|---|---|---|---|---|---|
| 1. In shop | .10 | .12 | .14 | .16 | .18 | .20 | .22 | .24 |
| 2. On ship | .14 | .17 | .20 | .23 | .26 | .29 | .32 | .35 |
| 3. Re-ck on ship after reaming | .35 | .40 | .45 | .50 | .55 | .60 | .65 | .70 |

Note—In shop, material to be delivered at machine.

### CT Cutting, Pneumatic

When the cutting is in the body of the metal further from the edges or deeper than ⅜ in., it will be counted as a cutting, the price for which will include payment for all chamfering and filing where such is required. Where work of cutting into metal is intended to remove an amount greater than that required for working the tool, it will be measured by area and average depth of cut. Price and a half to be allowed for all work in tanks and double bottoms when closed in. Intermediate sixteenths will pay the next lower price.

Prices per running ft. per ⅛ in. thickness of metal,

Straight cutting .......................... $.03
Circular cutting, holes 20 in. diam., and greater .............................. .04
Circular cutting, holes 6 in. to 20 in. diam... .06
Circular cutting, below 6 in. diam.......... .08

## CF Cutting off, Pneumatic

Shapes.

Price per cut based on cross-sectional area of shape cut, that is, weight in lbs. per running foot. For intermediate sizes, use price for larger size in Table.

| | Size lb. per running foot | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Under | 8 | 9 | 12 | 15 | 20 | 25 | 30 | 40 |
| | Price per cut | | | | | | | |
| 1. Straight cutting (work loose on ground or ship)............. | .05 | .07 | .09 | .11 | .14 | .17 | .21 | .28 |
| 2. Straight cutting (work in place).......... | .05 | .08 | .13 | .18 | .22 | .27 | .35 | .41 |
| 3. Cutting scarphs..... | .20 | .25 | .40 | .45 | .55 | .70 | .85 | 1.00 |

For cutting off by machine, see SHEARING

## CO Cutting out Rivets

| | | | | | |
|---|---|---|---|---|---|
| Diameter, inches......... | ½ | ⅝ | ¾ | ⅞ | 1 |
| Price per 100............ | 1.75 | 2.50 | 3.00 | 3.50 | 4.00 |

## CX Cutting, Oxy-acetylene Process

Prices, one-tenth of pneumatic cutting prices.

## DR Drilling, Pneumatic

All holes drilled into, or through, plates riveted together to be counted as solid metal, no plies to count. Holes in loose plates or in plates only bolted together will be counted for each plate drilled. Overhead work allows price and a half.

| | Diameter of Holes, Inches<br>Prices per hole | | | | |
|---|---|---|---|---|---|
| Depth of Drilling—Inches | ¼ | ⅜ | ½ | ⅝ | ¾ |
| Up to and Including ⅜.... | $.010 | .011 | .012 | .014 | .016 |
| ½.... | .011 | .012 | .014 | .016 | .018 |
| ⅝.... | .012 | .014 | .016 | .018 | .020 |
| ¾.... | .014 | .016 | .018 | .020 | .022 |
| ⅞.. | .016 | .018 | .020 | .022 | .024 |
| 1 .... | .018 | .020 | .022 | .024 | .026 |
| 1⅛.... | .020 | .022 | .024 | .026 | .028 |

DRILLING—*Continued*

| Depth of Drilling—Inches | 7/8 | 1 | 1 1/8 | 1 1/4 | |
|---|---|---|---|---|---|
| Up to and Including 3/8...... | .018 | .020 | .022 | .024 | —Per Hole— |
| 1/2...... | .020 | .022 | .024 | .026 | |
| 5/8...... | .022 | .024 | .026 | .028 | |
| 3/4...... | .024 | .026 | .028 | .030 | |
| 7/8...... | .026 | .028 | .030 | .032 | |
| 1 ...... | .028 | .030 | .032 | .035 | |
| 1 1/8...... | .030 | .032 | .035 | .038 | |

Note—that for each 1/8 inch increase, either in diam. or depth of holes, add .002 per hole.

## DT Drilling and Tapping

Including countersinking and running taps in hole ready for calking.

| | Diameter of Holes (in inches), Up to and Including | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3/8 | 1/2 | 5/8 | 3/4 | 7/8 | 1 | 1 1/4 |
| 1. Solid.......... | .030 | .035 | .045 | .06 | .08 | .10 | .15 |
| 2. Through....... | .025 | .030 | .040 | .05 | .06 | .07 | .09 |

## TP Tapping

Tapping only, prices six-tenths the prices for solid drilling and tapping above.

## ER Erecting

Includes picking up when in reach of Yard crane. Lines attached to plates included in price for plates; securing in place with sufficient bolts. Closed work refers to interior work where the crane cannot drop the plate or angle in the vicinity in which it is to be erected.

| | | |
|---|---|---|
| COAL BARGES. | Shell plates, bottom...... | $0.75 |
| | Shell plates, side......... | 1.00 |
| | Transverse frames complete | 1.50 |
| | Transverse bulkheads complete ................. | 2.00 |

| | |
|---|---|
| Deck plates | .075 |
| Deck doubling plates | .050 |
| Bulkhead plates | .050 |
| Bulkhead stiffeners | .010 |
| Clips | 0.05 |
| Brackets | 0.05 |
| Girder plates, longitudinal | 0.75 |
| Rider plates | 0.50 |
| Angles from 10 ft. down | 0.25 |
| Angles from 10 to 30 ft. | 0.35 |
| Bounding angles to shell | 0.25 |

GENERAL PRICES. Straight work on ship.

| | |
|---|---|
| Plates per sq. ft. | 0.01 |
| Shapes per lineal ft. | 0.01 |

Closed work 50 per cent extra.

## LO Laying off

Includes center punching and marking.

Straight price for shapes is for one flange. For two flanges add 50 per cent. Prices are per running ft., for shapes, and per sq. ft., for plates.

| | Shapes per ft. | Plates per sq. ft. |
|---|---|---|
| 1. Laying off from templates furnished. | $0.01 | 0.01 |
| 2. Making templates | 0.01 | 0.01 |
| 3. Making templates and laying off | 0.015 | 0.015 |

Usual allowance for closed work and overhead work.

Above prices are for all laying off except Universal work where amount of work is at least 1,200 sq. ft. for plates, or 1,000 ft. for shapes.

4. For this work: Laying off from Universal template, plates per sq. ft. .......... 0.05
   Laying off from Universal template, shapes per lin. ft., one flange .......... 0.07

5. Note:—For small plates or shapes in Classes 1, 2, and 3, where number of units from one template is less than 20, allow price and a half. Unit is sq. ft. or lineal ft.

## PT Painting Part one

Includes all necessary shifting and lowering of stages, but not rigging or unrigging. Smooth surface refers only to recent coat of paint. Scaled and wire-brushed surfaces to be considered rough or first coat.

| ITEM | $ per sq. ft. | Daily task, sq. ft. |
|---|---|---|
| 1. FIRST COAT RED LEAD............. Note:—Allowances will be made for overhead work in the form of 1.5 sq. ft. for each sq. ft. of overhead work done. | .0050 | 800 |
| 2. FIRST COAT SLATE COLOR over red lead. Working from stages....... | .0038 | 1,000 |
| 3. FIRST COAT SLATE COLOR over red lead. Working from floats........ Note:—Stages and floats to be set for the painters, to be adjusted by the painters. | .0027 | 1,500 |
| 4. FIRST COAT WHITE over RED LEAD, inside work, plain side............ Note:—Allowances will be made as follows:—Side, with rivets, 1 ft. equals 2 ft. plain side. Side, obstructed, 1 ft. equals 2 ft. plain side. Overhead, plain, 1 ft. equals 2 ft. plain side. Overhead, obstructed, 1 ft. equals 3 ft. plain side. | .0028 | 1,400 |
| 5. SECOND COAT WHITE............... Allowances:— 1 ft. plain side equals 1 ft. 1 ft. plain overhead equals 2 ft. 1 ft. obstructed, side equals 2 ft. 1 ft. obstructed overhead equals 3 ft. | .0019 | 2,100 |

| Item | Price per sq. ft. | Daily task, sq. ft. |
|---|---|---|
| 6. Burning Off Old Paint, plain side.. Allowances:— 1 sq. ft. plain overhead equals 2 units. 1 sq. ft. outside of boat equals 2 units. 1 sq. ft. inside of boat equals 5 units. | $.0100 | 250 units |
| 7. Cork Painting.................. | .0045 | 900 |

## PT Painting Part two

### SHIP'S BOTTOM

| | | |
|---|---|---|
| 1. First Coat Norfolk anti-corrosive bottom paint (applied to bare metal) Note:—Above task and price apply both in case of working from stages and working from bottom of dock; stages to be slung for the painters, to be adjusted by the painters. | .0015 | 2,700 |
| 2. Second Coat Norfolk anti-corrosive bottom paint (applied over painted surface)...................... Note:—Above task and price apply both in case of working from stages and working from bottom of dock; stages to be slung for the painters, to be adjusted by the painters. | .0014 | 2,800 |
| 3. First Coat Red Lead, ship's bottoms, outside, first coat........... No Allowances. Work to be brushed out thoroughly, but not laid off for appearances. | 0026 | 1,500 |

| Item | Price per sq. ft. | Daily task, sq. ft. |
|---|---|---|
| 4. SECOND COAT RED LEAD, ship's bottoms, outside. No Allowances. Work to be brushed out thoroughly, but not laid off for appearance. | $.0018 | 2,200 |
| Note:—Norfolk anti-fouling bottom paint-prices same as Norfolk anti-corrosive above—first and second coats respectively. | | |
| 5. BITUMASTIC solution—straight work | .0015 | |
| 6. BITUMASTIC enamel, $\frac{1}{16}$ in. thick or over | .0030 | |
| 7. BITUMASTIC cement, ¼ inch | .0020 | |

Allowances for 5, 6 and 7 for obstructed work etc., same as for PAINTING Part I, items 4 and 5, white paint.

## PL Planing

MATERIAL DELIVERED AT MACHINE

| | |
|---|---|
| 1. Up to and including ⅜ inch thickness—plates and shapes; per ft. | $.009 |
| 2. Above ⅜ inch thickness—plates and shapes; per ft. | .012 |
| 3. Taking all planing as it comes, heavy or light, shapes; per ft. | .010 |

## PU Punching

MATERIAL DELIVERED AT MACHINE

| | Per 100 holes |
|---|---|
| 1. Small plates or shapes, handled by 2 men | $0.10 |
| 2. Large plates or shapes, handled by 4 men, ½ inch and under | 0.20 |
| 3. Large plates or shapes, handled by 4 men, over ½ inch | 0.25 |

## RV Riveting Machine Part I.

| Class No | CLASS OF WORK determined by conditions (a) Accessibility for riveting (b) Complexity and difficulty determines skill required (c) Continuity or contiguity of rivets. | Price per 100, dollars and cents DIAMETER OF RIVET | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | ⅜ | ½ | ⅝ | ¾ | ⅞ | 1 | 1⅛ |
| | S—Size Number | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0. | ON GROUND—Riveting with Bull Machine | | 1.00 | 1.25 | 1.50 | 1.75 | | |
| 1. | ON GROUND—Easy structural work with air hammer | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | | |
| 2. | ON GROUND—Bulkheads—Decks—Floors | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | | |
| 3. | ON SHIP—Beam brackets and gussets—Bulkheads—Deck—Deck houses—Floors—Longitudinals | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.90 | |
| 4. | Keel—Keelson—Inner bottom—Shell—Hatches and Coamings—Bounding bars—Stringers—Turrets | 1.75 | 2.00 | 2.25 | 2.50 | 2.80 | 3.20 | |
| 5. | Boat cranes—Chutes—Trunks—Doors—Manhole Covers—Guards—Masts—Bulkhead staples—Clips | 2.00 | 2.25 | 2.50 | 2.75 | 3.10 | 3.60 | |
| 6. | Ammunition hoists—Bilge keels—Cofferdam—Chain lockers—Peak tanks | 2.25 | 2.50 | 2.75 | 3.00 | 3.50 | 4.10 | |
| 7. | Boiler saddles—Engine foundations | | 2.75 | 3.00 | 3.40 | 3.90 | 4.60 | |
| 8. | Stanchions—Miscellaneous foundations—Struts—Rudders | | 3.00 | 3.30 | 3.80 | 4.40 | 5.20 | |
| 9. | Stem—Stern post | | 3.25 | 3.70 | 4.30 | 5.00 | 6.00 | 7.50 |

**CLASSES 3 and 4 are Flush riveting prices, in new work. Deduct .25 per 100 for snap riveting prices in new work.**

## RM Reaming

Includes reaming all unfair, or small, holes to proper size and fairness. Only such holes as need reaming to be reamed or counted.

| Coal Barges and new work | Price per 100 | | | |
|---|---|---|---|---|
| Diameter, inches: | ⅝ | ¾ | ⅞ | 1 |
| 1. Decks, Inner bottom | $.30 | .40 | .50 | |
| 2. Shell (sides) Bulkheads | .35 | .45 | .55 | |
| 3. Frames, Shell (bottom) | .45 | .55 | .65 | 1.00 |
| 4. Trusses | .60 | .70 | .80 | |

Above is for two-ply. For three-ply add .05 per 100 holes.

General Prices. For new work same as for Coal Barges.

Repair Work, reaming price equals one-fifth riveting price.

## RV Riveting, Machine Part two

Scattered Rivets

| Number in One Locality Class 3 | Price per 100, dollars and cents | | | | |
|---|---|---|---|---|---|
| Diameter in inches | ½ | ⅝ | ¾ | ⅞ | 1 |
| 70 | 1.75 | 2.00 | 2.25 | 2.50 | 2.90 |
| 60 | 1.80 | 2.05 | 2.30 | 2.55 | 2.95 |
| 50 | 1.90 | 2.15 | 2.40 | 2.65 | 3.05 |
| 40 | 2.05 | 2.30 | 2.55 | 2.80 | 4.25 |
| 30 | 2.35 | 2.60 | 2.85 | 3.10 | 3.50 |
| 20 | 3.00 | 3.25 | 3.50 | 3.75 | 4.25 |
| 10 | 4.25 | 4.50 | 4.75 | 5.00 | 6.50 |
| 5 | 5.75 | 6.00 | 6.25 | 6.50 | 7.00 |

Interpolate for an intermediate number.

The above prices are for scattered work on ship, Class 3, as decks, bulkheads, floors and longitudinals. For other classes of work, more difficult or easier, add or subtract 25 cents a hundred to above prices per one change in class.

In general, the above prices are set by using the following allowances for PREPARATION, for various classes of riveting work:

| CLASS No. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Time allowance (minutes).... | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 |
| Cost allowance... | .16 | .20 | .24 | .28 | .32 | .36 | .40 | .44 | .48 | .52 |

The cost of PREPARATION is thus separated from the cost of OPERATING (driving, holding on, etc.), the same as for all other kinds of work.

The term "preparation" includes: 1. Travel from previous job to the new job. 2. Moving tools and equipment from previous job. 3. "Setting up" and removal of tools and equipment.

### ODD RIVETS

In case the rivets are so badly "scattered" that there are less than *five* rivets in one locality, they will be considered as "Odd Rivets" and the following prices paid:

Up to and including 5/8 in.......$6.00 per 100
Above 5/8 in.................... 8.00 " "

### SC Scaling

Includes removal of all paint, scale and dirt down to a clean metal surface. On bottoms, grass, barnacles, etc., to be removed prior to scaling.

Inside paint..$0.015 Outside paint..$0.008 per sq. ft.

These prices allowed only when the following daily task has been equaled or exceeded.

1.............Inside work 130 units
2.............Outside work 250 units

If the task is not equaled, day's wages for that day will be paid.

3. SCALING BOTTOM STEEL SHIP.

Task .................230 sq. ft. per day
Price ...............$.009 per sq. ft.

Note.—Stages will be slung for the scalers, to be adjusted by the scalers; no allowances.

Special prices, equivalents, and further particulars as follows:

The unit is one sq. ft. of plain side plating. For each pad eye, water-tight door, etc., units are allowed as per the following tables:

| INSIDE WORK | Units. |
|---|---|
| Between rivets, overhead work, beams, all obstructed work, each sq. ft. is equivalent to | 2 |
| Corrugated steel, each sq. ft. is equivalent to | 3 |
| Rivets (not flush) each equivalent to | 1/3 |
| Burning off paint, each sq. ft. is equivalent to | 4 |

OUTSIDE WORK

| | |
|---|---|
| Beading, each running ft. is equivalent to | 2 |
| Pad-eyes, each equivalent to | 3 |
| Davits steps, each equivalent to | 7 |
| Davit collars | 13 |
| Awning stanchion step, each equivalent to | 4 |
| Awning stanchion collar, each equivalent to | 8 |
| Water sheds over air ports, each equivalent to | 10 |
| Hinge and pad, each equivalent to | 2 |
| Eye bolts, each equivalent to | 1 |

Water-tight door (side with hinges):—Multiply length over stiffening ring on bulkhead, by width over stiffening ring, then multiply by two. This gives allowance for everything, except hinges and grab rod, and includes scaling the stiffening ring.
Grab rod.................................1 unit

Stanchions, davits, pipe, all rounds:

Multiply the diameter in inches by the length in feet. The result is the equivalent number of plain side feet.

## SH Shearing

1. Plates 3/8 in. thick and under, and toes of angles, per ft...................$ .009
2. Plates over 3/8 in. thick.............. .011
3. Taking all shearing as it comes....... .010

Equivalent: Cutting off shapes, one cut equals 1 ft.

## TL Tiling

Laying tiling only in unobstructed space, per sq. ft. ................................$ .12
Laying tiling and cement in unobstructed space, per sq. ft........................ .15

Allowances for obstructions:

One sq. ft. for each lineal ft. or fraction thereof of periphery of obstruction.

## WC Wood Calking

(Not including paying seams with glue or puttying same. Oakum will be furnished to calkers, already spun.)

| KIND OF WORK | No. of threads | No. of horsing | Cents per ft. | Daily task ft. |
|---|---|---|---|---|
| 1. New work—bottom and sides................ | 4 | 2 | .02 | 200 |
| 2. New work—bottom and sides................ | 3 | 1 | .015 | 267 |
| 3. New work, deck......... | 4 | 2 | .015 | 267 |
| 4. New work, deck......... | 3 | 2 | .014 | 286 |
| 5. New work, deck......... | 2 | 1 | .0135 | 295 |
| 6. New work, deck, 2 threads horse down and fill up with 1 thread left ⅛ inch below deck........ | 3 | 1 | .0125 | 320 |
| 7. Old work—Reeve out. putty, horse down and calk 1 thread.......... | 1 | 1 | .011 | 364 |
| 8. Old work—Reeve out, glue, horse down and calk 1 thread throughout.................. | 1 | 1 | .0133 | 301 |
| 9. Old work—deck; reeve out, horse down, calk 2 threads............... | 2 | 1 | .015 | 267 |
| 10. New work—deck; three threads, one horsing.... | 3 | 1 | .014 | 286 |
| 11. Old work—deck; reeve out, glue, horse down, calk 1 thread only where necessary............. | 1 | 1 | 0125 | 320 |

The above piece-work prices have been used on what is known as "straight work"—that is, where the work was continuous for a considerable period of time. In order to adapt them to "scattered" work, that is, where there is not a large amount of *continuous* work, special allowance has to be made, since the work of *preparation* is as great, or nearly as great, for performing a small number of units as a large number, as we have previously observed. The allowance No. 4 in table that follows covers this feature; these allowances are obtained or estimated from curves prepared from the records and from observation.

## Allowances

over straight work prices not otherwise specified above

No.

1. Overhead work, allow extra....... 50 per cent
2. Beveled shapes and rolled or furnaced plates ................ 50 " "
3. Closed in compartment or corner work ...................... 50 " "
4. For "scattered work"—that is when the number of units of work in one location is less than N in table below, allow extra price per unit as indicated:

Total Price for a small number of units (n) is obtained by adding to the straight work price an extra allowance for "Preparation" (which includes shifting location). This allowance (No. 4) to be equal to P below for 1 unit, and to $(\frac{N-n}{N})$ times P for n units.

This total price for n units divided by the number of units (n) gives the unit price.

| Operation | Class | N | P | Allowance 1, 2, 3 | Unit |
|---|---|---|---|---|---|
| BO............ | | 150 | .12 | 1, 2, 3 | Bolts |
| CA............ | | 50 | .08 | 1 3 | Lin. ft. |
| CM........... | 1 | 10 | .10 | 3 | Cu. yd. |
| | 2 | 80 | .10 | 3 | Sq. ft. |
| CH............ | | 80 | .08 | 1 3 | L. ft. |
| CC............ | | 80 | .08 | 1 3 | Rivets |
| CK............ | 1, 2 | 500 | .08 | 1 3 | Holes |
| | 3 | 250 | .08 | 1 3 | Holes |
| CT............ | | 16 | .08 | 1 | L. ft. |
| CF............ | 1, 2 | 25 | .10 | 1, 2, 3 | Cuts |
| | 3 | 8 | .12 | 1, 2, 3 | Cuts |
| Co............ | | 70 | .08 | 1 3 | Rivets |
| CX............ | | 16 | .20 | 2 | L. ft. |

| Operation | Class | N | P | Allowance 1, | 2, | 3, | Unit |
|---|---|---|---|---|---|---|---|
| DR............ | | 100 | .08 | 1 | | 3 | Holes |
| DT............ | | 30 | .08 | 1 | | 3 | Holes |
| TP............ | | 50 | .08 | 1 | | 3 | Holes |
| LO............ | 1, 2, 3 | 200 | .10 | 1, | 2, | 3 | Sq. or L. ft. |
| PT............ | 1, 2, 7 | 600 | .06 | | a | See Remarks | Sq. ft. |
| (1)............ | 3, 4, 5 | 1,200 | .06 | | a | | Sq. ft. |
| | 6 | 120 | .04 | | a | | Sq. ft. |
| PT............ | 1, 2, 4 | 1,500 | .06 | | a | | Sq. ft. |
| (2)............ | 3 | 800 | .06 | | a | | Sq. ft. |
| | 5, 6, 7 | 1,000 | .80 | | a | | Sq. ft. |
| PL............ | | 120 | .05 | | a | | Lin. ft. |
| PU............ | | 1,000 | .08 | | | | Holes |
| RM............ | | 500 | .08 | 1 | | 3 | Holes |
| RV............ | | 70 | .16 to .52 | | a | | Rivets |
| SC............ | 1 | 80 | .04 | | a | | Sq. ft. |
| | 2, 3 | 150 | .04 | | a | | Sq. ft. |
| SH............ | | 200 | .08 | | - | | L. ft. |
| TL............ | | 200 | .20 | | a | | Sq. ft. |
| WC............ | | 200 | .10 | | a | | Lin. ft. |

**REMARKS:** (a) Covered in prices above by the Classifications and Equivalents, and no other allowances 1, 2, or 3 to be given.

Operation includes ALL classes unless noted otherwise in class column.

The only other allowances for special or unusual conditions is for work at a remote distance from previous job.

For travel in excess of 300 yds. allow 2 mins. day pay per 100 yds. extra.

## Unstandardized Work

The foregoing piece rates cover most of the operations involved in the shipfitter trade, as well as some operations by painters, riggers, common laborers, and wood calkers. Only a few other trades will be discussed.

ANGLESMITH WORK. The piece-work schedules for anglesmith work are frequently very extensive and in considerable detail, but no satisfactory method of classifying all such work in a simple manner, similarly to riveting, has been worked out, as far as the writer is aware. Prices depend upon the size and shape of the units worked on, the number of units assigned at one time, the number of bends and corners, and character of operation. Typical sketches should be prepared for each separate or distinct group or class of object, and each group further classified as to: (1) Cross-sectional area or pounds per running foot. (2) Square or beveled shape; straight or curved. (3) Length in feet (for bending, beveling or cold pressing). The weight or bulk of the unit may also affect the cost of handling.

Where there is a large amount of work of the same general type, an average price can sometimes be set for the whole job; for example, for beveling and bending all the main and reverse frames of a battleship,—3 cents per lineal foot is a sample price. For bending and welding rings 24″ diameter and under, \$0.75 for $1\frac{1}{2}''$ flange to \$2.75 each for $4''$ flange. All piece rates should be based on thorough observations and study, and not set by guesswork.

Examples of piece rates for bending and welding are shown on page 49. "S" equals size of flange on which bending and welding is done, in inches.

FORGE WORK. The separation of all forge work in a repair shop into elementary operations, and attempting to standardize them, is a big task; and for purposes of ordinary estimating, this hardly seems necessary at present. The simplest element to base estimates upon seems to be weight; grouping or classifying all the forge work into a few simple classes, similar to good foundry practice. This classification cannot be made all at once, but must result from a study of actual records of unit costs,—such unit costs to show the object in detail, the weight, and the number of pieces. In order to obtain such records properly and completely, a good planning system and a good cost keeping system are, of course, essential. This remark applies equally well to the obtaining of any valuable estimating data whatsoever, and is so evident to any student of the subject that it seems unnecessary to state it, except for the unfortunate fact that a great many executives or managers demand and expect from their subordinates accurate estimates for both new and repair work for which the plant has never furnished any reliable estimating data because of this very lack of an adequate planning system and a good cost-keeping system.

SHOPS IN GENERAL. In this connection, the general principles governing the separation of ship-yard operations into logical and practical classes are ably discussed by Naval Constructor G. C. Westervelt, U. S. N., in the U. S. Naval Institute Proceedings, No. 148, of December, 1913, in an article dealing more particularly with the bearing which detail planning and the classifying of operations into "schedules" has upon the cost of production. The present discussion only attempts to cover briefly the best means of obtaining good estimating data for ordinary purposes. Mr. Westervelt's observations, however, apply with force to both phases of the subject. He says:—

In order that the use of these schedules might be of practical value, they should be in terms of operations readily understood. . . . They should be designed with the ease of recording directly in mind;

## JOGGLES

| S Inches | Single Sq. | Single Bev. | Double Sq. | Double Bev. |
|---|---|---|---|---|
| 1½ | .03 | .04 | .10 | .12 |
| 2 | .05 | .06 | .12 | .15 |
| 2½ | .06 | .07 | .15 | .18 |
| 3 | .07 | .08 | .18 | .20 |
| 3½ | .08 | .09 | .20 | .22 |
| 4 | .09 | .10 | .22 | .24 |
| 4½ | .10 | .11 | .24 | .26 |
| 5 | .11 | .12 | .26 | .29 |
| 6 | .12 | .14 | .29 | .32 |
| 8 | .18 | .22 | .36 | .40 |

## CORNERS

| S Inches | Inside Sq. | Inside Bev. | Outside Sq. | Outside Bev. | Joggled Sq. | Joggled Bev. |
|---|---|---|---|---|---|---|
| 1½ | .16 | .20 | .20 | .25 | .20 | .25 |
| 2 | .18 | .23 | .25 | .30 | .23 | .28 |
| 2½ | .22 | .30 | .30 | .35 | .35 | .42 |
| 3 | .33 | .40 | .38 | .42 | .45 | .56 |
| 3½ | .45 | .50 | .55 | .60 | .55 | .60 |
| 4 | .65 | .70 | .70 | .75 | .75 | .80 |
| 4½ | .80 | .90 | .90 | .95 | .90 | .95 |
| 5 | .90 | 1.05 | .95 | 1.10 | .95 | 1.10 |
| 6 | 1.00 | 1.25 | 1.15 | 1.30 | 1.15 | 1.30 |
| 8 | 1.50 | 1.75 | 1.60 | 1.80 | 1.80 | 2.00 |
| 6x6 and 7x7x⅝ and ¾ thick | 1.50 | 1.70 | 1.80 | 2.00 | 2.10 | 2.20 |

Angle rings, when welded only: one-third of list prices will be paid. These prices are for welding on the small or narrow flange, if welded on the wide flange, take next higher price.

and this, more than anything else, would force a departure from a strictly theoretical schedule to a schedule which, while still theoretical, would be practical. . . . The following bases for schedules give good practical results:—Shipfitter shop and sheet metal shop, in terms of elementary operations of trade; sail loft, in terms of feet of stitching and number of eyelets, or of elementary operations; joiner shop, in terms of elementary operations of trade, or of related groups; ship smith shop, in terms of weight; paint shop, in terms of square feet, of elementary operations and of weight.

PIPING WORK. The same general remarks apply to piping work as to furnace work, regarding the lack of a simple method of standardization. There are so many different kinds of piping and fittings, used for such a variety of purposes, that it would seem to be impossible to tabulate or plot cost data for such work in a satisfactory manner. Using the same general principles of classification, however, as outlined for other branches of ship work, considerable useful estimating data can be collected in convenient form. Piping work can be grouped into (1) Purpose or object of piping, which also means "kind" in most cases,—for example (a) Water systems, (b) Voice piping, (c) Air piping, (d) Conduit. These can be further subdivided into physical characteristics. Then comes the classifying of a job in any group into (1) Size and weight of pipe, (2) Length, (3) Number of joints, (4) Number and character of fittings, (5) Location of work,—that is, accessibility, (6) Description of operation,—as Disconnect, Remove, Lead-line, Bend, Assemble, Solder, Make joint, etc.

Instead of trying to keep a separate card record for each particular operation, all carefully indexed, especially in the case of piping repair work, it will be better at first to go more slowly and be sure that the data collected is worth while, and that it can be plotted to advantage by logical and simple operations. Here, as in most repair work, the number of units of work performed must be considered, as a large part of cost of piping work consists in "getting started." The collection of estimating data for work done in the field or on shipboard will be much more difficult to get than for shop-work. Planning such work in detail, with the operations set down in logical sequence and scheduled, and with care taken to specify the number of units, will be indispensable toward getting any estimating data of value,—and incidentally will lead toward increased efficiency of production.

Plumbing work estimates are fully as difficult to make as estimates for piping work proper, and the same general process can be followed in collecting data. Until it is practicable to standardize such work in a measure, it will be found useful as a preliminary guide and in making rough estimates to estimate direct labor as bearing a certain ratio to cost of material for different classes of work. These classes would distinguish between jobs involving removal of old work and those of installing new work.

It is no easy task to determine the best practical bases for classifying cost data for miscellaneous work, where each job or even each operation is different from any previous job or operation; and yet, until some simple and useful classification is used, and cost records properly "digested" and analyzed they will be of very little use to the estimator in estimating on future work.

It has been seen that in either repetition manufacturing work, or in new construction work, we can sometimes classify costs by the total costs of *objects* or parts, specified by the technical name of the object, article or part. We can also go further and classify costs by operations,—independently of the *names* of articles or parts, except so far as needed to define the conditions or character of the operations as regards (1) *Accessibility* of the work, (2) *Difficulty* or complexity of the work, compared to some simple basic or *standard* degree of complexity, defined by an example, (3) *Continuity* of the units comprising the operation, as determined by the number of units (whatever the unit of measure chosen) which can be performed one after the other without stopping or shifting position of men or equipment.

We can go still further, and subdivide or analyze each of these three main groups of condition factors into its elements, somewhat as Mr. Gilbreth describes in his "Motion Study,"—a book that each estimator should read diligently. The extent to which it will be profitable to analyze operations will depend somewhat upon the use to which we wish to put our data, and upon the expense involved in making the analyses. For operations which seldom recur, even in general form or character, to say nothing of those which never recur in identical form, extreme refinement will seldom pay.

In repair and jobbing operations, the best way I have ever found to decide how far to go in the classification or analysis, is by *plotting* costs on cross-section paper, as above mentioned. This matter will be further taken up later on. The costs can then be analyzed or separated into a few *classes,* with a smooth curve to represent each class. A simple way to look at a class number is to consider it the sum of the three *condition factors* mentioned; and to have only three or four grades or factors for each condition. For example, 0, 1, 2, and 3 for each of the three conditions; the lowest cost class (0) would mean Accessibility 0, Complexity 0, and Continuity 0. Then we get any combination up to Class No. 9,—which means the factor 3 for each condition.

We have already applied this method to classifying "riveting" on pages 38, 39; it has been done for castings, forgings, and other work where the unit of measure is the *pound;* for templating, painting, and other operations where the unit is the *square foot;* and can be applied to practically all operations, with a little study and ingenuity.

## SYMBOLIZING LABOR OPERATIONS

IF an operation is to be performed by day work, the relative efficiency of the day workers and of piece-workers must be taken into account in estimating. The cost of day work will average between 25 per cent and 50 per cent greater than piece-work cost under the ordinary form of management. The actual figures for estimating this percentage, however, must be obtained from the detail cost records, as they will vary with each plant, and with each class of operation. The individual records of the efficiency of each workman, on both piece-work and day work (which should in time be furnished by an efficient planning and cost keeping system), will give this data for any particular job. It would, of course, be desirable to have every operation performed by piece-work or by some other profit-sharing system, provided the prices were properly fixed by the most thorough observations practicable, or possible from an economic standpoint. This would also make estimating simple and easy. This condition, however, cannot be realized in a short time on complicated repair work, and it may be many years before even the major part of miscellaneous operations "in the field" can be standardized. Furthermore, men are averse to doing a small number of units of work, or scattered work, by the piece or "operation" unless thoroughly convinced that they can make good money by it, and that they can be assured of continuous employment.

It is with this feature of the "Art of Estimating" and collecting estimating data that the "Art of Management" is so intimately connected and concerned. The estimator has to look to the good manager, with progressive but fairminded ideas, and of broad experience, for the methods, means and assistance required to collect all the valuable data needed for estimating and planning work properly.

Since the "outside" work (as distinguished from "shopwork") in a ship repair plant is probably the most difficult of all work to estimate on, due to lack of standardization, and as it comprises more than half of all ship repair work, an attempt will be made to indicate briefly to what degree it seems practicable within a few years to standardize the most difficult of all classes of work, and to see what beneficial results are likely if not certain to follow every intelligent effort in this direction. In the matter of planning work and of providing equipment, materials and clear instructions for the workmen, experience seems to show that the greater the difficulty of so doing the greater the need.

Planning of work by operations or consecutive steps may be of a very general nature, simply designating "*what* is to be done" by each workman or group of workmen, in logical sequence; or it may be of a very scientific nature, by still further subdividing each step or element performed by one man or group into its distinct components or elementary operations, and not only state *what* is to be done but also exactly *how* to be done; these elementary operations may be the subject of accurate and extensive time-studies and motion-studies. No discussion will be entered into of the merits of either method, as we are at present concerned merely with the obtaining of the best estimating data our present methods of performing work and collecting cost data will furnish us. What we desire to find out, as far as the estimating of costs is concerned, is what will be the probable actual cost of the job before us, for which we have definite specifications.

We will confine our proposed classification of operations or elements for the present to the Hull work of a ship (as distinguished from Machinery), and to the present classification of hull trades. The term "operation" in the proposed classification will be used broadly to indicate a definite act, such as Measure, Remove, Cut,—and the object of this act or operation will be designated by the kind of material worked upon, and also by the kind or class of product or finished object which results when all the successive operations are finished.

These steps or operations are of such a nature that with proper preparation and routing each one can be performed without an interruption, that is "at one sitting." If all the work of a trade upon a job is grouped together, in planning, regardless of *natural* interruptions, allowances will have to be made, in estimating costs, for these interruptions.

We will designate each element or step in a production order or job by a four-letter symbol, which will indicate (1) The trade performing the operation, (2) The operation or action performed, (3) The kind of material operated upon, (4) The class of finished object or product. It will be noted that the class of product is a generic class and does not correspond necessarily with the usual or accepted names of the parts of a ship, but each class may comprise several kinds of parts or objects in a ship. The classes chosen, combined with the kind of material, are so chosen for their simplicity and convenience in collecting unit costs by objects or products.

I am indebted to Naval Constructor J. E. Otterson, U. S. N., for reducing this proposed classification for shipwork to the simple form given on pages 62 and 63.

Shop-work symbols for machine operations are not given, as they are much easier to classify, and present no special difficulties.

In planning work, each step may be indicated by the four-letter symbol therefor, and may be supplemented by figures for the number of units, and for conditions which differ from an assumed standard.

For example:

| | |
|---|---|
| F T P B | indicates: Shipfitter to make template for plates for a bulkhead. |
| F T P B<br>5.84 4 108 3 | indicates: Shipfitter and helper (day pay $5.84) to lay out 108 square feet of plates for bulkhead: Templating (a small number of units, allowance No. 4 in table to be given)—Bulkhead (a confined space,—allowance No. 3 to be given). For operations which have been standardized and made the subject of piece rates, or even sufficiently standardized for ordinary estimating purposes, the estimated time and cost should be entered. By reference to piece-work prices, page 34, it will be seen that the total piece-work price for the operation is (.01 x 108 x 1.5) + .16 equals $1.78. Time allowance equals 2.2 hours. |

The time allowance is such that if the task or operation is just completed in the time allowed, a bonus of 10 per cent over days' wages rate is earned and paid. (See Piecework Schedule, "General Notes.")

The total number of practical combinations of these symbols—that is, the number of separate generic operations which may occur in hull ship work, outside of the shops—is about 2,200. For purposes of estimating costs, the 2,200 operations can be segregated into a much smaller number of groups, and thereby about three-fourths of all the costs of ship work can be plotted clearly and profitably on 50 sheets of cross-section paper.

These symbols and other methods of symbolizing trades and operations referred to later, are given merely as suggestions, and can no doubt be improved upon by the reader for his own purposes. The symbols actually used in planning the repair job shown on pages 75 to 82 inclusive have been found convenient for planning purposes, and are easily understood by supervisors and workmen.

The classification of operations which is given on pages 64, 65 is from "The Cost of Manufactures" by Captain Henry Metcalfe, Ordnance Dept., U. S. A. (Retired).

## Symbols for Shipwork

| Symbol | Trades | Symbol | Operations |
|---|---|---|---|
| A | Acetylene Welder | A | Accounting, Measuring |
| B | | B | Bolting, Screwing |
| C | Chipper, Calker | C | Chipping, Cutting out, Reeving out |
| D | Driller | D | Drilling |
| E | Sheet Metal Worker | E | Erecting, Assembling |
| F | Shipfitter | F | Fitting |
| G | | G | Reaming, Countersinking |
| H | | H | Hauling, Carrying, Handling |
| I | | I | |
| J | Joiner | J | Making Joints, Gasketing, Wiping |
| K | | K | Calking |
| L | Laborer | L | Laying out |
| M | | M | Cementing |
| N | Painter | N | Painting |
| O | | O | |
| P | Plumber | P | Tapping |
| Q | | Q | Soldering, Welding |
| R | Rigger | R | Rigging |
| S | Shipwright | S | Scaling |
| T | Tile layer | T | Templating |
| U | | U | Undoing, Disconnecting, Taking down |
| V | Riveter | V | Riveting, Hardening down |
| W | Wood calker | W | Wire brushing, Sand papering, Polishing |
| X | | X | |
| Y | | Y | |
| Z | | Z | Testing |

| Symbol | Materials | Symbol | Products |
|---|---|---|---|
| A | Armor | A | Ammunition and Ash Hoists, Coal trunks |
| B | Brick | B | Bulkheads |
| C | Coal, Dirt, Refuse, Weights | C | Covers, Manhole, Gunports, Doors, Hatch, Air port, Scuttle |
| D | Lead | D | Decking (wood or metal), all kinds of flat horizontal surfaces |
| E | Equipment, as lines, shrouds, etc. | E | Eye bolts, Pads, Deck bolts, Hooks, Brackets, Chocks |
| F | Forging, Castings (Brackets, fittings—followed by weight) | F | Frames, Longitudinals, Beams, Stem and Stern castings |
| G | Lagging (felt, wool, asbestos) | G | Galley ranges, ovens |
| H | | H | Hull (shell) |
| I | | I | |
| J | Piping (followed by kind and diameter) | J | Inner bottom |
| K | | K | Lockers, Shelves, Racks. Furniture |
| L | Linoleum, Cork, Sheet rubber tiling | L | Ladders |
| M | Cement, Tiling | M | Masts, Spars |
| N | Paint | N | |
| O | | O | |
| P | Plates (followed by weight) | P | Supports, Foundations, Stanchions, Davits |
| Q | | Q | |
| R | Rubber | R | Rails |
| S | Shapes: Ls, Ts, Channels, Half-rounds | S | Sheathing, Casing |
| T | Tubing: Slip joint, Voice, Mast | T | Tanks |
| U | | U | Turrets |
| V | Rivets, Bolts | V | Ventilation system |
| W | Wood | W | Water service |
| X | | X | |
| Y | | Y | |
| Z | Zinc | Z | |

## Captain Metcalfe's Analysis of Operations

### Class 1

#### Operations Causing Changes in Condition

| | | |
|---|---|---|
| Heating | Blacking in oil | Painting |
| Drying | Browning | Varnishing |
| Annealing | Plating | Whitewashing |
| Tempering | Polishing | Stamping |
| Case-hardening | Burnishing | Printing |
| Pickling | Oiling | Stenciling |
| Cleaning | Puttying or filling | Etching |
| Washing | | |

#### Changes of Situation

| | | |
|---|---|---|
| Moving by hand | Moving by team | Moving by power |

### Class 2

#### Operations Causing Changes in Shape

| | | |
|---|---|---|
| Straightening | Indenting | Blocking into shape |
| Bending | Winding | Mandreling |
| Forming | Twisting | Spinning |
| Folding | | |

### Class 3

#### Operations Causing Changes in Form by Plastic Means

| | | |
|---|---|---|
| Moulding | Rolling | Swaging or pressing |
| Casting | Forging | Drawing (like wire) |

### Class 4

#### Operations Causing Changes in Form by Cutting

*1 Shearing*

| | |
|---|---|
| Shearing proper | Punching, outside, including trimming |
| Punching, inside, including trimming | Combined punching and cupping (double action press) |

### Class 5

*2 Paring Tools Producing Surfaces of Revolution*

| | | |
|---|---|---|
| Turning | Boring | Reaming |
| Clamp milling | Drilling | Thread-cutting, female |
| Screw milling | Counterboring | Burring |
| Thread cutting, male | Countersinking | |

### Class 6

*3 Paring Tools Producing Ruled Surfaces*

| | | |
|---|---|---|
| Planing | Broaching | Milling, straight or curved lines |
| Slotting | Sawing | Profiling |

### Class 7

OPERATIONS CAUSING CHANGES IN FORM BY SCRAPING TOOLS

| | | |
|---|---|---|
| Scraping | Filing rotary | Grinding |
| Filing by hand | Tumbling | Lapping |

### Class 8

OPERATIONS CAUSING CHANGES IN OBJECTS BY UNITING THEM

| | | |
|---|---|---|
| Welding | Nailing | Mixing |
| Melting together | Screwing | Assembling (includes loading) |
| Brazing | Riveting | Packing |
| Soldering | Basting | Assorting and other operations expressing dis-union |
| Gluing | Sewing | |

### Class 9

MISCELLANEOUS OPERATIONS

| | | |
|---|---|---|
| Superintending | Weighing | Miscellaneous hand work |
| Designing | Gauging | Miscellaneous Machine work |
| Recording (clerks) | Inspecting | |
| Fitting or finishing | Miscellaneous work | |

## NEEDS FOR GOOD ESTIMATES

GOOD estimates of production costs are needed by the superintendent or manager in order that they may fix the selling cost of the product properly, or know what the profit will be if the selling price is practically fixed by competition or by the state of the market. Good estimates are made by accurate comparison with the previous costs, allowing for any special changes in equipment or methods, and hence a good estimate becomes a standard with which to compare the actual cost when the production is completed, and thus show any increase or decrease in efficiency of the plant in respect to the particular product. If the estimate is made by operations, the change in efficiency of operations can be localized and investigated. It is of no benefit to know that inefficiency exists unless it can be localized, investigated and possibly remedied.

Good estimates of labor costs are needed both by the management and the workman, in order to mark the efficiency of each workman justly. When there is no systematic way of keeping records of individual efficiencies, there is sometimes a temptation for supervisors to show favoritism; and in any event, no one can judge of men's efficiencies correctly without detail records.

Good estimates of labor costs, or of what constitutes a fair task for a good workman, are essential for the establishment and successful working of any piece-work or profit-sharing system of pay. Practically all the troubles which have arisen and will arise in the usual form of piece-work systems can be traced to poor estimates of what constitutes a fair task for a given time, resulting in piece rates being reduced later on, when the error in the original estimates is discovered.

The best system of determining what overhead costs are, and the method of distributing them to various production orders, are based upon estimates.

So we see that all records of efficiency, rating of workmen, and the question of wages and profit are all dependent upon *estimated standards.*

In a plant where no attention is paid to standards or to good estimating, how often we hear a workman reprimanded for not doing more work, when the supervisor or manager who complains has no real, definite, idea whether the workman is doing a fair day's work or not. Frequently these complaints occur at a time when the workman is taking a short "rest"—a legitimate and proper rest from exacting and strenuous physical exertion, such as forge work, riveting, or heavy lifting; the workman is reported for "loafing," whereas the actual record of "output" for the full day's work if compared to a standard for a good day's work, would show a high efficiency of the workman. On the other hand, low efficiency can be readily detected from observing the efficiency records day by day, the causes can be properly and consistently investigated, full justice obtained, and the causes eliminated in whole or in part.

Knowledge and facts thus replace guesswork and bluff, a sense of fairness and the square deal prevails, and both the employer and employee benefit by the increased efficiency and personal reward for merit. When a workman is assigned a job, and the material, tools and specifications are all provided for him beforehand, how much better it is to know when he starts how long it ought to take to complete, with a fair degree of accuracy; and if the workman does the job in less than the estimated time, to reward him suitably, not only for his application and skill, but also for his co-operation in doing the work the best way?

In fixing or estimating what reward the workman is entitled to for performing a task in less time than he would *without* this reward or incentive (and it is only human nature to accomplish more with the hope of reward), the management naturally figures how much it can *afford* to pay extra to the workman as his share of the profits for his increased efficiency, and at the same time share the profits due to the extra efforts and expenses of the management. In figuring these rewards or profits, due to increased output, the gain to the management in the time saved is frequently overlooked or underestimated. Time saved is money saved, both directly and indirectly. The overhead expense or incidental charges incident to any operation,—and particularly a machine operation,—is about the same each hour; not exactly the same, but it varies more directly with the time than it does with any other single element. Hence a saving in hours of labor is a corresponding saving in dollars to the management. This matter will be more fully discussed under the subject of "Estimating Overhead Expense."

There are several well-known methods in use of estimating this very important item of reward or profit; and of giving to the employee an equitable share. The very variable human factor enters so much into this very human and practical problem that it is not capable of exact solution. A good or satisfactory solution in one factory, under a certain form of management and with certain local conditions, would be a failure in another factory.

## PLANNING AND ESTIMATING BY OPERATIONS

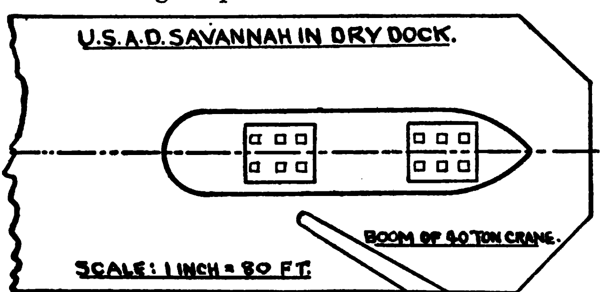
A LARGE ship repair job will be used to illustrate fully the simplest form of analysis of repair work which it is possible to make, and provide at the same time that the elements or units be of such a nature that they can be scheduled and estimated for from recorded data; and (it may be boldly asserted) any estimate which is not made by comparison, mental or written, with *recorded* data, is unreliable. The *shop work* has not been separated into its elements, for the reason that the shops are distant and too widely separated to plan and route work from the central office. Each shop organization plans the sequence of operations on its shop work and assigns work to machines, so as to meet the desired date of completion of the shop orders. Shop work is naturally much easier to schedule or estimate on, as a rule, than work outside the shops, for the latter is so much more difficult to standardize—either as to

(1) Accessibility, (2) Complexity, or (3) Continuity of units—which terms we have chosen as our terms for "variable conditions."

The job whose "Plan of Work" is given was taken at random from thirty miscellaneous repair jobs on the U. S. Army Dredge "Savannah," upon which all the work was done day work, and all estimates came about as closely to costs as this job. In fact, the same may be said of practically all estimates made by the methods outlined above. The job as planned is recorded *verbatim,* with its imperfections, and no attempt made to claim that repair jobs can be as scientifically planned or estimated upon as new work, except at great expense. It would probably not pay to plan ordinary repair work or construction work in such detail as repetition manufacturing work can be profitably planned. In fact, many will claim that it does not pay to plan repair jobs even in as much detail as here illustrated, but this contention can hardly be made by any one who has given it either rigorous thought or a fair trial. Without at least this kind of simple planning by trades and "steps," the scheduling by dates for trades or operations is impossible, unnecessary delays and interruptions are unavoidable, and any attempt at *accurate* estimating is wholly futile. Note that, with small exception (due to lack of proper recorded data, at the time, on forge work), nearly every operation or step was estimated for fairly accurately, and that the job was begun and completed on the scheduled dates. This can be done for each and every job, if each job is properly planned and scheduled.

The nature of the "Savannah" job could not be determined until the vessel went into dry dock, when the inspector in charge of the vessel went over the work with the planner. The work was under the bottom of the ship, somewhat inaccessible, and several trades were working simultaneously, so that to the layman it looked like a job *impossible* to estimate upon. Piece work was not permitted, owing to the contract being for actual cost, at so much per hour for each man of each trade. The job could have been done by piece work considerably cheaper. Even as it was, the inspector was highly pleased both with the low cost and the good workmanship, on this and all the other jobs—a total cost of about $20,000. In fact, this work led to additional contracts for $47,000 worth of new work. From the verbal instructions of the inspector, the following specifications were issued, and the labor planned for as shown on Plan of Work sheets (pages 75 to 82) which were based on the following:

SPECIFICATIONS: Repair 12 bins and gates. Inspection of vessel in dock shows following necessary work:—Renew: 12 angle box frames (4 ft. sq.); 24 hinges and pins (forgings); 8 strongbacks each 20 ft. long; 5 new bands for strongbacks; 2 face plates in gate openings. Strengthen: 24 male sections of hinges by welding in metal and re-drilling for pins.




As frequently happens on difficult repair work, the exact procedure and every step to be taken could not be foreseen at the beginning, but had to be settled as the work progressed. These unforeseen items or changes in program cause no more confusion or unnecessary delay on account of planning, and instead of being an argument against planning, they are really an argument for it, because the resultant effect on the cost and time of the whole job can be seen at a glance if it has all been scheduled out; and new

FORM D

## PLAN OF WORK.

Date 1-26-14.
Planner [illegible]

J.O. 501-54-1. SHIP U.S. Army Dredge SAVANNAH. SHEET No. 1

ITEM Repair bins and gates.

Begin: 1-26-14.
Complete: 3-12-14.

Began 1-26-14
Completed 3-12-14

| | Auxiliary Job Orders | Mk. | No. | Hrs. | Pcs. | Planned Dates Jan. \| Feb. | Estimated Cost | Actual Cost |
|---|---|---|---|---|---|---|---|---|
| 1 | Remove 12 bin gates. (Est. wt. 12,000 lbs., Distance 50 yds. | lb | 4 | 4 | | | 5.00 | 5.80 |
| 2 | Cut 48, 1-1/4" pins from bin gates & cut out 1532, 7/8" rivets in bottom angles as marked by Outside Supt. | cc | 4 | 58 | | | 100.00 | 104.55 |
| 2-A ✱ | Drill out 7/8" rivets that cannot be backed out. (Est. No. 108 holes, 4" deep; No. localities, 12) | dr<br>h | 1<br>1 | 48 | | | 25.00 | 24.42 |
| 3 | Mark and center punch rivets to be cut from strongbacks in bins over gates. In ford. bin stbd. #1, #2, #3, & port #2 and in after bin stbd. #4, port #4, #5, & #6 to be renewed. Remove U straps on the following strongbacks to forge shop: ford. bin stbd. side #1 & #3, after bin stbd. side #1, #3, #4, & #6; port side #4. | sf<br>h | 1<br>1 | 8 | | | 6.00 | 6.00 |
| 4 | SHOP WORK: Forge U bands. Sample to be furnished to G by shipfitter. (Est. wt. 225 lbs.) | G | | 8 | | | 8.00 | 7.04 |
| 5 | SHOP WORK: Lay out holes in five new U bands for gate gear, punch holes. (Est. No. 20 holes). | T | | 4 | | | 1.00 | 1.00 |
| 6 | Remove 8 strongbacks from bins as cut away. (Est. wt. 2720 lbs; Distance 50 yds.) | rg<br>lb | 1<br>2 | 2 | | | 2.00 | 1.51 |
| 7 | SHOP WORK: Cut 160 ft. of 1/2" thick from bulb angle, bend 8 bulb angles using old strongback for sample; lay out, punch, shear, & ck. | X | | 24 | | | 35.00 | 35.50 |

dates of completion can be set at once, with intelligence and confidence.

The first item of this kind was:

Aux. 2A.—In cutting out rivets, it was found that a number could not be backed out. Auxiliary Job Order No. 2A (operation number) was therefore issued to drill out rivets, for which unforeseen work an additional estimate of $25 was submitted, and approved by the inspector.

Sheet No. 2

| | Auxiliary Job Orders | | | | | Planned dates Feb. March | | |
|---|---|---|---|---|---|---|---|---|
| 8 | Put 8 strongbacks for bins in place as directed by shipfitter, also put angles for bins in place. (lbs. 6,226) Crane used. | rg lb | 1 2 | 2 | | | 2.00 | 1.52 |
| 9 | Bolt strongbacks for bins in place ready for riveting, re-fastening bands and 5 new U bands. (116, 7/8" bolts). | sf h | 2 2 | 8 | | | 12.00 | 12.16 |
| 10 | Lift templates for renewing angles at bot. of bins. (No.lin.ft.216). | sf h | 2 2 | 40 | | | 50.00 | 56.88 |
| 11 | SHOP WORK: Bend 5" x 5" x 16.2# angles for bot. of bins, lay out angles, punch, shear, & ck. (No.bends 48, No.lin.ft.layed off 216, No.welds 50, punch 1524 holes ck. 1524 holes, shear 12 cuts). | X | | 72 | | | 200.00 | 198.71 |
| 12 | Bolt 12 box angle frames in place ready for riveting around bot. of bin gates. (508, 7/8" bolts). | sf h | 2 2 | 24 | | | 36.00 | 35.10 |
| 12-A * | Renew face plate on one side of bin gate, one in ford. & one in after gateway. (wt. 900 lbs). | | | | | | 86.00 | 81.32 |
| a | Cut out 216, 7/8" rivets. | cc | 2 | 16 | | | | |
| b | Make template for 36 sq.ft. face plate. | sf h | 1 1 | 2 | | | | |
| c | SHOP WORK: Lay off 36 sq.ft. 25# face plate, punch 36, 7/8" holes, shear 36 lin.ft. 5/8" med. steel plate. | X | | 16 | | | | |

Other unforeseen items arose later, as explained in the notes, but all were promptly attended to, and the work was prosecuted without any delays.

For explanation of symbols, see page 81.

NOTE.—Aux. 12-A. After removing angles, it was found that face plates around 2 bins were entirely eaten away; Aux. No. 12-A was then issued by outside superintendent, to cover all work of renewing. (Est. $80.00 to cover this extra work.)

As to the "extra" cost of this method of estimating, by operations, there is no real extra cost. The material has to be ordered by some one anyway, the steps to take and the *sequence* of operations have to be determined by some one, and the proper date of completion should be determined by some one. It happens that in planning and estimating work in this way, the man who assists so materially in these things is the man with the recorded data, which enables him to do it right; and incidentally he relieves foremen, leading men and workmen of unnecessary clerical work, annoyances and interruptions in their own important and legitimate work. There is always a total net saving in every job properly planned and scheduled.

From our previous discussion, and from the more specific remarks later upon the "Preparation and use of curves" in estimat-

**Sheet No. 5.**

Planned dates.
Feb. March.

| | AUXILIARY JOB ORDERS | Mar | No. | Hrs. | Prec. | Planned dates | | |
|---|---|---|---|---|---|---|---|---|
| d | Bolt 25# face plate in place, 72, 7/8" bolts. | sf<br>h | 1<br>1 | 6 | | | | |
| e | Ream 104, 7/8" holes in 25# plate. | dr<br>h | 1<br>1 | 4 | | | | |
| f | Drive 216, 7/8" rivets in 25# face plate, 2 localities. | rv | 1 | 40 | | | | |
| 13 | Cut out leaky rivets marked to be renewed around angles bot. of bin gates. (Est.No.160, 7/8" rivets; No.of localities 12). | cc | 2 | 16 | | | 10.00 | 10.56 |
| 14 | Drive rivets in strongbacks, angles bot.of bins, & odd rivets cut out in bins. (No.rivets 812; No.of localities 19). | rv | 3 | 24 | | | 10.00 | 11.16 |
| 15 | Calk angles renewed in bins. (Est.No.ft. 440). | cc | 4 | 16 | | | 30.00 | 34.40 |
| 16 | Ream holes in strongbacks and angles at bot. of bin gates. (No. of localities 19; 812, 7/8" holes) | dr | 3 | 24 | | | 40.00 | 37.95 |
| 17 | Remove bin gates to shop 1. (Est.wt. 12,000 lbs; No.yds.travel 12) | lb | 3 | 8 | | | 5.00 | 4.56 |
| 18 | Cut out cement in way of angles of bin gates. (Est.12 cu.yds). | lb | 5 | 24 | | | 25.00 | 14.32 |
| 19 | SHOP WORK: Cut out 144, 1" rivets from pads of hinges & back out rivets. (Piece work price $5.76) | : | | 16 | | | 7.00 | 6.84 |

ing, the method followed in estimating the above labor costs of operations will be understood. Standard curves, representing average performances, are plotted from recorded data like those furnished by the above job; separate curves for various kinds of operations, and a separate curve (usually) for each classification under each general operation. The proper *unit* to choose as the basis for plotting curves requires close study. As there are a great many variables which affect the cost of an operation, we have to select the most important or determining variables for our units. For example, in handling weights, we may select *weight* times *distance* (number pounds times number yards) as the unit (plotted as the abscissa). The number of pieces of material handled is taken care of by the *condition factor* for *continuity,* which is allowed for in the *class* or Classification number. For example, *class* No. 1 would

**Sheet No. 4.** **Planned dates.**

| | Auxiliary Job Orders | Mch. | No. | Hrs. | Pos. | Feb. / March | | |
|---|---|---|---|---|---|---|---|---|
| 20 | SHOP WORK: Forge 48, 1/2 sections of female part of hinges for bin gates, sample furnished by K. (Est.wt. 1152 lbs). | G | | 48 | | | 175.00 | 159.16 |
| 21 | SHOP WORK: Forge 24 bolts for hinges. To be of 1-1/4" diam.med. steel, length under head to be 7-1/4". To be finish forged & not machined. (Est.wt. 88 lbs). | G | | 16 | | | 10.00 | 11.60 |
| 22 | SHOP WORK: Drill 48, 1-3/8" holes in female sections of hinges for bin gates, also drill 144, 1" holes for securing hinges to gates, thread 24, 1-1/4" bolts to be used for hinge pins, bolt 48 hinge pads in place ready for riveting, 96, 1" bolts, ream 72, 1" holes & drive 144, 1" rivets. | K | | 24 | | | 34.00 | 33.90 |
| 23 | SHOP WORK: Cut 24 pieces of 1-1/4" galv. pipe for fitting in male part of hinge pads in bin gates. (24 and 25 cancelled). | K | | 8 | | | 10.00 | 0.03 |
| 24 | Oxy-acetylene weld 24, 1-1/4" pipe bushings in male part of hinge sections on bin gate. (aux. cancelled. See Aux. 32. Specifs. changed by Inspector). | ok h | 1 1 | 32 | | | 10.00 | 4.56 |
| 25 | Put bin gates in place when repairs are completed. (Est.wt. 12,000 lbs; Distance No.yds. 50). | rg lb | 1 6 | 8 | | | 10.00 | 9.12 |

represent handling *one* weight—all the units in one handling—with the conditions for accessibility and complexity also favorable.

NOTE.—Auxs. 23 and 24. These auxiliaries were experimental, as the male part of cast hinges were badly eaten away and it was thought that pipe bushings oxy-acetylene welded in the hinges would prove satisfactory, but this work was not successful. These two auxiliaries were cancelled and Nos. 32, 33, and 34 issued to cover the work. (Original estimate cancelled and actual cost considered the revised estimate. Result: Decrease in estimate $25.44.)

Sheet No. 8.

| | Auxiliary Job Orders | Mk. | No. | Hrs. | Prec. | Planned dates March 3 5 7 9 | | |
|---|---|---|---|---|---|---|---|---|
| 26 | Fasten 24, 1-1/4" bolts in hinges as gates are shipped, when nuts are screwed up, batter threads with hammer to prevent nuts from coming off. (No. bolts 24). | sf h | 2 2 | 6 | | | 11.00 | 15.40 |
| 27 | Replace cement, removed under aux. #18. (Est. Vol. 12 cu. yds). | lb | 10 | 16 | | | 30.00 | 31.04 |
| 28 | Place tarpaulins over bins on SAVANNAH to protect shipfitters from weather. (Est. wt. 1600 lbs; Est. distance 120 yds). | rg lb | 1 4 | 8 | | | 5.00 | 5.32 |
| 29 | Lower oxy-acetylene plant into dry dock. (Wt. 5000 lbs; Distance 50 yds). | rg lb | 1 6 | 2 | | | 1.00 | 2.40 |
| 30 | SHOP WORK: Mfr. 12 wedges for connecting hoisting rod to bin gate as per sample. (Est. wt. 16 lbs). | G | | 8 | | | 5.00 | 5.18 |
| 31 | SHOP WORK: Drill 12 holes in bin gate wedges as per samples furnished by forge shop. (12, 1-1/2" holes). | K | | 4 | | | 1.00 | .50 |
| 32 | Oxy-acetylene weld 24 holes in male sections of cast hinges in bin gates. (Oxy-acetylene welding pipe bushing as covered by Aux. #24 not successful). | ox h | 1 1 | 80 | | | 50.00 | 48.44 |
| 33 | Drill 24, 1-3/8" holes 2" thick in male section of cast iron hinges in bin gates where oxy-acetylene welded. | dr h | 1 1 | 56 | | | 25.00 | 28.00 |

It will be noticed that in most cases the description of the operation on the Plan of Work is not in itself complete enough to classify an operation absolutely, except to one who is familiar with the work. A little practice by a good estimator, however, will enable him to classify operations quite accurately, by reference to the standard estimates and curves which he has prepared from the actual cost of previous jobs which he has planned.

NOTES.—Aux. 32. It was decided to weld old worn holes solid and redrill. The estimate for this additional work was $50.00, superseding original estimates on Auxs. 23 and 24 (of $30.00).

Aux. 33. To cover cost of drilling holes after being welded, the estimate was increased $25.00.

### KEY TO SYMBOLS USED IN PLAN OF WORK

Single capitals in column Mch. (mechanic) signify SHOP designations. Small letters are symbols for TRADES.

K—Shipfitter shop (shop work)
G—Shipsmith shop (shop work)
sf—Shipfitter (mechanic, handwork, outside of shop)
cc—Chipper and calker (mechanic, pneumatic tool, on ship)
rv—Riveter (mechanic, pneumatic tool, on ship)
ox—Oxyacetylene welder (mechanic, portable equipment, outside)
rg—Rigger (mechanic, handwork, outside)
lb—Laborer (unskilled workman, handwork, outside)
h—Helper (unskilled workman, assists mechanic)
b—Boy (unskilled workman, assists mechanic)

Sheet No. 6.

Planned dates. March.

| | Auxiliary Job Orders | [illegible] | [illegible] | [illegible] | [illegible] | 3 5 12 [illegible] | | |
|---|---|---|---|---|---|---|---|---|
| 34 | Trim edges of male section of hinges of bin gates where oxy-acetylene welded. (24 sq.ft.) | cc | 1 | 8 | | | 4.00 | 3.4 |
| 35 | SHOP WORK: Mfr. 75, 7/8" x 4-1/2" pan head rivets to be used on aux. #14. These rivets were requested but not in store. (Est.wt. 99 lbs) | 3 | | 8 | | | 5.00 | 4.70 |
| | # Note: Estimates for unforeseen work developing during progress of repairs. | | | | | | | |

NOTE.—Aux. 34. To cover cost of trimming rough edges after welding due to unforeseen Aux. 32. (Est. $4.00.)

NOTE.—Aux. 35. Rivets requested on material sheet were not in store, and had to be manufactured. (Est. $5.00.)

## SUMMARY

| | |
|---|---|
| Original estimate totaled................ | $969.00 |
| Additional estimates made, and approved by Inspector, during progress of work... | 163.56 |
| Total of estimates for work actually done.. | 1,132.56 |
| Total cost ...................... | 1,102.28 |
| Difference—Cost below estimate.......... | 30.28 |

Result: Actual cost within 3 per cent. of estimate.

## RECORD OF ACTUAL COST OF ESTIMATING, PLANNING, AND ORDERING MATERIAL

Estimator: W. M. Kennedy, Leadingman Shipfitter.

| Date | | |
|---|---|---|
| 1–25–14. | On ship getting information and notes | (2 hrs.) |
| 1–26–14. | Planning and making out material sheets from notes from ship | (4 hrs.) |

| Date | | |
|---|---|---|
| 1-28-14. | Going over work with Inspector | (1 hr.) |
| 2-20-14. | On ship getting information to estimate aux. 2-A and 12-A | (1½ hrs.) |
| 2-25-14. | On ship getting information to replan aux. Nos. 23 and 24. Most of time spent with Inspector devising some plan of repairing cast male part of hinge | (4 hrs.) |
| 2-28-14. | Certain size rivets not in store, changing material sheet, and issuing aux. | (1 hr.) |
| 2-28-14. | Going over work with Outside Supt. and Master Shipfitter | (2 hrs.) |
| | Total time: 15½ hrs. at $0.50 per hr., | $7.75 |

At the time of the estimating and planning of the above example of repair work, the method used had been in operation only a few months. The mechanic who did the work had been selected about a year previously to inaugurate, and take charge of, the Estimating Section, which was then established along the lines of similar sections at other navy yards. This mechanic had never had any previous experience in estimating, and the records of previous costs had not been kept in such shape as to furnish any reliable estimating data.

All estimating had thitherto been made directly by the foremen, in as careful and conscientious a manner as foremen's estimates by judgment and meagre records are usually made in a jobbing plant; but, as is also usual in such cases, such estimates were at the best only skillful guesses, and no practical use could be made of them. All the valuable time they had spent upon estimating was practically wasted. Such estimates,—made by skillful guessing alone, without comparison with any sort of *standards,*—can never serve the real purposes of estimating. They do not assist the planning and scheduling by dates of the separate operations by trades, so essential to economical performance of work. They do not assist in determining the relative efficiencies of individual workmen, so essential to individual efficiency. They do not assist in locating the causes of inefficiencies, nor in improving conditions. It seems strange that the old methods of guessing at costs, and the false ideas about proper estimating from recorded data costing too much, should still be clung to by some managers. Prof. Hugo Diemer's very able discussion of management forcibly covers this phase of the subject in these words:

In order to determine workmen's efficiency as craftsmen, it is necessary to have some system whereby comparative records are made of time required to do individual operations. Such systems are absolutely essential in order to bring a day-rate system to a state of higher efficiency. When these systems are once installed, it requires but very little additional labor to take care of the payroll and statistics of a gain-sharing system.

The estimating by operations, for the most difficult of all work, has been illustrated. The use of individual cards for operations will enable us to obtain valuable estimating data and records of workmen's efficiency. The practical detailed accomplishment of these matters, by the use of curves, will now be taken up.

## PREPARATION AND USE OF CURVES

CURVES which represent actual costs of operations, and which show the relation between the number of units and cost (and incidentally show the average cost of "getting ready," or preparation), are easily plotted from the records, if a good (or even fair) timekeeping system is in use, which will give either the time in hours (or minutes), or the labor cost, of each operation. If a separate record card, or time card, is used for each operation, these cards can be sorted out by the general operations,—such as templating, punching, riveting, etc.; then still further grouped into *classes* under each operation. The use of symbols on operation cards will facilitate this work. Supposing we have thus segregated a number of records for riveting, for example,—and that each record is specific and in detail as to the character and conditions of work (which determines the *class number*), as to *size* (diameter) of rivets, and gives the *number* driven. The record must show these three things, for any operation whatsoever, to be of any value as estimating data, and if it does show them, the record can be easily plotted.

Suppose the records we have selected out as above are for ¾-inch ship riveting (day work with pneumatic hammers), and that the essential parts of some of the records we want to plot are as follows (See classification in piece-work prices):

| Record No. | Location of work | Class No. | No. units | No. hrs. | Cost |
|---|---|---|---|---|---|
| 1 | Inner bottom | 4 | 275 | 10.6 | $8.88 |
| 2 | Manhole covers.... | 5 | 30 | 2.5 | 2.16 |
| 3 | Bulkhead.......... | 3 | 993 | 27.7 | 23.28 |
| 4 | Shell plate......... | 4 | 74 | 3.6 | 3.00 |
| 5 | Ammn. trunks..... | 6 | 97 | 6.0 | 5.04 |
| 6 | Boat Crane........ | 5 | 45 | 2.9 | 2.40 |
| 7 | Main deck......... | 3 | 120 | 4.7 | 3.96 |
| 8 | Fender guard...... | 5 | 266 | 10.6 | 8.88 |

All these records and all other records for ¾-inch riveting could be plotted on one sheet,—the number of rivets as *abscissæ,* and the number of hours (or cost, if preferred) as *ordinates,* as shown on Fig. 3. By way of illustration, this diagram or plot shows forty records plotted this way, those cited above being marked with the record number, for identification. Through the spots or points thus plotted, fair curves are shown drawn for each *class,* which will thus represent the *average* result for all the records plotted. The greater the number of records of the same character, the better the curve will be for estimating purposes, or for using the curve as a temporary standard.

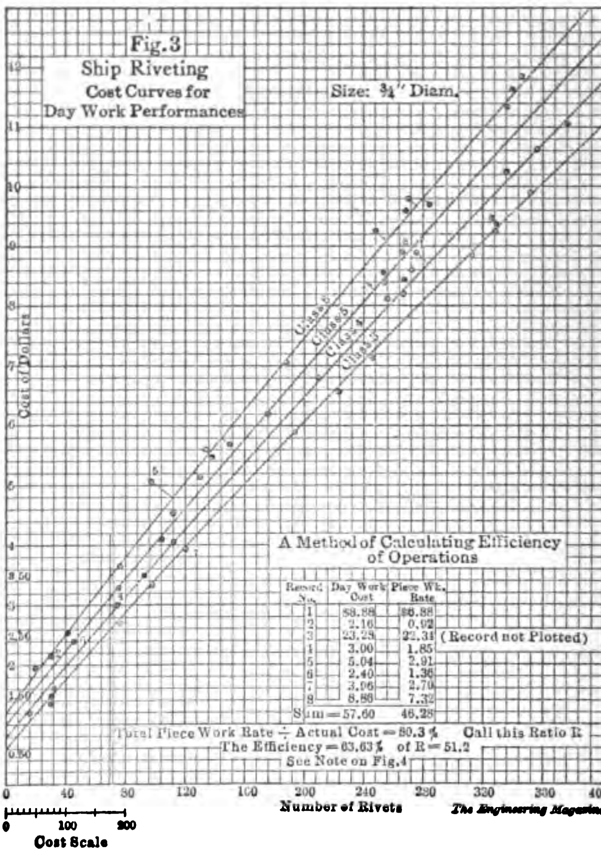
It may be well to explain briefly how to draw a fair or representative curve through a series of points or observations. A curve can be drawn free hand fairly closely, as to FORM of curve,—and a smooth curve drawn in later.

First mark representative spots along the page, as shown marked thus * such spots to be approximately the mean, or "center of gravity," of all the observations or points in its vicinity. Through these representative or mean spots, draw a smooth curve which will be of the proper form, but which may be too high or too low on the page. In order to determine this fact, simply see whether the sum of the distances of all points which are above our tentative curve equals the sum of the distances of all points below the curve, by measuring off in succession the distances on a strip of paper. If these sums are not the same (which they are not likely to be), divide the difference of the sums by the total number of points or observations, and the result or quotient will represent the distance which our tentative curve has to be moved bodily up or down on the page.

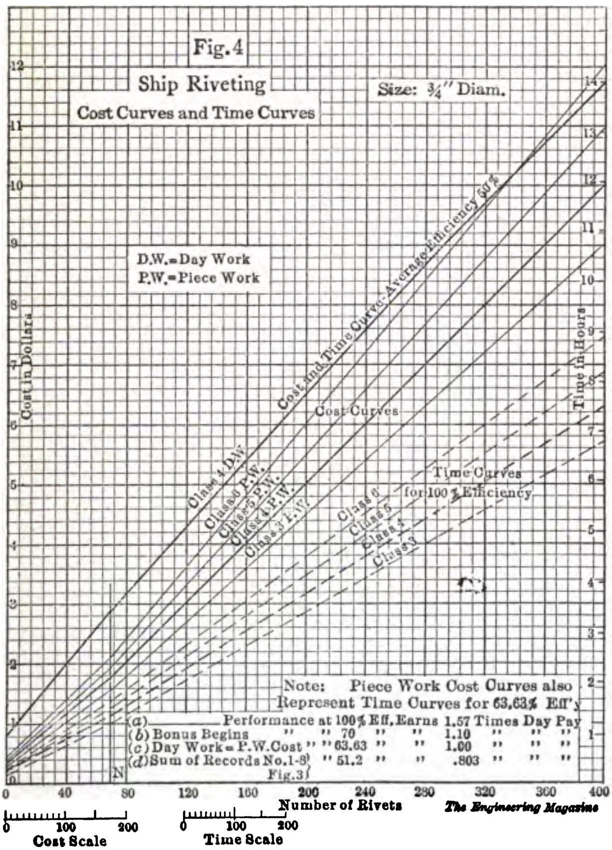
We now see that the number of units for "scattered work"—which comprises a very large proportion of repair work, and which incidentally costs so much money—has a very decided bearing on unit costs, and on total costs; which we started out to observe at the very beginning of our discussion. This fact is well known by all who have stopped to think of it—certainly by all who have tried to compare unit costs for different quantities or volumes of work; yet it is frequently ignored by good estimators, and is seldom made the subject of mathematical inquiry and investigation by even the best of estimators.

In plotting miscellaneous operations in this manner we will notice wide variations from the average curve drawn; it would be profitable to look into the reasons therefor where practicable. If our classifications were exact or perfect (which we cannot expect right away)—and if we took only the records for one workman, and if we also observed the workman carefully at each performance,—as to time spent in preparation, moving tools or position, etc.,—then we would not only expect our points to be more uniform and regular, but we would also have, by our independent observations, the exact reasons for any variation.

The records for riveting here plotted are more regular than we will usually get for miscellaneous operations, as they represent the continuous work of a single gang under similar working conditions. Although the



usual method in manufacturing work for plotting records and for estimating efficiency is on the basis of the number of *hours* of



work rather than the *cost,* yet in miscellaneous operations there is an advantage in using the *cost* as the basis; in such work we may frequently use different classes or grades of labor to perform the same classes of work, and wish to determine what class of labor does the work at the lowest total cost, not necessarily in the shortest time.

We observed at the outset that work costs more per unit for a small number of units, and up to a certain practical number of units. In manufacturing work, this limit is arbitrarily fixed by questions of convenience, and of accommodation of the shop toward other orders ahead. A machine cannot be operated indefinitely on one set of objects or parts, if there is other work in the shop which should be routed to this machine. It is the same in jobbing or repair work. Workmen have to be changed frequently from job to job, and from one kind of operation to another, for the reason that there are more different varieties of operations than there are workmen. Frequently many workmen have to work not only at different sub-trades, or operations, but at different recognized trades, in the ordinary parlance, as well.

As far as circumstances permit, however, and as far as proper planning and scheduling of operations will assist, it is the object of management to keep a workman or a gang continually employed at one class of operations, and at one definite operation until it is finished. Every break or interruption in the midst of an operation costs money,—and our data put into the shape of curves will estimate for us how much money these breaks cost. The cost of stopping a gang of riveters on one job and starting them on another (if day work) will average about $1.00 each time. An interruption requires stopping and removal of tools or material, moving to another job, and "getting ready" to start thereon; that is, it is what we have called the "Preparation Cost." These estimated preparation costs for piece workers, for which allowances are made (in table 4 of allowances on piecework prices, in Column P), will vary with different trades, and for different conditions. The curves from recorded data show the average value of preparation cost as the ordinate at the origin, as originally stated in the discussion of general methods of plotting costs by curves or graphs.

The interruptions which come during a working period are most to be avoided. For operations which do not last a full working period (of four hours in a plant in which eight hours is a day's work, as it is on all government work),—the unit costs vary considerably with the number of units performed, due to the relatively high cost (or time spent) for "preparation." For over a half-day's work, this cost of preparation (which is still about the same, regardless of the number of units) does not bear such a high ratio to total labor costs, and thereafter a straight unit price can be set without any large error being made as to actual values, and the error which is being made is in favor of the workman, mathematically.

The use of curves for studying cost data is by no means original with the writer. Their use has largely been confined, however, to repetition manufacturing work, or to standardized operations. A very thorough discussion of their practical usefulness may be found in "The Management of Engineering Workshops," by Arthur H. Barker, B.A., B.Sc., etc., wherein he describes how the total time occupied in doing each job, taken from the time sheets, is entered in a book, classified under the various jobs, together with all particulars which have an effect on the time required to do them. He states that:

> When sufficient entries have been made in this book, they should be plotted on curves on squared paper, whose abscissæ represent size in any convenient way, and whose ordinates represent time occupied. The points marked will, in almost every case, be found to vary widely, so that the curve will be a mean between them. The author has found that the points representing one man's performance usually lie on a fairly smooth curve.

He also observes that it will be found that it is better to use a large sheet of paper for plotting. This will be particularly the case for the general use of curves as advocated herein, for all sorts of miscellaneous and unstandardized operations, where the time spent on a large number of units as well as on a small number are plotted on the same curves.

For practical use for all kinds of miscellaneous work, curves will be found quite as valuable as they are for repetition work or manufacturing work, particularly for estimating purposes. They will be found to be the final judge or criterion of whether a cost record is worth keeping or not. If a cost record is not in sufficient detail to classify and plot intelligently on the same sheet with similar records, then it is not worth keeping for future use. This will be found to be a simple but invaluable test, and will serve a double purpose: First, to indicate wherein the record is incomplete, either as to character of unit, size of unit, number of units, or conditions attending the work; second, to permit the destroying of old or useless records, without fear that something useful has been thrown away. There is a great and almost uncontrollable tendency in some offices to file perfectly useless data and records.

If time cards or time sheets are used for detail cost purposes, and if these are filed by elementary classes of operations, it is not necessary to copy these data again, into a book, but the data should be plotted at once on the proper sheets of cross-section paper, if the data are worth keeping; if they cannot be plotted, the cards should be thrown away. After the data are plotted, compared to the standard curve, and the efficiency of the workman properly recorded, the card can be destroyed at the end of the pay period.

The plotting of all possible cost data serves many other very useful purposes, which space does not permit to discuss fully. This plotting can be started for almost any operation, before it has even been possible to classify the operation properly. In fact, the plotting of miscellaneous operations will assist greatly in working out a practical method of classification. Before an operation can be classified, the *unit* must be decided upon for the abscissa: the meaning of the word "*size*" of unit must be defined; and the variable conditions of (1) Accessibility, (2) Complexity, (3) Continuity,—must also be defined and each assigned its relative value or influence as to the cost of the operation. In some operations, such as riveting, these three condition factors will have about equal influence upon cost; in other operations,—such as laying linoleum, tiling or decking, the relative effect of varying these conditions for different jobs can best be seen after a number of records have been plotted.

After the number of classes to use are decided upon for an operation, and the relative values of the three condition factors decided upon, tentatively, then we can begin to establish a temporary standard curve of average performance for each *class* of the particular operation, for a particular size of unit. Later we can in many cases combine several curves on one sheet, for comparison.

As more and more detailed records are plotted, and as better standards or average performance curves are established, it will be possible to begin gauging succeeding performances by the standard and to mark the relative efficiencies of workmen. A separate record should then be started for each workman, and his efficiency on every operation marked, and his average efficiency for the week or pay period marked. Although these efficiency marks will not be absolute, yet they will be comparative between workmen of the same trade.

The eight records for riveting given on page 87, and plotted on page 90, Fig. 3, are the successive records of a riveting gang for a period of 68.6 hours. If we use the piece-rate prices as our standard, with 100 per cent efficiency representing an output earning 57 per cent over day pay, we would figure the total efficiency of this gang for the period at 51.2 per cent, as may be seen from a study of the curves on page 91. The efficiency is simply the ratio of time actually taken by the gang, for all the work of the period, to the time which would have been taken by a gang which is 100 per cent efficient—that is to say, the ratio of 35.1 hours to 68.6 hours, or 51.2 per cent.

Although the usual method of estimating the efficiency of operations is by comparing the estimated time with actual time taken, yet in a plant where a piece-work system is in use or contemplated, or where estimated costs or prices are used instead of estimated hours, and particularly where operations or tasks extend over portions of two or more days,—it will be simpler to estimate efficiencies by the week or period in another manner—simply multiply the ratio between estimated cost (or piece-work price) and actual cost by a *Constant,* which is easily determined. See Figs. 3 and 4. For piece work, the amount earned determines the efficiency.

Monthly efficiency reports, summarized from the weekly or periodic reports, should be made out for workmen—for all day workers, as well as for all piece workers.

It will be found that the rating of workmen in the manner outlined will, on the average, be very fair to all, and the results will far more than repay the small amount of clerical work involved. At the same time, real and reliable estimating data will be collected in concise and convenient form; the general efficiency of the working force will increase; and the management will have at hand the accurate knowledge necessary to effect improvements in management in an intelligent manner.

A study of performance curves will show more clearly and impress upon the management more forcibly than almost any other method, the low efficiency of miscellaneous operations of short duration,—and will lead to studying and investigating in a sensible and business-like manner the underlying reasons for this low efficiency. The further study of processes and of *operating* efficiency, the elimination of wasted energy, and the determination of the one best way for every operation, is another subject—a comprehensive subject beyond the scope or intent of this discussion.

In miscellaneous repair work, and in unstandardized operations in general, the efficiency of *operating,* of a day worker, may often average as high as that of a piece worker, but the efficiency of *preparation* is usually much lower. Problem: How increase the latter? Whose fault is it? Is it really the workman's fault or the management's fault? Probably the latter. How remedy?

Answer: Plan and schedule work properly; and by planning is meant providing all necessary material and working equipment, so as to permit the workman to start operating the tool in the shortest practicable time. Query: Why is the piece worker so much more efficient in "preparation": i. e., getting ready and starting upon the productive operation? Answer: One reason is, that he plans ahead for himself and insists on the management's preventing probable delays, due to other trades, or to lack of material. He becomes a part of the management, whose duty is to plan, and to prevent avoidable delays and interruptions. The day worker has not the incentive to plan, is not really paid to plan ahead, and cannot be expected to do the manager's work unless suitably rewarded. That is to say, the reward which a man is offered by a gain-sharing system is mostly for co-operating with the management in following the best plan and thus preparing for the highest efficiency "at the point of the tool." There is a trite but true saying that "A man is worth just a dollar-and-a-half from his neck down." It's the use which he makes of his brains that earns him more than that.

The question of preparing to do work, as distinguished from operating, or doing what is commonly called productive work, brings us to a consideration of preparation in the largest sense,—the kind of preparation which the management has to make before the workmen could produce at all. This preparation is just as necessary to production as machine work or forge work or painting, and the cost thereof enters into the cost of production just as certainly as the operating of machine tools; but on account of the complex and diversified nature of these preparation services and expenses,—they are usually kept separate from the direct labor and material costs of specific operations and jobs, and are known as incidental or overhead expenses. As they cannot be conveniently charged directly to operations or job orders,—like the time of the workman can (whether he is *preparing* to do productive work or is actually *producing*), these general services are charged indirectly, by distributing them by an estimating process over all jobs, and hence they are sometimes called *indirect* charges.

## ESTIMATING OVERHEAD EXPENSE

THE total cost of production consists of direct labor, material, and incidental or overhead expense. All expenditures, of course, resolve themselves into the cost of labor and the cost of material; but in getting at the cost of a product, there are certain incidental expenses which it is not practicable nor convenient to split up into small units at the time each charge is made and apportion to each order its proper share. This distribution of expense can be made indirectly, however, against each job order, by various bookkeeping methods. There are certain items of overhead expense which pertain to each shop individually, such as supervision, upkeep and repairs, light, heat, interest on shop plant investment, insurance and depreciation. These may be called "shop expense," localized by shops and distributed over all the orders in the particular shop. There are certain other items of expense incurred in the factory or plant as a whole, which are necessary to the production in all shops,—such as transportation, clerical force, upkeep of general offices, salaries of manager and superintendents, etc. These items of "general expense" may be divided up between the various shops first, and later distributed to the production orders in each shop.

The simplest and most common method of distributing both general and shop expense (which compose the overhead or indirect expense or "burden") is according to the amount of productive or direct labor charged to each production order; and most cost-keeping systems distribute the overhead by shops, so that all the estimator has to do is to base his estimate for overhead expense on the percentage of direct labor which the system gives to each shop.

As far as the duties of the estimator are concerned, he is usually content with making the estimated overhead expense come fairly close to the actual charges for overhead expense, these charges being automatically determined by the cost system. But if we look at the matter from the standpoint of the management, which is anxious to have the cost system distribute overhead charges over all jobs in as logical and equitable a manner as the expense of so doing will warrant, then we must look a little more critically into the customary methods of pro-rating all these charges. There is no such thing as absolutely accurate costs, except for the simplest kind of organization and manufacturing; and the approach to accuracy in costs may require a more expensive cost system than can be justified by the results obtained. There have been so many able treatises written in recent years upon the various methods of calculating and distributing overhead expenses, that the reader is requested to consult some of these authorities for the exposition of the subject in detail; and to regard the brief discussion which follows as a simple attempt to present in an unconventional and graphic way the relation between total production costs and its component parts.

We have confined our estimating of direct labor costs principally to miscellaneous jobbing or repair work—work in which the elements or operations are so numerous, and the variable conditions so difficult to classify, that standardization of operations has made but little progress. Each job is practically a new proposition; and before any comparison can be made with previous jobs, we have seen that we must break up each job into its elements,—into elements or operations which are similar to corresponding elements in other jobs. In no other way can we make intelligent comparisons or estimates for miscellaneous work. In manufacturing work, where standard articles are turned out in a regular way, with the sequence of operations pretty well fixed, and with the same machines or producing units always performing the same operations, it is a comparatively simple matter to analyze the various elements of cost—both direct labor and overhead expense incidental to processes and operations. That is, it is simple compared to miscellaneous jobbing work, where the equipment is necessarily more diversified, where a smaller proportion of productive work is done by machine tools, and where a considerable portion is done by portable tools and equipment—with a still larger proportion done by handworkers outside of the shop buildings.

A great many writers upon the practical distribution of overhead expense to production orders go on the principle that the simplest method is the best, and proceed to describe the simple method of pro-rating all overhead charges on the basis of direct labor costs; by simply adding to the direct labor charges the estimated percentage thereof to cover overhead expenses. The simplest use of this method is to apply a uniform rate for the whole factory; but with several departments composing the factory or plant, the accounts for each department are usually kept separate for all expenses which can be thus localized, and a separate rate is used for each department or shop for which one foreman is responsible. This simple method has its advantages from a managerial standpoint,—in placing the responsibility and control of shop expense in the hands of the shop foreman; but before accepting this system as the best for cost-keeping purposes, it will be well to attack the whole problem from an entirely different angle, by first trying to determine what system of estimating overhead expense incidental to processes and operations appear to be the most nearly accurate as well as the most advantageous to the management; after that is done, in the case of any particular plant, the practical question becomes: "What system of cost keeping will approach the ideal one in value to the management, and at the same time be simple enough for every-day application, and pay for itself?"

Cost keeping, like estimating, is simply a means to an end; they are both only adjuncts and aids to good management. Records of cost, however accurate, do not *in themselves* produce economy; it is only by the proper presentation of these records in convenient and convincing form to the executives who are responsible for costs that the executives can benefit by these records, and remedy inefficiencies pointed out by the records, through improvements in organization, in administration, and in individual processes and operations. It is better to have a few main headings for cost accounts, each with a definite and distinct meaning, than to have a mass of meaningless figures scattered through a hundred account headings, all bunched together and then arbitrarily distributed all over the cost of work, and the significance and value of individual items entirely lost. Unfortunately, in the development of systems of cost records, the purpose of such records in respect to increasing the efficiency of production have not received the attention which the mere accounting for expenditures of all kinds has received. The expert accountants have made wonderful progress in devising systems of reporting total expenditures under very logical groups, and making the books balance; whereas it is only in recent years that the managers and superintendents in general have realized the great possibilities for improving the efficiency of production which proper cost records open up.

In trying to determine the most nearly accurate system of cost keeping, and the one most advantageous toward promoting efficiency of production, we might take up one by one the principal methods in use, but this hardly seems necessary, in view of the thoroughness with which the subject has been studied and discussed by so many others, whose names have become familiar as authorities. They practically all agree (as any one will who studies the question) that the most advantageous cost system will furnish records of costs by operations, or certainly by units which are comparable with other cost records. They practically all agree that the simplest method in use of distributing overhead expense—on the basis of direct labor charges—is far from accurate, especially in a plant with a variety of products and with diversified equipment. As stated by Prof. Diemer, "This method, while simple, is objectionable because it does not differentiate articles in the manufacture of which the more inexpensive machines of a plant are employed, from articles involving the use of very expensive machinery."

The distribution of expense on the basis of hours of productive labor is open to the same objections. A more equitable method than these, in most cases, is to charge each job so much per hour for machine time as well as for man time. The difficulty with any arbitrary basis of distribution, as expressed by Prof. W. D. Ennis, M.E., is that overhead expense does not depend *on any one measurable factor*. He analyzes the various items of overhead expense, and shows graphically the distribution of elements constituting cost, briefly as shown on page 111:

Prof. Ennis then goes on to say:

> This method of distributing surcharge is as definite, logical and complete as any system could be. The objection to it is on the ground of its complication. As a matter of fact, it is complicated to devise and first apply, but simple in its continued application after having once been inaugurated. If it is worth while to study costs at all, it is worth while to pursue the study until our knowledge is accurate. It

may easily take two or three years to get a system like this in working order; it may need frequent modification and revision. Hard and fast rules cannot be laid down; and in all cases some simplification is permissible.

| | | | |
|---|---|---|---|
| TOTAL COST | Direct labor<br>Materials<br>Direct expense | INITIAL PRIME COST | Corrected Prime Cost |
| | Distributed burden: Charged against labor time | Wasted time<br>Taxes (part)<br>Heat<br>Depreciation (part)<br>Light<br>Foreman and supervisors<br>Employers' liability insurance<br>Rent (part), Fire insurance on buildings (part)<br>Non-productive labor (part) | |
| | Distributed burden: Charged against machine time (productive machines only) | Power, boiler insurance<br>Repairs and replacements<br>Repair supervision<br>Depreciation (part)<br>Rent, taxes (part of each)<br>Non-productive labor (part)<br>Fire insurance on buildings (part) | |
| | Distributed burden: Charged against corrected prime cost (or labor cost) | Fire insurance, except on buildings<br>Non-productive labor (part)<br>Factory indirect expenses<br>Selling expense<br>Administrative expense<br>Spoiled work<br>Standard patterns, tools, jigs, and templates<br>Designing and development expense | |

Analysis of Overhead Expense (Diemer)

On account of the distinction between the "cost of production," with which the present discussion is exclusively concerned, and the total or "selling cost," the following quotation in regard to work done by Government plants, which are mainly concerned with the cost of production, will be used, taken from the Report by the Keep Commission dated December 29, 1906, upon the subject of "Cost Keeping in the Government Service," to draw the distinction between cost keeping and cost accounting:

> Cost keeping as a branch of accounting is a comparatively modern development, and while largely employed in the commercial world has not yet been introduced to any considerable extent in the Government service. . . . In cost keeping, expenditures of money, material, and service are analyzed according to the purpose for which they are used, and it thus becomes possible to know the cost of any given piece of work or of any operation upon a single unit, or many identical units. A cost system, if properly devised and operated, will furnish information enabling the responsible head of the organization to know where economies may be effected by introducing new arrangements in organizations or new methods in operation, to estimate more intelligently on the probable cost of future operations along similar lines. . . .
>
> Cost keeping is that branch of accounting which is concerned with the segregation of the various items of expense, incurred in the prosecution of a single piece of work, from among all other items of expense incurred in a general line of industry, and the setting over against the total of such segregated items the quantity of resultant work or product.

In a method of cost keeping which makes use of the machine-hour rate, the usual practice of estimating this rate is on the basis of the probable number of hours the particular machine will be in operation for the ensuing year, and dividing the estimated annual expense incident to the machine by this number of hours. If the estimates are accurate, the total expense will ultimately go against the cost of production. A modification of the usual machine-hour rate has been advanced by Mr. A. Hamilton Church, which appears to the writer to separate the actual cost of *production* from the total cost or expenditure in a most logical manner. He proposes to introduce a supplementary machine rate, in which will be included the expenses incident to each producing unit when it is idle; and to keep this cost due to unemployment of producing units separate from prime costs, because it is not really incident to production, but incident to upkeep and maintenance of idle machines. Every producing unit or machine in the plant is given an estimated hourly rate, based upon the plant running at full capacity, so that when the plant does run at capacity all the overhead expenses of the plant will be absorbed in, or go into, the cost of production. If, for any reason, the volume of work fluctuates, the hourly rate remains the same for charging the services of a producing unit to the work it is engaged upon; and the unabsorbed incidental expenses which are due to the state of trade and to machines being idle, are for wasted time for which the production centres are not responsible, and they may be called "establishment charges." They are not due to production but to non-production.

In speaking of Mr. Church's "Production Factor" method, Prof. Kimball says:

> Any claims of refined accuracy in this, or any other method of distributing expense, must (therefore) be taken with caution. Nevertheless, the machine rate offers a more logical method of solving this problem than any other. It will probably be some time before an extended use of the refined method outlined by Mr. Church is realized; but a machine rate for classes or groups of machines can be readily applied, and is, in fact, in common use; and there is no doubt but that this method in connection with the supplementary rate offers the best solution of the problem for most plants of diversified equipment.

It should be borne in mind that a cost system for any plant must be adapted to the scheme of organization upon which it rests. No uniform system is possible for organizations of different kinds. It may even be necessary in some plants to sacrifice some valuable features of cost keeping to bookkeeping features; but if we are looking for the system which will be ideal for a jobbing or repair plant, where the only elements of jobs which can be compared as to costs are *operations,* it is evident that the only kind of costs which will be valuable as comparative data is the cost of *operations.* If total direct labor costs of job orders cannot be intelligently compared, evidently it is useless to add to these costs an arbitrary overhead expense and expect to benefit by it; the only *total* costs which can be intelligently and usefully compared in such cases are the costs of *operations.* Of course there will be some jobs even in a repair plant where total costs of *jobs* are comparable with other jobs; the data for figuring the proper overhead expense thereof should be at hand. It becomes a puzzling problem how far to go in the matter of pro-rating overhead expenses to job orders, in order to get correct total costs when they will be of some use, but at the same time to avoid collecting a lot of useless data on so many jobs, which will probably never occur again.

This brings us to a consideration of the practical use to make of records of overhead charges, aside from pro-rating them to individual job orders; and of estimating what these charges should be for any shop or for any group of producing units, or even for a particular producing unit. It is just as important to keep track of expenditures for upkeep of buildings, machine tools, portable power tools, hand tools and equipment, etc., as it is to keep track of direct charges for labor or material. It is also necessary to be able to judge of the probable effect upon the total costs of operations, whether we *distribute* the overhead charges to operations or not. Therefore it will be found worth while to figure out, in the best way we know how, the overhead charges which are incident to, or due to, standard operations; and we may find it advisable to estimate as close as we can the overhead charges due to the operation of individual producing units. A producing unit may be an expensive machine tool, with an hourly overhead cost when in operation of $1.00; or it may be a pneumatic chipping hammer, with a rate of 30 cents an hour; or it may be only a handwork unit, using no power, and with inexpensive hand tools requiring little expense for upkeep, with an hourly rate of only 10 cents, to cover supervision and the proper share of organization expenses. Whatever the character of a producing unit, the overhead cost for any operation performed by that unit can be estimated fairly closely, if proper records of overhead expenses for the plant have been kept separately under a few main or most important headings; the estimate will, of course, be more accurate if individual records have been kept for each machine or other kind of producing unit, showing costs for power, upkeep and repairs, etc., for each unit. The main headings which I shall use are chosen from Mr. Church's "Production Factors" and "Expense Burden," with a slight rearrangement for purposes of calling attention to the relatively high overhead expense incident to operations performed by expensive machine tools, compared to the low expense incident to operations performed by hand. In a jobbing plant, both kinds of operations more frequently come under the supervision of one foreman than they do in a manufacturing plant, and consequently when the same overhead rate is used for all the work under one foreman it is impossible from the cost records to know the true total cost of any particular operation. All the overhead expenses incident to production in a shop can be conveniently grouped under six main headings, and then by careful analysis, along the lines described by Mr. Church, the proper share of expense incident to each producing unit (or operation) can be estimated quite accurately,—much more accurately than can be expected from the *automatic* estimating and distribution by any ordinary form of cost-keeping system. The main headings are given on page 119.

In a jobbing plant, of diversified equipment, it will be found convenient to consider a "producing unit" as the combination of men and tools necessary to perform any definite "operation"; and in order to estimate the total cost of the operation, add to the wages of the operators the "rental value" of their tools and equipment. This rental value or overhead cost incurred by the management for the benefit of producing units may be figured at so much per hour for each producing unit; it includes the carefully estimated amount of benefit that the producing unit derives from each of the main groups of expense above enumerated. There is considerable value in this method of considering the overhead expense incident to any operation as the "rental value" of the facil-

## Analysis of Expense by Production Factors

(1) Building and Land Factor.
- a Interest, insurance, depreciation.
- b Repairs, cleaning, painting.

(2) Power Charges.
- a Electric, Pneumatic, Steam, Hydraulic,—power.
- b Lighting.
- c Heating and ventilation.

(3) Stores-transport Factor.
- a Storehouses,—building factor.
- b Store-keeping expense.
- c Transportation of material.

(4) Organization Factor.
- a Wages of time-keepers, planners, etc.
- b Stationery and supplies.
- c Cost-keeping department expenses.
- d Watchmen and janitors.
- e General offices,—including building factor.

(5) Supervision.
- a Salaries of manager and superintendents.
- b Salaries of foremen and leading men.
- c Cost of inspection.
- d Shop office expenses,—including building factor.
- e Special offices,—including building factor.

(6) Tools and Equipment.
- a Interest, insurance, depreciation.
- b Maintenance and repairs.
- c Operating supplies,—oil, waste, etc.
- d Tool room charges.
- e Jigs, dies, templates.

ities provided by the management to the operators to assist production, when we come to compare the total cost of operations which are comparable. This rental value of facilities represents the outlay by the management for "preparation" for efficient "operation" by the workmen, to enable them to turn out the largest output in a given time with the least effort. This preparation by the management is entirely analogous to what we termed "preparation" by the workmen, in discussing the direct labor costs of work; they are both incidental to production, both a legitimate and necessary part of total cost of production.

There are certain portions of this necessary preparatory work, preceding the actual operating of the tool by the workman, which is sometimes performed by the workman himself, and sometimes by the management; that is, it sometimes enters into total cost as a direct labor charge, and sometimes as an overhead charge, depending on the organization and shop methods. Examples of these functions are: handling material; providing tools, clamps, battens, etc.; grinding of tools; excessive time spent on "setting up" a job (a direct labor charge) due to lack of proper instruction or supervision (an overhead charge). Therefore the only conclusive way to compare the efficiencies of operations is by the total cost,—which includes all the proper charge for direct labor (the time of workmen in "preparation" and in "operating"), plus all the proper indirect charges for "preparation" by the management. Such comparisons will explain to a great many who do not understand what overhead charges really mean, and who think a reduction in overhead charges *per se* indicates increased efficiency, that the form of organization, and the rules for charging men's time which are used, determine almost entirely whether certain important services are charged in as direct labor or are charged as overhead expense; and will also explain why total costs may be less,—and the efficiency greater,—in one plant with a very high overhead charge, than in another plant which boasts of a low overhead expense.

Overhead cost should be kept as low as is consistent with efficient production, of course; but so should the cost of so-called direct labor, and the cost of material. And the only positive proof of efficient production is the sum of these three items of expense, each properly determined. If the cost of direct labor can be reduced $100 by increasing the overhead cost $50, the net saving is $50. This form of test applied to standardized "operations," or to comparable operations, should in time disclose the most efficient known method of performing those operations.

## THE USE AND DANGER OF "ROUGH ESTIMATES"

FREQUENTLY it is necessary to furnish a rough or approximate estimate for purposes of general information, and in such event speed is more important than accuracy. In the case of repairs or other work for which definite specifications cannot be prepared, it is impossible to make anything but a rough estimate. Rough estimates are useful to prospective customers or to superior officials when the total funds available are limited and it is necessary to decide without delay what work shall be undertaken and what postponed or not undertaken. There is no use wasting time trying to make an accurate estimate for an item where the specifications are incomplete, for any reason, or where promptness is more important than accuracy. A rough estimate, however, should *never* be submitted as a *bid* or contract price, but only as a matter of general information, or as a basis for allotment of funds.

For new projects, or new machines or equipment, or for contemplated changes affecting plant efficiency, rough estimates may sometimes be close enough to determine if the project or changes will pay.

Since rough estimates, then, have their use, it will be wise to have at hand in convenient form general estimating data by which such estimates can be readily made. Total costs and unit costs of the kind likely to be used should be kept up to date.

The danger of getting into the habit of rough estimates is in the temptation to make rough estimates when careful and accurate estimates can, and should, be made. In this case, rough estimates are a good deal worse than none at all. They serve none of the purposes for which real and accurate estimates are intended, and besides being a waste of time are misleading and are liable to cause trouble. Rough estimates in bidding may cause either the loss of a desirable contract, or may get an undesirable contract and lose money on it. Rough estimates on how much work a man can do in a day for a certain wage cause injustice and trouble, and if such estimates are still further used as a basis for a piece-work system, then trouble and discontent are almost sure to follow.

In making rough or quick estimates, when the necessity arises for this kind of estimate, data collected by the estimator in the shape of total costs will usually be used; the total cost includes direct labor and material, and the overhead cost (which may run from 15 to 100 per cent of the direct-labor cost). With the average form of management, in a plant doing general construction and repair work, the overhead or indirect percentage for work in machine shops or other metal-working shops equipped with expensive machine tools will ordinarily be from 40 to 60 per cent; with a functional form of management, where all or nearly all of the "preparatory" work is performed by special supervisors and planners, and hence is charged as indirect expense instead of as direct labor, the indirect percentage may easily be 75 to 100 per cent. For work not done by machine tools, but entirely by hand, the overhead cost is much less, as it is composed mostly of supervision and administration expense, and may be as low as 15 or 20 per cent of the labor cost.

Data for rough estimates should be kept

on record cards, classified and indexed for ready reference. Costs of manufactured articles would be recorded by unit costs—that is, cost per article. Costs of new construction work would usually be recorded by the cost per ton or pound, for different types of construction. In the case of buildings, the approximate cost is often estimated at a certain price per cubic foot of contents; this will vary greatly with different types of buildings, from 10 cents per cubic foot for cheap frame buildings, without heat or plumbing, up to 60 cents per cubic foot for fireproof office buildings. Data for estimating *repair* work are difficult to collect for *whole jobs,* as no two jobs are identical, and a more detailed analysis must be made of the job into its elements, somewhat in the manner which has been illustrated in the preceding pages. There is, however, a simple way of approximating the cost of a large repair job, if there is not sufficient time allowed for a detailed estimate; this is by estimating the cost of *material*—which can be done fairly accurately in a short time after the specifications for the repair job are prepared—and then estimating the cost of *labor* as being the cost of material multiplied by a *constant;* the constant for this method of estimating to be determined from the records and tabulated for different classes of jobs. For new steelwork —such as alterations or additions, involving no removal of old work—the constant (or factor) will be, for example, 2.0; hence, for constructing and installing a new ship's bridge estimated to weigh 15,000 pounds—a rough estimate would be Material $300, Labor $600, Indirect (at 50 per cent) $300—Total estimate $1,200. For repair work, involving both the removal of old material and replacing with new, the factor or ratio of labor to material will be found to be two or three times as great as for additions only. There are many other rapid methods for approximate estimating, for different kinds of work, which will not be given but they can be found in reference works; and doubtless some can be devised by the ingenious estimator for his particular purposes.

Only two more examples of the kind of ready reference data which each estimator should prepare from the records of his own plant will be given. One example is for joiner or ship-carpenter work, and the other is for miscellaneous castings for ship work.

## Rough Estimating Data for Joiner Work

| | Labor Cost Only |
|---|---|
| Laying canvas on new deck; no hatches, deck-houses or coamings to interfere with the work | $0.06 per lin. yd. |
| Laying canvas on old deck; with hatch coamings, deck-houses, boat cradles and various fittings, interfering with work | .25 to 60 per lin. yd. |
| Laying flashing straight, viz: along waterways, sills, coamings, etc | .10 per lin. ft. |
| Laying flashings curved, viz: around ventilators, stack coamings, boat cradles, coal scuttles, steel pads, etc | .35 per lin. ft. |
| Laying sheathing felt under canvas, on clean deck | .01 per sheet |
| Same, if deck is freshly painted | .013 per sheet |
| Laying ⅞ in. tongue and groove decking, 100 sq. ft. or less, ready for canvas | 5.00 |
| Laying ⅞ in. tongue and groove decking, 1,000 sq. ft. ready for canvas | 25.00 |
| Note: Data like the last two items can be expressed as previously discussed: Cost of *n* units equals the cost of "preparation" or getting ready plus *n* times the unit cost of "operating." | |
| Manufacture and install doors, complete with trim and hardware, each | 7.00 |
| Erect complete ⅞ in. tongue and groove bulkhead, including door and window openings, 100 sq. ft | 9.00 |
| Manufacture and install complete, with trim and hardware, each window (single sash) | 4.00 |
| Laying deck (4 in. x 4 in.); this includes fastening and dubbing off for straight decking | .07 per lin. ft. |
| Laying deck (4 in. x 4 in.); this includes fastening and dubbing off for curved decking | .15 per lin. ft. |
| Calking—deck, three threads, including pitching; all butts, circles, etc., to count double | .02 per lin. ft. |

JOINER WORK—(*Continued*)

| | Labor Cost Only |
|---|---|
| Manufacturing cushions and transom backs | .50 per sq. ft. |
| Manufacturing spars, masts, etc., sizes as follows: | |
| Not over 10 inches in diameter... | .85 per ft. |
| Not over 20 inches in diameter... | .90 per ft. |
| Not over 24 inches in diameter... | 1.00 per ft. |
| Not over 30 inches in diameter... | 1.20 per ft. |
| Laying linoleum, average (cut around fittings).......................... | .75 per sq. ft. |

## COST OF CASTINGS MANUFACTURED BY NAVY YARD, CHARLESTON, S. C., 1914

| | |
|---|---|
| (A) Labor Per Pound on Cast Iron: | |
| Sub-marine cylinder heads and water jacketed fittings, pipes for submarines, other engine cylinders and miscellaneous light fittings for engine or machine parts................. | .0425 per lb. |
| Miscellaneous other engine and machine castings, as piston, ring blanks, cylinder covers, bearing caps, light cored bitts, light cleats and chocks, etc... | .03 per lb. |
| Miscellaneous light cored castings.... | .0175 per lb. |
| Miscellaneous light castings without cores......................... | .0125 per lb. |
| Light grate bars.................... | .01 per lb. |
| Medium weight grate bars........... | .008 per lb. |
| Heavy grate bars.................. | .00625 per lb. |
| (B) Labor Per Pound on Bronze or Brass: | |
| Light bronze or brass castings with cores as small scuppers, hose fittings, small pipe and voice tube fittings... | .07 per lb. |
| Light bronze or brass castings, as boat fittings, hinges, small, cleats, chocks, etc., without cores, or the heavier pipe fittings.................... | .06 per lb. |
| Medium weight bronze or brass castings, as airports and frames, cleats, chocks, engine brasses and bushings, flanges, etc...................... | .04 per lb. |

COST OF CASTINGS—(*Continued*)

| | |
|---|---|
| Heavy bronze or brass castings, as coal scuttles, door frames, large cleats, and chocks, propeller wheels and heavy engine brasses and large bushings | .03 per lb. |
| NOTE: The above is for labor only. The cost of material, which includes all indirect cost, is to be added to labor. | |
| Cast Iron | .02 per lb. |
| Bronze Composition, "G" | .24 per lb. |
| Bronze Composition, "M" | .16 per lb. |
| Bronze Composition "H" | .15 per lb. |
| Brazing metal Composition "F" | .20 per lb. |
| Scrap Brass, "S" | .13 per lb. |
| Naval Brass, N-c | .13 per lb. |
| Manganese Bronze, Mn-c | .16 per lb. |

## DEVELOPING AN ESTIMATING SECTION

IN a very small plant, a separate staff or section for estimating or planning work may not seem necessary, and their duties may be well done by the foreman. But in a plant of any size the foremen have too many other legitimate and important duties to do, and should be given a fair chance to do them well, by establishing a special estimating section,—which may consist of only one or two or may consist of a dozen, depending on the size of the plant and the character of work performed.

In our Navy Yards it was customary up until a very few years ago for nearly all estimating to be done by foremen in addition to their other multitudinous duties. The success attending the establishment of special staffs for estimating and planning work, which, of course, includes ordering material, cannot be questioned.

It makes no difference what titles you give people who plan or estimate or set tasks—the functions are all similar, and it is largely a question of finding the men naturally fitted for such duty and then training them diligently. A new man put at estimating, however good a mechanic or draftsman he may be or however ambitious or intelligent or systematic, needs instruction and guidance from the superintendent in charge. Without both guidance and encouragement he may flounder around for a year, more or less hopelessly, collecting a lot of experience and some good data, and improving his ability to "guess" what a thing will cost, but he may never become a first-class estimator. He should be given a chance, and should be taught and encouraged to benefit by the recorded experience of others. For instance, I do not see how a man can become a good planner or estimator (and they are both the same thing) without studying Mr. F. W. Taylor's "Shop Management," or some of the works of later investigators who have succeeded in planning work along the principles first so clearly expressed by Mr. Taylor. There should be a library of modern works on management always accessible to the estimators and planners. They should be instructed and encouraged to make up note books of their own—a kind of handbook—entering such data as are constantly needed for estimating. Each kind of industry and each trade requires a different set of tables and data of this kind.

Estimators should be taught that their estimates cannot possibly be more accurate than the recorded cost data warrant; and that they are simply wasting time and money by estimating costs to the nearest cent wherever there are no records in the plant that would warrant any one being *sure* of estimating closer than a dollar.

I have seen well-intentioned, intelligent, careful, but misguided men of very good education, submit estimates to the nearest cent on a new construction job that aggregated over $200,000! Think of it! The data upon which the total estimate was based would not warrant anyone guaranteeing to come within $5,000. The very best sort of estimating data hardly ever warrants estimating closer than 5 per cent on small jobs and possibly 2 per cent on a very large volume of work, on anything but repetition manufacturing work or work which can be done piece-work. How many precious hours are wasted in needless and useless figuring to the *n*-th decimal place! Every estimator (and incidentally every draftsman) should, if possible, take a course in the "Precision of Measurements," even if only enough to grasp firmly the absurdity—I was about to say asininity—of endless, needless figures which cannot possibly add to accuracy.

This important qualification for intelligent estimating,—that of giving to all the elements of a problem their proper weight or valence, and not becoming so involved in small and relatively unimportant details that the main issue is obscured,—is no less important to those higher up in an organization than it is to the estimators and draftsmen. There are problems connected with submitting bids or total estimates of much greater import, of much greater resultant effect on the profits and dividends, than the mere work of planning and estimating in detail the costs of individual operations, as above described. It would prolong this discussion beyond its immediate intent to attempt to discuss these important variables, from the standpoint of the superintendent who receives from the estimator of details his data based upon past records and who adds to these probable costs of actual production the allowances for the state of the market, for the effect on the factory as a whole of obtaining new contracts and keeping the plant going at as near capacity as possible, and for many other considerations. For that reason, the discussion has been limited throughout to the work of estimating the cost of production, pure and simple. This limited definition of an estimate confines the subject matter to the kind of data which particularly concerns the detail planner and estimator.

There is one phase of the broader subject of submitting estimates and taking account of the effect of greater output upon the relative cost of overhead expenses, which even the detail estimator must not ignore. For an estimator to put down an estimate for overhead expense as a percentage of labor cost, in parrot fashion, from the records of past months, in the case of a large contract which would have the effect of reducing such a percentage very considerably—would make the final bid upon this basis very unreliable. This can be better explained by a concrete example, and although the example given is of the most general character, yet the process of analysis used applies to any specific job which may arise. It would be well for the principle involved to be understood by each planner and estimator,—for it is the guiding principle, the paramount consideration, in all estimating; namely, the relation of volume of work to cost of work. The principle has been expressed graphically by curves and examples; for any shop or factory the average effect upon unit cost or total cost caused by varying the output may be worked out mathematically.

Take an example of a plant which has been laid out and equipped and organized for turning out 100 tons of finished product a month, working at maximum capacity, with a productive working force of 500 men. Suppose that under average trade conditions and state of the market, you have been able to keep the plant going at 80 per cent of capacity; but that conditions become unsettled, and sometimes you cannot get orders enough to make your average output over 30 tons a month; occasionally you get a big order and run for a month or two at full capacity of 100 tons a month. Let us analyze the following assumed figures of the total costs of operating the plant, especially the varying ratio of overhead expense to productive labor costs; let us see the relation between volume of production to production cost, total cost, and profit.

Figures given are for one month, being the average for previous records, under conditions given.

FIXED CHARGES: Such as interest, insurance, and depreciation of buildings, tools and equipment
$5,000 a month

These charges or expenses are ever present and are fairly constant; they do not vary with output nor with the number of productive employees. They amount to about one-half of the total overhead cost when the plant is operating at 40 per cent of its capacity,—to about one-third the total at full capacity.

SEMI-FIXED CHARGES: Charges which are due to *operating* the plant, but which are large even with a very low output, and do not increase in proportion to the increase in output. Such as: Power, light and heat; repairs and upkeep of tools and equipment; organization expenses (see page 119), the sum of these semi-fixed or slowly variable charges may amount to 50 per cent of the productive labor charges at a very low output, the ratio decreasing until at maximum output these charges may amount to 15 per cent of the productive labor charges.

That is,—at an output of 20 tons a month (plant operating at only 20 per cent of capacity), semi-fixed charges are $2,000

At maximum output (100 tons a month), semi-fixed charges are $4,500

VARIABLE CHARGES: Charges due to operating, and which vary more nearly in proportion to variations in output, such as: Supervision (see page 119); operating supplies, etc. The sum of these charges may vary from 20 per cent of the productive labor

TABULATION OF THE ASSUMED COST FIGURES LISTED IN PAGES 137 AND 139

OUTPUT IN TONS (OR PER CENT CAPACITY)

| | 0 | 20 | 40 | 60 | 80 | 100 |
|---|---|---|---|---|---|---|
| Productive labor cost | $ 0 | $ 7,500 | $ 15,000 | $ 22,500 | $ 30,000 | $ 37,500 |
| Total overhead cost | 5,000 | 8,000 | 10,500 | 12,500 | 14,000 | 15,000 |
| Total cost or outlay | 5,000 | 15,500 | 25,500 | 35,000 | 44,000 | 52,500 |
| Total cost per ton | ...... | 775 | 638 | 583 | 550 | 525 |
| If competition fixes the maximum selling cost at $700 a ton, maximum sales cannot exceed | ...... | 14,000 | 28,000 | 42,000 | 56,000 | 70,000 |
| Maximum possible profit | —5,000 loss | —1,500 loss | 2,500 | 7,000 | 12,000 | 17,500 |
| Notice the variation in overhead percentages | ...... | 106 | 70 | 56 | 47 | 40 |
| And in per cent PROFIT on total cost or outlay | —100 loss | —10 loss | 10 | 20 | 27 | 33 |

NOTE:—The cost of *material* is left out of account above, for the sake of simplifying the analysis, and may be assumed to be a constant amount per ton of output.

charges at a low output, to 15 per cent at maximum output.

That is,—at 20 per cent of maximum output, variable charges are............$1,000

And at maximum output, variable charges are $5,500

The productive labor charges are $37,500 at maximum output,—with 500 productive employees, or about $375 per ton output.

Tabulating the total charges for various outputs, we see in a practical and forcible way that as far as profits are concerned, and as far as bidding is concerned, the output compared to capacity is the most important consideration. See page 138.

The general method of analysis of cost records above indicated can be used to advantage for almost any sort of costs (down to costs of output of individual machines), furnished by any sort of cost-keeping system. A closer study of the above example will make clear to the reader the essential difference between various methods of pro-rating overhead costs to productive orders. Let us look at the figures in the light of the "Production Factor" method of separating the overhead cost per hour into its elements: 1st, Cost incident to actual production by producing units. 2nd, Cost incident to idle machines and equipment,—which is *waste* due to lack of work. The second element of overhead cost is the extra expense incurred in maintaining a larger plant than is required for doing all the work which can be obtained. When orders fall off to a certain point, this extra expense eats up all the profits, and one of three things must be done: (1) Get more orders; (2) operate at a loss; or (3) close up the plant.

(Note:—The low output is assumed to be due entirely to lack of work and not to inefficient operation. That is another subject.)

Considering the above plant as a "large machine" or "producing unit," the hourly rate, or overhead cost per hour (based on maximum output conditions, and operating 200 hours a month) is seen to be $75.00. If it operates at only 40 per cent capacity, this would be equivalent in output to operating at full capacity 40 per cent of the time, or 80 hours; the other 120 hours of the month the plant is *virtually* "idle." The overhead charges due to actual production would be $6,000 for the month, 80 hours at $75.00 an hour. The remainder of the actual overhead charges, whatever they came to, would be wasted overhead, due to maintaining a larger "capacity to produce" than was utilized. We see from our records above, or from similar records in the form of curves (overhead charges plotted upon output), that the total actual charges for overhead cost for the month were $10,500. Hence the remainder, of $4,500 (or $22.50 an hour), over and above that due to and charged to the actual production of 40 tons output, of $6,000, is "wasted." It is virtually a "loss," not a loss due to inefficient *production,* but a loss due to not operating at full capacity; and as such it can be kept separate in the statement of total cost.

Putting the presentation of the great waste due to idle equipment and tools in another manner, we may imagine the above plant to contain 200 similar machines, 80 of which are in constant operation, and 120 of which are always idle. The actual "rental value" of the 80 operating machines is only $30.00 an hour; the rental value would be $75.00 an hour for all the 200 machines in operation. That is 37½ cents per operating machine per hour. We are actually paying $10,500 rent for the use of the plant,—including all overhead expenses,—or $52.50 an hour, for which we get only $30.00 an hour real "rental value." The balance of $22.50 is wasted, amounting to nearly 19 cents per idle machine per hour. That is, if we operate the plant at only 40 per cent capacity, we pay 19 cents an hour for every idle hour of every machine, and 37½ cents an hour for each machine in operation.

The average estimator may not be expected to analyze cost records as a Superintendent would, in the manner illustrated, for his own amusement; but if he has been taught the use of curves by the Superintendent, in plotting expenses of all kinds as ordinates upon output or labor as abscissæ he can present to the Superintendent in compact and convenient form the most important and significant facts of the whole business.

The estimating and planning department is the connecting bond between the cost returns and the producing units; it assists production at the tool point on the one hand, and assists the executives to read correctly the records of production outputs and costs, on the other. Without this intelligent interpretation of records, the executives are without the eyes or ears to discover the specific causes of inefficiencies, and without the means to correct them properly, even if they were known.

In estimating the cost of work by prime elements or "operations," which, of course, means planning the work at the same time,—all work can be scheduled by dates, for trades and sub-trades (*operations*); thence scheduled by job orders; thence scheduled by larger groups, for example, by ships in ship-work. Schedules can also be prepared (by means of the same data) for the total work *in hand* and *ahead* for each trade, for each sub-trade, for each machine or other form of "producing unit." Orders can be properly "routed" and the progress of any item of work controlled in a systematic and efficient manner. All this has been done successfully in manufacturing work, and has been done to some extent in repair and jobbing work; the latter field is even more promising than the former, because of the greater inefficiencies which exist,—supposed by many to be inherent in such work, for the reason that no one could *estimate* how long it would take (much less how long it *ought* to take) to do a specified piece of work. If the art of estimating is once mastered, the discovery and partial remedy of these inefficiencies will be possible.

## CONCLUSION

WE have attempted to illustrate by examples, description, and references to the accepted methods of planning and estimating in manufacturing work, the application of the basic principles of logical planning and estimating to the most complex, uncertain and unstandardized kind of work in the world, namely, repairs and alterations to vessels. A few years ago, any one who claimed that such a thing as "standardizing" this kind of work, even in a limited degree, was possible, would have been laughed at as a theoretical crank. But already a start has been made, here and there, and, strange to say, always with marked success. The results have been so remarkable that only a few have acknowledged them,—outside of those who brought them about. A few years hence, and many others will give the methods a fair and unprejudiced trial.

The "Variable Conditions" for miscellaneous work to be standardized we have repeatedly recognized as belonging to three groups defined as:

(1) Accessibility,
(2) Complexity,
(3) Continuity.

These are, of course, very broad terms, and until the estimator has actually tried from recorded data, plotted and analyzed, to combine these variable conditions for an unstandardized operation into a single class, i. e., give it a classification number,—he may be skeptical as to the practicability of using this method to advantage.

A little reflection may persuade the estimator to make an actual trial: By extension of the analysis of any class of operation which occurs, into its further elements of "Motions,"—and making detailed time studies thereof, we will see that these three variables are but a general grouping of the broad results of more detailed study, and consequently quite possible of being made the subject of accurate estimates. We must remember (for we surely realize) that final elementary motions, or ultimate analysis of any operation into motions or even mental activities which are common to all kinds of operations and trades and to all kinds of work, are certainly possible, and that a combination of these ultimate elements make up what we commonly call an "operation." Likewise we can take any operation which occurs under various conditions of *accessibility* of work, *complexity* of material worked on, and *continuity* of performance,—and by ultimate analysis into motions determine what extra motions, or what awkward motions, or what unusual fatigue, or what delays and natural interruptions, appear due to each of these various conditions. Thence we can proceed to the total or combined effect of the elements upon the total time it takes to perform a definite operation under various conditions.

This is a huge undertaking to study and reduce to rules the physical and mental laws which govern labor. Well may the leaders in Scientific Management say that the study of only *one trade* could more than occupy the lifetime of the most competent and skilled observer. On top of this, we are told and believe from experience that only one man in a hundred or so can ever become a competent and skilled observer. So what a chance the average jobbing plant has, with its fifty or a hundred different trades, and more sub-trades than employees, to solve its own problems unaided!

The solution even in a limited degree will require that each worker upon the problem receive the benefit of what others have done, and that each contribute to the General Fund of information what little results he may have the authority, opportunity, time or means to observe or study. If the task of collecting, classifying and disseminating all the useful information is too great for private enterprise, then this becomes the function of the National Government, under a Bureau of Trades, or of Industrial Research, as proposed and seconded by Mr. Gilbreth, Mr. Franklin and others.

In the meantime—which may be a long meantime—can not we approach the solution in several different ways? For whatever steps we take toward the equitable reward of the efforts of labor, physical or mental,—we are on the road to justice for all and to profit for all.

# APPENDIX



Additional cost data for estimating purposes, which are in course of preparation for printing, will be added in the appendices to later editions. Any contributions from interested readers will be appreciated and gratefully acknowledged.

The writer realizes that the subject of estimating is far too comprehensive to treat fairly or convincingly in a brief article, and that nothing short of an Encyclopedia would suffice as a useful reference work; hence, the discussion has been limited to a few simple methods and principles which have been successfully tried. To the manufacturer of standard articles, made one after the other from the same design, the methods discussed will seem common-place and too conservative; to the manager of a jobbing or repair plant who has never tried planning by "operations," and who has always "put it up to the foreman," the methods will seem impracticable and visionary.

The audience which the writer has attempted to address in this short and incomplete appeal for efficient estimating is composed of men who have grown tired of "guessing" at things; who have, like the writer, been inspired by the successful and somewhat remarkable accomplishments in workshops of the "modern management" men; and who are willing to investigate the possibility that the old methods of estimating can be improved upon.

## I. Scale of Wages at Navy Yard, Charleston, S. C., for the Trades Performing the Work for Which Cost Data Are Given in the Text.

There are four grades or rates of pay for each trade. Only the highest and lowest rates are given. Rates are per day of 8 hours.

| Trade | Highest | Lowest |
|---|---|---|
| Acetylene welder | $3.44 | $2.80 |
| Anglesmith | 3.76 | 3.04 |
| Blacksmith | 3.28 | 2.24 |
| Calker, wood | 3.44 | 2.56 |
| Calker and Chipper (iron) | 3.44 | 2.80 |
| Driller | 2.48 | 1.76 |
| Forger (heavy) | 4.00 | 2.80 |
| Galvanizer | 3.04 | 2.24 |
| Joiner (ship) | 3.52 | 2.24 |
| Light-metal worker | 3.04 | 2.80 |
| Loftsman | 4.32 | 3.68 |
| Molder | 3.76 | 2.80 |
| Painter | 3.04 | 2.24 |
| Plumber | 4.00 | 2.56 |
| Puncher and Shearer | 2.56 | 1.76 |
| Rigger | 3.52 | 3.04 |
| Riveter, Machine | 3.44 | 2.80 |
| Shipfitter | 3.60 | 2.88 |
| Shipwright | 3.44 | 2.56 |
| Upholsterer | 3.52 | 2.80 |
| Wire-worker | 3.28 | 2.48 |

| Trade | Highest | Lowest |
|---|---|---|
| Laborer | $1.52 | $1.04 |
| Helper, General | 2.00 | 1.28 |
| Helper, Painter's | 1.76 | 1.28 |
| Helper, Rigger's | 1.76 | 1.28 |
| Helper, Steel-worker's | 2.00 | 1.28 |
| Helper, Wood-workers | 1.76 | 1.28 |
| Holder-on | 2.56 | 1.76 |
| Boy | 1.28 | 0.56 |

The total number of employees at the Charleston Navy Yard in the above trades for 1914 was about 300, with a total pay per day of about $770, average daily wage per man $2.56, or 32 cents an hour.

## II. Reference Works

### Cost Keeping and Business Organization


1. Cost of Manufactures and the Administration of Workshops.
   Capt. Henry Metcalfe, Ordnance Dept., U. S. A. John Wiley & Sons, New York, 1885.
2. Commercial Organization of Factories.
   J. Slater Lewis. E. & F. N. Spon, London, 1896.
3. Management of Engineering Workshops.
   Arthur H. Barker. Technical Publishing Co., Manchester, 1899.
4. Engineering Estimates and Cost Accounts.
   Francis G. Burton. Technical Publishing Co., Manchester, 1900.
5. Complete Cost Keeper.
   Horace Lucian Arnold. Engineering Magazine Co., 1900.
6. Cost Accounts.
   C. A. Millener. Hunter-Rose Co., Toronto, 1901.
7. Factory Manager and Accountant.
   Horace Lucian Arnold. Engineering Magazine Co., 1903.
8. Principles of Industrial Organization.
   Dexter S. Kimball. McGraw-Hill Book Co., 1913.

9. Factory Organization and Administration.
Hugo Diemer. McGraw-Hill Book Co., 1910.
10. Proper Distribution of Expense Burden.
A. Hamilton Church. Engineering Magazine Co., 1908.
11. Production Factors in Works Management.
A. Hamilton Church. Engineering Magazine Co., 1910.
12. Works Management.
W. D. Ennis. McGraw-Hill Book Co., 1911.

APPLIED METHODS OF SUCCESSFUL MANAGEMENT

13. Shop Management.
Fred W. Taylor. Transactions American Society of Mechanical Engineers, June, 1903.
14. Work, Wages and Profit.
H. L. Gantt. Engineering Magazine, 1911.
15. Efficiency as a Basis for Operation and Wages.
Harrington Emerson. Engineering Magazine, 1909.
16. Profit Making in Shop and Factory Management.
Charles U. Carpenter. Engineering Magazine, 1908.
17. Betterment Briefs.
H. W. Jacobs. John Wiley & Sons, 1909.
18. Methods of the Sante Fe.
C. B. Going. Engineering Magazine, 1909.
19. Applied Methods of Scientific Management.
Frederic A. Parkhurst. John Wiley & Sons, 1912.
20. Motion Study.
Frank B. Gilbreth. D. Van Nostrand Co., 1911.
21. Scientific Management and Cost Keeping.
Holden A. Evans. McGraw-Hill Co., 1911.

22. Ford Methods and the Ford Shops.
Horace L. Arnold. Engineering Magazine, 1914.
23. The Practical Introduction of Efficiency Principles.
C. E. Knoeppel. Engineering Magazine, 1914.

MISCELLANEOUS ESTIMATING DATA

24. Radford's Estimating and Contracting.
Wm. A. Radford. Radford Architectural Co., 1913.
25. Handbook of Cost Data for Contractors and Engineers.
Halbert P. Gillette. Myron C. Clark, 1905.
26. Hicks' Builders' Guide.
I. P. Hicks. David Williams Co., 1913.
27. Estimators' Price Book and Pocket Companion.
I. P. Hicks. David Williams Co., 1911.
28. Engineering Estimates, Costs and Accounts.
By a General Manager. Crosby, Lockwood & Sons, 1889.

ANALYSIS OF COST RECORDS

29. Cost Reports for Executives.
Benj. A. Franklin. Engineering Magazine Co., 1913.

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For further reference works, the reader is referred to the bibliography in "Factory Organization and Administration," by Hugo Diemer (reference work No. 9 above). Prof. Diemer gives a brief outline of the subject-matter of various reference works.

In the attempt to keep the present volume *brief,* for convenience of reference, the writer realizes that the treatment of many important propositions discussed by the various able managers and writers has been very incomplete. In fact, in some cases, it has been impossible to convey the main meaning of the authors in this kind of treatment; and the reader is requested to study the books referred to, at some length, for a clearer understanding of their application to the subject of estimating and cost keeping. This request applies particularly to Reference Works Nos. 1, 3, 11, 12, 18, 20.

A detailed method of planning and scheduling by operations is clearly and fully described in Reference Work No. 23, published in *The Engineering Magazine* the latter part of 1914.

A few brief quotations from some of the above reference works will be given, in the hope of emphasizing certain features of the discussion by the weight of well-known authorities of wide experience and unusual powers of accurate thinking and expression, and in the hope of further persuading the reader of the profit to be gained by more extensive study.

## III. Quotations from Authorities

To the majority of contractors it appears to have occurred that there is but one advantage in accurate cost keeping, namely, the ability to predict the value of future work with slightly greater accuracy. The truth is, however, that this advantage is slight, indeed, compared with the discovery of laziness that results from keeping an itemized daily record of costs. I am speaking not only from my own experience, but from the experience of several of the most successful construction companies in America, whose managers have furnished me with many striking examples of reductions in cost effected by a study of the daily records of work done.—Gillette.

There is no question that the cost of production is lowered by separating the work of planning and the brain work as much as possible from the manual labor. When this is done, however, it is evident that the brain workers must be given sufficient work to keep them fully busy all the time. They must not be allowed to stand around for a considerable part of their time waiting for their particular kind of work to come along, as is so frequently the case.

The belief is almost universal among manufacturers that for economy the number of brain workers (or non-producers, as they are called) should be as small as possible in proportion to the number of producers (i. e., those who actually work with their hands). An examination of the most successful establishments will, however, show that the reverse is true.—TAYLOR.

Of all the farces in management the greatest is that of an establishment organized along well-planned lines, with all of the elements needed for success, and yet which fails to get either output or economy. There must be some man or men present in the organization who will not mistake the form for the essence, and who will have brains enough to find out those of their employees who "get there," and nerve enough to make it unpleasant for those who fail, as well as to reward those who succeed. No system can do away with the need of real men. Both system and good men are needed, and after introducing the best system, success will be in proportion to the ability, consistency and respected authority of the management.—TAYLOR.

There is considerable part of the work of most establishments that is not what may be called standard work, namely, that which is repeated many times. Such jobs as this can be divided for time study into groups, each of which contains several rudimentary elements. . . . When some special job, not to be repeated many times, is to be studied, then several elementary items can be grouped together and studied as a whole, in such groups, for example, as:

Getting job ready to set.
Setting work.
Setting tool.
Extra hand work.
Removing work.

And in some cases even these groups can be further condensed.—TAYLOR.

THE COST SYSTEM.—The possibility of ascertaining the cost of the article is often the only thought in the manufacturer's mind when the "cost system" is mentioned, and is accordingly its only function that is developed. In fact, however, the valuable analyses of costs, operation by operation, to be secured from an efficient cost system, supply the manager with invaluable data from which to work in *reducing* costs. Nor does their effectiveness stop there. If it is decided to start a campaign to increase the efficiency of the factory force and to eliminate the inefficient men, then the individual records of the men will be secured from the cost records. In large bodies of workmen a steady and intelligent campaign along these lines will work wonders.

While to some this last point may appear to be an unnecessary refinement, it must be admitted by all that a cost system must provide a method of cost analysis which will unerringly reveal the points of high and excessive costs throughout every stage of manufacture. The failure to accomplish this means the failure of the chief function of any cost system, namely, *making possible the greatest economy in manufacture.*—CARPENTER.

Two fundamental principles of cheap production lie hidden away amongst inefficient shop processes, bewildering disorder of shop conditions, and lax, inaccurate and utterly misleading shop methods. They are of the greatest importance and yet nine times out of ten a searching investigation will prove that little consideration has been given them in ordinary shop practice. They are so closely related that their simultaneous discussion is advisable. They are both essentially "time savers." These two principles are:

(1) The determination of "standard time" for each job and its tabulation, introduction and enforcement.

(2) The absolute elimination from the workman's routine of every duty but that of running his machine

continuously and efficiently; the bringing to him of tools and stock for his next job before he is ready for it.—CARPENTER.

No record can, as a rule, be kept of men doing miscellaneous work unless it is properly planned ahead of time with that object in view. If it is intelligently planned and an increased compensation given for increased efficiency, an improvement will result which will far more than pay for the expense of planning and record-keeping.—GANTT.

If the operation is but seldom done, it may not pay to spend much time training workmen to do it with great efficiency. In this case we should not make the task too severe, but such as a good workman can do without the preparation of special training.

This studying of the elements of a piece of work and setting proper tasks or piece rates, though an important part of any proper system of management, is only a part. The broad problem which includes all others is to develop a system that encourages the study of all operations and adequately rewards all that co-operation [sic] for their continued, efficient performance.—GANTT.

Although in this particular shop—a repair shop for a large corporation—costs had never been considered of commercial importance, it was found absolutely necessary to provide a standard method of determining costs, applicable equally to the five-minute task of a single worker or to a month's output of the whole shop.

Costs can be subdivided into three divisions: (1) material costs, (2) direct-labor costs, and (3) indirect or overhead or surcharge costs, this last division embracing everything that is not material or direct labor. Indirect charges (3) were subdivided into four classes: (1) power, (2) maintenance, (3) rent,

(4) administration. As a general production proposition, there is no difference between a man and a machine, the mere fact that the man is paid wages and the machine is virtually a slave (in which capital is invested, which has to be maintained and which, in time, perishes) being a financial and not a productive difference. Therefore all the expenses of power, maintenance, rent, and administration were subdivided partly to men and partly to machines, thus giving the foundation for a standard cost of any operation for any unit of time. Each of the four subdivisions of overhead or burden was put under the care of a staff specialist.

When a simple system of stating all costs—whether for a single task for man or machine, or for all a man's work for any period, or for all the work of a gang or department, or for a whole plant, is available; when this system permits parallel statement of actual and standard costs—then the whole problem is well-nigh solved, patience, persistence, fidelity, and high ideals accomplishing the results, through the use of staff specialists.—EMERSON.

No matter how minutely subdivided the various records of departmental and other varieties of expense may be for purposes of comparison and localization, this minute subdivision need not in any way at all interfere with utmost simplicity of the double entry accounting records necessary to merge the cost system into the financial accounts.—DIEMER.

There is, however, a growing interest in the recording of basic data and its systematic use in all lines of industrial work. The possibility of successfully planning industrial work rests directly upon the possession of such data. The extent *to which* it *will pay* to plan work in advance will be governed by the regulative principle of the relation between unit cost and volume of product.—KIMBALL.

The aim of time study, planning and standardization is to see ahead—to unfold the mysteries the future holds—to *predetermine*. To check results properly against this predetermination, analysis of the most careful kind is necessary—a work so important as to warrant the statement that the success of the entire undertaking is more or less dependent upon it. A broad experience conclusively shows me that many otherwise excellent betterment campaigns have failed, simply because the right kind of analytical work had not been considered in conjunction.—KNOEPPEL.

The charts shown, along with the others which would naturally suggest themselves to the engineer, should be placed together in a compact space, like a Babson desk sheet. Cost facts, production data, burden, can be charted.—KNOEPPEL.

The use of department, operation and other symbols is necessary to the efficient routing of work by reducing the amount of writing and the space required. It would be a hopeless task to write out in long hand all the documents used in connection with modern management.—PARKHURST.

The main trouble with the majority of departments operating chiefly by manual labor is the lack of correctly determined standards for every move. The solution is motion study, combined with standardized equipment and methods. These standards should include all the elemental operations incident to the equipment, including machines and other kinds of tools. A big step in the right direction will be taken when all machine tool builders (preferably through the Machine Tool Builders' Association) develop and publish a correct set of standard elementary times.

This record should be compiled under one cover and include all types and sizes of machines of all makes. The author hopes to see this same scheme extended to embrace other branches of the trades.—PARKHURST.

COST-KEEPING.—The object of cost-keeping is twofold. It is, firstly, to localize profits and losses, so that the firm may be able with certainty to tell, down to the smallest details, what part of their business is paying them and what part is not. Its object is, secondly, subsidiary to the making of estimates; that is, to give the management accurate and reliable experience of what has in the past been the cost of similar work to that of which it is desired to estimate the cost.

Estimate making, pure and simple, is quite distinct from the determining of the price to be quoted to a customer. When a manager has the estimate before him, the question that he has to ask himself is, What is the greatest price that, considering all the commercial circumstances, can be put on this estimate for profit, so as not only to secure the order, but not to choke off future orders? The maker of the estimate, on the other hand, asks himself what is the probable price for which this can be made in the works (taking into account all the expenses of the establishment of every kind), so as not to lose by executing the order.—BARKER.

In its dealing with the internal affairs of the business, the cost system, to be right and practical, must not merely present fairly true and proved costs of all articles produced (which has long been considered the chief if not indeed the only use of a cost system), but it must present constantly and comparatively pictures of the progress of certain sections of the business, showings of the divisions and departments,

**wastes, variations from the standard of costs of operations of labor and expense. It must, beginning at general or specific totals, be prepared to run back over the ground and show fact and reason, in slightest detail, of differences observed by comparison, or of operations desired for whatsoever reason.—Franklin.**

The peculiar feature which characterizes the Santa Fe methods, and which localizes the interest that the road and its policies hold for students of efficiency in the manufacture of transportation, is the uniform standardization of all operations and all shop schedules for repairs to motive power and rolling stock, and the performance of all work for these accounts under the efficiency system of bonus payment. This covers comprehensively work done in round house, machine shop, erecting floor, blacksmith shop, boiler shop, paint shop, coach shop, car shop, tin and pipe shop, and coppersmith work. About 23,000 operations in all departments are now recognized as standard, but additions are being made. The plan of standardizing these operations contemplates (1) a complete and permanent numbering system; (2) a practical arrangement of the numbered schedules in logical sequences; (3) a complete description of the work included under each schedule in language upon which only one interpretation can be placed; (4) a complete set of sketches showing the construction of all parts, for the instruction of time-keepers, foremen and workmen; (5) a substantial make-up and satisfactory method of reproducing the schedules; (6) a central organization having entire charge of all schedules. While the plan is now in effect in all the departments mentioned above, the schedules are not fully standardized except in round house, car shop and coach shop, the standardized schedules in these three departments numbering about 3,500, 5,000, and 1,500, respectively. The perfection of schedules in standard form, however, is progressing rapidly in other departments, about 25 per cent being now standardized in the erecting shop and from 15 per cent to 20 per cent in the boiler and blacksmith shops.—GOING.

RECORD OF ENTIRE SHOP.—By setting "Standard Time" on each operation performed by each workman, after expert analysis of conditions, a totaling of standard times for all operations of all men and actual times can be determined, showing the efficiency of each shop department and for the shop as a whole. By thus determining the efficiency of different divisions and shops a much better comparison of the amount of work turned out can be reached than by the old haphazard method of counting the mere number of engines or cars repaired. This old method is inconclusive owing to there being no set measure of the amount or character of the work done on each car and engine, nor of the condition of the car or engine when received at the shop and when again placed in service. The attempted classifications of character of repairs now in vogue are mostly based on the amount of money spent, with scarcely any reference to amount of work done. Such methods tend to show for the shop with poor organization and high and inefficient labor costs, a more creditable output than that of a shop with good administration and low and efficient labor costs.

By having centralized supervision of detailed operation cost at each shop, it is mathematically practicable to determine the shop where each class of work can be most efficiently performed and the methods of the efficient shops can be applied to the places whose practice needs improvement.

The system as outlined has reduced the cost of repairs, raised the pay of the workmen, and established the output of the shops.

It is a task in itself to urge and develop practically such methods. It is a greater task to convert others into sympathy and cooperation with new ideas so that the workmen will not feel that it is a scheme to get something from them for nothing and to take away their liberty, but that they may be brought to realize that while the plan helps the railroad it also helps the workmen in a fair proportion.—H. W. JACOBS, in *American Engineer and Railroad Journal*, October, 1907.

Accurate cost keeping is very difficult in a large ship yard, which is engaged both on new work and repair work. There are numerous independent shops in such an establishment which vary greatly in equipment and in the class of products. It is necessary that the costs be known not only by the many jobs included in the whole, but also by shops and by the classes of labor employed. The proper distribution of the overhead burden is also exceedingly difficult.—EVANS.

In repair plants, or in establishments where work of large magnitude is undertaken, which requires several years to complete, as in shipbuilding, it is difficult to compare costs or to measure the output.—EVANS.

## MISCELLANEOUS QUOTATIONS

This question of estimating is a big one, and the writer does not intend here to go into the problems concerned with the manner of making estimates. There are many who believe that it is practically impossible to make any great improvement in the accuracy with which the probable cost of naval repair work can be foretold, placing their opinions on the ground that no two jobs are sufficiently alike to warrant the expectation that past performances can be duplicated in future work. They also point to the fact that it is the unexpected element which so frequently renders final cost disproportionate to the estimate, as, for example, when a boiler, whose condition must be judged from the outside only, is opened up for repairs and found to be in a much worse state than was anticipated.

The writer believes that a close study of this subject will prove that while practically all repairs differ when considered in toto, yet there is some uniformity in the various operations which go to make up various classes of completed work, and that these operations can be, to a certain extent, *classified.* Estimates based upon a series of operations, each of which has a probable cost fixed by experience, should then be more accurate than merely considering the proposed job as a whole.—PAYMASTER CHARLES CONARD, U. S. N., *Proceedings of Naval Institute,* Vol. 137, March, 1911.

Extract from *The Iron Age,* November 5, 1914. "Manufacturing with a Planning Department," by GEORGE DE A. BABCOCK.

An equation for cost is given which represents Cost as composed of the cost of planning plus the cost of operating plus all other expenses chargeable to the order.

Then follows: Since the labor cost of any work is the rate paid labor times the time taken, the combination of these two fundamentals must be carefully considered in estimating from an analysis. The second factor, time, is so usually the unknown and therefore such an uncertain one that managers are inclined to distribute their classes of work on the basis of rate only. This is unsound.

The world lacks woefully information as to unit times for standard efforts. Tremendous inefficiencies exist due to the fact that one manager after another must go to extraordinary costs in securing the same information. This does not in any sense entirely enrich our industrial world, either through capital or labor.—BABCOCK.

Many small engineering shops, dotted about the country, depend mainly upon jobbing and repair work for a living. The majority of these concerns are old-fashioned in every sense of the term, the principles, foreman, workmen, methods and equipment being entirely out of date when compared with a modern machine shop. The standardization and systematic manufacture of machinery—which has now become almost universal—tends to benefit these jobbing and repair shops, as such work cannot be profitably carried on in conjunction with systematic production of standard machines or appliances. On the other hand, competition has seriously affected the prices obtainable for odd work, and estimates from several firms are demanded where open orders were given out a few years ago. Furthermore, correct estimation of such work demands good judgment, as figures for previous jobs of a similar character are seldom available in a usable form, hence prices are, to some extent, guessed at and are hopelessly wide of the mark. This contention is amply supported by the estimates sent in for comparatively simple jobs, the highest being generally double the lowest, whilst the latter is not infrequently below cost price when standing charges have been adequately allowed for. The effect of such estimating is naturally to lower prices for everyone concerned, and it is generally traceable to lack of system in connection with the accounts of the lowest tender.—W. O. HORNSNAILL, in "A Simple System for Jobbing and Repair Shops," in *The Engineering Magazine.*