nuisance of excessive noise, does not reduce vibration or unevenness of motion.

There is a limit to the pitch-line velocities at which spur gears can be operated beyond which it is unsafe to use them. This limit is far below the minimum velocities which can be used in connection with steam turbines of economical design and high power.

Accurate herringbone gears operate quite smoothly at velocities which are impossible for other types. This feature would appear to reserve for them a field of application which has great possibilities and is likely to cause some great changes in the standard practice of to-day.

# EXPENSE BURDEN: ITS INCIDENCE AND DISTRIBUTION[1]

## BY STERLING H. BUNNELL

Almost any engineering construction can now be produced with materials and methods in easy reach. The question, "Can it be done?" has given place in importance to "Will it afford an attractive return on the investment?" The engineer must now master the problems of financial operation, the principles of estimating correctly and providing for fixed charges, as well as operating expense, and all the other details of accounting required for the continued successful operation of an enterprise.

By far the most difficult of the problems presented for joint solution by the engineer and the accountant is that of the distribution of factory burden on correct principles. The usual method adopted for carrying out the calculation has been to distribute the expense either as a percentage to cost of labor, or as an hourly charge to be added to the wages cost of every hour's labor performed. Where this conception and practice exist, every bill that happens to be paid in a given month, or at the best, every charge incurred during that month, is regarded as expense to be distributed over the product of that month. If something breaks down and is repaired at heavy expense, the goods cost more that month because of making the repairs at that particular time. Accounting of this character has made it possible to operate many a factory at a huge profit, until the economically worn-out shell could be unloaded on some capitalist innocent enough to dispense with engineering advice, and purchase on the book figures of past operation.

The basis of this scheme of distributing burden by scattering it as evenly as possible over everything in sight, is the wholly erroneous conception that all the operating expenses of the factory can be divided into two classes, productive and non-productive, the first including all useful work on the manufactures to be sold later, and the second all waste, a dead loss to the organization. The logical development of the theory teaches that the ratio of non-productive to the productive expense should be kept as low as possible; the best manager is he whose expense ratio is the lowest; and increase of expense ratio by high-powered machinery, trained helpers to save the time of skilled workers, and liberal outlay for good tools and their upkeep, causes loss. The absurdity of the conclusion and therefore of the premise, is evident. No legitimate expense is truly non-productive, and some other definition must be found for the expense burden in order to indicate its true significance.

The ratio of indirect or direct expense is no indication of the efficiency of the management, except as between two precisely similar operations. In fact, a high ratio of direct to indirect may indicate extreme inefficiency, exactly the opposite of the accepted belief, and this under widely differing conditions; for instance, with a badly managed shop where every man charges his full time direct to a product, and runs his own errands or serves as his neighbor's helper on

[1] Paper (slightly condensed) read before the American Society of Mechanical Engineers, New York, Dec. 6, 1911.

occasion; or, on the other hand, with a factory equipped with automatic machines under the care of skilled men whose time is charged direct to the cost of product.

Experience with the cost accounts of factories and shops covering a wide range of manufactures shows ratios of indirect to direct varying from 20 to 150 per cent; and even higher percentages would not necessarily be surprising or discreditable to the management. The introduction of scientific management always increases the ratio of indirect to direct expense, and yet decreases gross cost as well as prime or direct cost. High indirect and low direct costs are to be expected with modern equipment, even without scientific management. Heavy cuts by a powerful machine tool in charge of an efficient semi-skilled man at usual day wages often involve an operating cost of $1 per hour for the machine (an item of the expense account), against a direct wages cost of 30 cents for the man, a ratio of 330 per cent. Whenever, as in this case, the direct cost is a mere fraction of the expense burden, to keep accurate costs of the labor and material items only is nothing less than absurd.

Scientific management, while increasing the ratio of indirect to direct expense, decreases direct expense in greater proportion. The net saving cannot therefore be ascertained except by accurate knowledge of the details of each class of expense. This knowledge must be continuous, always at hand for instant use. The exact result of each new task-setting operation, change in method, and improvement in equipment, not only in regard to the wages and supplies of to-day, but also with respect to the operating expense accounts of the month and the fixed charges of the year, should be known in detail and at once. These requirements can be met only by a clear and comprehensive analysis of the true incidence of the fixed charges, and of the indirect details of operating expense, followed by the introduction of methods by which each item of factory product may be charged with that proportion of the indirect expense which corresponds to the cost of maintaining the shop facilities used in performing the manufacturing operations upon that item. The same degree of precision obtained in charging to the cost of work the direct expense for material and labor, should be reached in charging the large and important indirect expense.

The first step in the solution of the problem is to analyze the data and conditions. Of the items which go to make up indirect expense or factory burden, some of them are observed to have a very clear incidence upon definite points within the factory. Consider the annual interest on the value of a factory building. Surely it will not rise with an increase in wages or cost of material; nor with an increase in output; nor does it concern anything which takes place in some other building. The building is there to serve a useful purpose; and whatever benefits by that purpose should pay its share toward the interest on the cost of the building. The purpose is evidently the housing of machines and their operators, each of which machines forms a unit in the productive scheme of the factory. Let the building be divided accordingly (by imaginary lines) into productive units, and require each to earn the interest on that part of the whole building which is occupied by the equipment, operator and work in progress, of the unit.

Once attacked from this point, the problem of a correct distribution of expense burden becomes easy of solution. The first step in the process is to obtain a schedule of annual fixed and operating expense. This includes the reserves for interest and depreciation, taxes, insurance and other fixed charges, a reasonable allowance for the expected average repairs, and the expense for supervision, small tool upkeep and power cost. Each of these charges is to be split up and apportioned among the particular productive units to which it belongs, the total to be carried as an element of the cost of that part of the factory product which passes through that particular productive unit during the year. The incidence of each detail of the burden being clearly on the productive unit, which comprises equipment, accessories and a portion of the building and land, the whole of the annual charge has as direct an incidence on the work passing through the production center in the year as the wages of the operator on the equipment of the center. The labor cost is the amount paid the operator, on day, hour, piece, premium, bonus or whatever system is used. The equipment cost is a suitable fraction of the annual burden. As most of the burden elements (interest, taxes, etc.) have a time factor, it is convenient to reduce the annual charge to an hourly rate, and to make the charges to cost of work on the same time units that are provided by the work records of the operatives.

TABLE I.—SCHEDULE OF EXPENSE.[2]

| | |
|---|---|
| Interest on Land and Building | $50.00 |
| Depreciation, 2½% on $1,000 Valuation | 25.00 |
| Taxes, 1% on $1,000 | 10.00 |
| Insurance, per year | 5.00 |
| Heat and Light, Share of this Building | 50.00 |
| Building Repairs estimated at | 25.00 |
| Total Building Charge | $165.00 |
| Interest on Equipment, 5 per cent on half new value | $168.25 |
| Depreciation, per schedule | 407.00 |
| Taxes, 1% on assessment | 39.00 |
| Insurance | 35.00 |
| Total to Distribute to Equipment | $649.25 |

[2]A unit value of $1,000 for land and building and a new cost of $6,620 for equipment are taken as a basis for these estimates.

In the practical application of this system of apportioning expense burden, several interesting conceptions have been brought out. The labor of calculation is reduced by following a standard procedure, commencing with the schedule of expense, Table I. The items belonging to the land are first grouped, and divided by the square feet of occupied land to obtain a land factor in dollars per year per square foot of land. Next, the portion of land belonging to each building is tabulated, and the area of each portion in square feet is multiplied by the land factor to give the total land charge for each building. This forms the first element of burden for the building. The interest, taxes and insurance are calculated on the book value of the building; the annual cost of heat and light are computed and the items totaled to obtain the annual building factor, and divided by the floor area of the building to give the square foot factor. The next step is a map or diagram showing each production center with its working floor space, including erecting floor spaces, benches, and all equipment on which men are employed or operations performed. The centers are then to be tabulated in order by departments as in Table II, with the appraised value and square feet of floor space occupied by each. Multiplying the latter by the square foot factor, the total building factor of each productive unit is obtained.

Accessory equipment goes with the producing machine of each production center, that is, shafting, belts, all or a share of a motor, small tool equipment, and the like. The value of such equipment is generally much less than the value of the principal machine, so that absolute accuracy in apportioning accessories is not essential. If the value is very small, it may be divided among the units in proportion to the value of their producing machines; if large, shafting and belts may be apportioned to the units on the basis of the floor space occupied by each, motors driving groups on the basis of the working horsepower-hours of each productive unit, and small tools by judgment. If the greatest accuracy is desired, the accessories may be treated separately and each one measured, appraised and assigned to the productive units accordingly.

The remaining calculations are carried out for each unit independently, including the value of the accessories with that of the main machine. A depreciation rate is set for each unit, or class of machines, and the corresponding annual charge is computed. Interest on the value of the machine, taxes and insurance are also provided for. All these are definite quantities, not open to argument. There remain certain items not as definite: power cost, repairs, general labor, factory supplies and (in a machine shop) cost of tools, each of which requires special treatment. Power, if it could be metered separately to each productive unit, would become a direct charge; but as this is impracticable, and the power cost is not of the greatest magnitude, a reasonable approximation can be made by estimating the average power consumption, the average running time, and so the average annual horsepower-hours of each unit, and multiplying by the cost of a horsepower-hour to obtain the power factor of the burden charge. Supplies and general labor are best divided by estimate and judgment. Repairs to the individual units cannot possibly be foretold; but the average total repair cost of the plant, or even of the several departments of the plant, can be estimated with some degree of precision, and distributed to the productive units in any of several ways. Perhaps the most practicable is to set by estimate figures representing the probable proportion of repairs likely to be required by each kind of machines, placing 1 opposite the machine likely to require the least expense for upkeep, 2 for those machines likely to require twice as much expense, and so on. By adding these figures for a denominator and using each figure separately for a numerator, the total estimate for repairs can be divided up among the several units. There is no advantage for cost-keeping purposes in attempting to charge the actual cost of repairs into the

## TABLE II—DEVELOPMENT OF BURDEN CHARGES.

| Equipment Number | No. of Machines | Description of Equipment | Equipment Appraisal: New Value: Each | Equipment Appraisal: New Value: Total | Equipment Appraisal: Life: Age | Equipment Appraisal: Life: Future | Building Factor: Sq. Ft. | Building Factor: Charge | Power: Estimated H. P. Indiv. Motor | Power: Estimated Running Time | Power: H. P. Ratio | Power: H. P. Hours | Power: Charge | Share of Accessories Value: Motor (on H. P.) | Share of Accessories Value: Small Tools and Grinders: Ratio | Share of Accessories Value: Small Tools and Grinders: Charge | Share of Accessories Value: Shafting and Furniture (on Sq. Ft.) | Present Value of Equipment | Total Value Accessories | Interest, Taxes and Insurance (on Total Equipment and Accessories) | Depreciation | Repairs: Ratio | Repairs: Charge | Total Columns 9-14-21-22 and 24 | Foreman and Helpers | Total Annual Burden Cols. 25 and 26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| 1634 | 1 | Engine lathe, 16 in. by 6 ft., 8 in. chuck | $350 | $350 | 10 | 10 | 45 | $6 | 2½ | 2400 | 6000 | 2480 | $29 | $27 | 7 | $25 | $15 | $175 | $67 | $14 | 23 | Repairs apportioned by judgment, and include small tool repairs. | 19 | 91 | 135 | 226 |
| 1635 | 1 | Engine lathe, 13 in. by 5 ft., 6 in. chuck | 300 | 300 | 10 | 10 | 60 | 8 | 2 | 2400 | 4800 | 1990 | 24 | 18 | 7 | 25 | 20 | 150 | 63 | 12 | 20 | | 16 | 80 | 135 | 215 |
| 1636 | 1 | Milling machine, 6 in. vise | 600 | 600 | 10 | 10 | 138 | 17 | 2 | 2000 | 4000 | 1650 | 20 | 18 | 10 | 36 | 46 | 300 | 100 | 24 | 39 | | 33 | 133 | 112 | 245 |
| 1637 | 1 | Driller, 10 in., 15 in. swing | 125 | 125 | 20 | 10 | 61 | 8 | ½ | 2400 | 4200 | 493 | 6 | 4 | 5 | 18 | 20 | 42 | 42 | 5 | 8 | | 7 | 34 | 135 | 169 |
| 1638 | 1 | Driller, 11 in., 24 in. swing | 175 | 175 | 20 | 10 | 77 | 10 | 2 | 2400 | 4800 | 1980 | 23 | 18 | 5 | 18 | 25 | 58 | 61 | 7 | 11 | | 10 | 61 | 135 | 196 |
| 1639 | 1 | 4 Spindle drill | 200 | 200 | 20 | 10 | 63 | 8 | 1 | 1000 | 1000 | 413 | 5 | 10 | 5 | 18 | 21 | 57 | 49 | 7 | 11 | | 42 | 42 | 56 | 98 |
| 1640 | 1 | 1½ Milling machine | 530 | 530 | 10 | 10 | 99 | 12 | 2 | 1800 | 3600 | 1480 | 18 | 18 | 10 | 36 | 33 | 265 | 87 | 21 | 34 | | 29 | 114 | 102 | 216 |
| 1641 | 1 | Screw press | 50 | 50 | 10 | 10 | 16 | 2 | .. | .. | .. | .. | .. | .. | .. | .. | 5 | 25 | 5 | 1 | 3 | | 3 | 9 | .. | 9 |
| 1642 | 1 | Shaper, 15 in. stroke, 8 in. vise | 330 | 330 | 10 | 10 | 16 | 2 | 2 | 1800 | 3600 | 1490 | 18 | 18 | 3 | 11 | 5 | 165 | 34 | 12 | 19 | | 18 | 69 | 102 | 171 |
| 1643 | 1 | Milling machine, small | 350 | 350 | 40 | 5 | 30 | 4 | ¼ | 1000 | 250 | 103 | 1 | 2 | 6 | 22 | 10 | 29 | 34 | 4 | 12 | | 19 | 40 | 56 | 96 |
| 1644 | 1 | Universal grinder | 250 | 250 | 15 | 10 | 36 | 5 | 2 | 100 | 200 | 83 | 1 | 18 | 4 | 15 | 12 | 100 | 45 | 8 | 14 | | 14 | 42 | 6 | 48 |
| 1645 | 1 | Screw machine | 550 | 550 | 20 | 10 | 25 | 3 | 2½ | 500 | 1250 | 501 | 6 | 26 | 7 | 25 | 8 | 183 | 59 | 14 | 23 | | 30 | 76 | 28 | 104 |
| 1646 | 1 | Cutter grinder | 150 | 150 | 20 | 10 | 30 | 4 | ¼ | 100 | 25 | 10 | .. | 2 | 3 | 11 | 10 | 50 | 23 | 4 | 7 | | 8 | 23 | 6 | 29 |
| 1647 | 1 | Surface grinder | 150 | 150 | 10 | 10 | 30 | 4 | ⅜ | 1000 | 375 | 155 | 2 | 4 | 1 | 4 | 10 | 75 | 18 | 6 | 9 | | 8 | 29 | 56 | 85 |
| 1648 | 1 | Surface grinder, small | 125 | 125 | 10 | 10 | 20 | 3 | 1-16 | 500 | 31 | 13 | .. | 2 | 1 | 4 | 7 | 63 | 13 | 5 | 8 | | 7 | 23 | 28 | 51 |
| 1649 | 1 | Polishing lathe | 30 | 30 | 20 | 5 | 35 | 4 | ⅛ | 500 | 62 | 26 | .. | 2 | 3 | 11 | 12 | 6 | 25 | 2 | 6 | | 2 | 14 | 28 | 42 |
| 1651 | 1 | Small forge and equipment | 40 | 40 | 10 | 10 | 35 | 4 | ¼ | 750 | 188 | 78 | 1 | 2 | 1 | 4 | 12 | 20 | 18 | 2 | 4 | | 2 | 13 | 42 | 55 |
| 1653 | 1 | Power hack saw | 40 | 40 | 10 | 10 | 35 | 4 | ¼ | 500 | 125 | 52 | .. | 2 | 2 | 7 | 12 | 20 | 21 | 2 | 4 | | 2 | 12 | 28 | 40 |
| 1654 | 1 | Speed lathe, 12 in. by 6 ft | 75 | 75 | 10 | 10 | 48 | 6 | ⅛ | 300 | 38 | 16 | .. | 2 | 4 | 15 | 16 | 38 | 33 | 4 | 7 | | 4 | 21 | 17 | 38 |
| 1655 | 1 | Lathe, with collets and turret attachment | 300 | 300 | 10 | 10 | 66 | 8 | 2 | 1000 | 2000 | 825 | 10 | 18 | 10 | 36 | 22 | 150 | 76 | 13 | 22 | | 16 | 69 | 56 | 125 |
| 1656-1650 | 4 | Rivet bench lathes | 450 | 1800 | 10 | 10 | 92 | 12 | ⅛ | 4800 | 600 | 250 | 6 | 9 | 32 | 116 | 31 | 900 | 156 | 64 | 105 | | 98 | 285 | 917 | 602 |
| | | Bench space for two men | .. | 100 | 10 | 10 | 255 | 31 | .. | 4800 | .. | .. | .. | .. | 12 | 43 | 83 | 50 | 126 | 11 | 18 | | 5 | 65 | 270 | 335 |
| | | Totals | | 6620 | | | 1312 | $165 | | | 34,144 | 14,088 | 170 | 220 | 138 | 500 | 435 | 2931 | 1152 | 242 | 407 | | 361 | 1345 | 1850 | 3195 |
| | | Accessories | | | | | | | | | | | | | | | | | | | | | | | | |
| 1650 | 1 | Wet grinder, 12 in | 80 | 80 | 10 | 10 | 34 | | | | | | | | | | | | | | | | | | | |
| 1652 | 1 | Grindstone | 30 | 30 | 10 | 10 | 61 | | | | | | | | | | | | | | | | | | | |
| | | Shafting, $180; trucks, etc., $200 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Storage space | .. | .. | .. | .. | 62 | | | | | | | | | | | | | | | | | | | |
| | | Totals | | 6730 | | | 1469 | | | | | | | | | | | | | | | | | | | |

operating expense of each unit. In repairs for lightning and the like, which generally strikes without warning, there is no reason why the expense burden and therefore the cost of work done by one of several similar machines should be temporarily increased merely because that machine suffered breakage and was repaired at this particular time. Standard power and repair costs are a great help in rational cost-keeping, since they minimize fluctuations in cost not due to difference in management. By opening separate repair accounts, charging these accounts with actual cost, with all its momentary variations, and crediting the standard estimates, the varying balances tell an interesting story of the work of the repair gang, and keep the fluctuating costs of repairs from exerting a disturbing influence on the cost of product. A power-plant account similarly operated is also very useful.

The tabulation now includes subdivisions of all the expenses which go to make up the factory burden, up to the point at which the completed goods leave the factory, but exclusive of the administrative expense. If the total burden chargeable to each unit is divided by the respective annual working hours of the units running full time, an hourly rate for each productive unit will be obtained, which, if applied to the cost of the work done by each unit, will in a normal year of full working time accumulate a credit which will balance the shop expense burden. There are, however, many lost hours in the course of the working year and such losses reduce the credit which is to stand against the annual shop burden, and tend to produce a deficit. Short time may be due to any of three causes, each of which gives to the resulting deficit a different significance. In the ordinary operation of a factory, time is lost by the productive units through illness of operatives, changes in the force, breakages and repairs, and lack of capacity in other units. Obviously, a deficit in the credit against burden due to losses of this character is a manufacturing expense, and should be distributed to the cost of work.

Lost working time, however, may be due to sales department conditions, as when machinery is installed for the manufacture of goods which have a seasonable demand, so that they can be sold during only part of the calendar year. A deficit due to lost time of this character is selling expense, and not part of manufacturing cost. In such a case, the sales department undertakes to earn, through profit on the sales, the necessary amount to pay for the use of the capital invested in the equipment over the period of idleness. The manufacturing cost cannot be increased merely because consumption ceases after a time, so that the machines have to be stopped. If it costs $1,000 to operate equipment for three months, and another $1,000 for the following three months, it is not to be supposed that it costs $2,000 to operate for the first three months only. Factory product can be made continuously, stocked up during an idle period, and sold at the proper time; if such a course is inadvisable, by reason of tying up capital, or loss of interest on the money represented by stored goods, or risks taken, the expense of intermittent operation falls outside of the manufacturing account. Admittedly, someone must pay the fixed charges for each period of idleness; but the party liable in cases of the kind supposed, is not the works manager, who would be glad to operate continuously, but the selling division of the organization, which must take the consequences of sales conditions. Correct accounting practice will not justify the distribution of selling expense to goods before they are sold; wherefore, manufactured goods should not be placed in stock with a burden allowance which includes selling expense, though it is quite proper to include all other items of burden.

The third possibility of the deficit due to lost time is that it is a consequence of bad trade conditions. Lost time of this character is neither manufacturing nor selling expense, but a business loss which should be made up out of the profits of good years. Conservative management accumulates a surplus to give stability to the rate of distribution to the stockholders, by reserving a portion of the earnings of good years to be used in maintaining dividends in times of depression. With correct methods in distributing factory burden, the loss due to short time operation, usually buried out of sight among other expenses which have no relation to running time, is clearly shown, so that an appropriation may be made from the surplus account to carry the deficit of poor years by the extra earnings of good years.

The divisor used on the annual burden of each unit should therefore be less than the full annual shop hours, at least by a suitable allowance for holidays and other lost time. In the case of a large special machine for which there is work only part of the time, the expected working hours only should be used as a divisor, for such a unit, to be profitable, must earn its annual charges in the running time which can be given it. Whenever conditions change so that such a unit can be operated a larger proportion of the time, the hourly charge should be correspondingly reduced.

There remain some items like salaries and office expense, the incidence of which cannot be traced to definite productive units. This class of expenses, however, is incident to the operation of the factory as a whole. The larger productive units, with their greater capital value and heavier operating expense, involve a greater tax on the management and administration than the smaller units. The burden charges belonging to the units provide a very fair measure of the responsibility of the management in connection with each, and serve well as a basis of distribution of the overhead charges. It is proper, therefore, to express the overhead expense total as a percentage of the total burden distributed to all the productive centers together, and to raise the hourly rate of each unit by the same percentage. Thus, if $100,000 is distributed to centers, and there is an undistributed overhead of $10,000, the rates can be raised 10 per cent, which will provide for carrying the whole $110,000.

Each productive unit of the factory is thus valued at an hourly rate which is to be charged in the cost of each operation performed by the unit. The total cost of an operation accordingly consists of a labor charge and an equipment charge. The basis of each machine rate is a careful investigation of the operating costs of the particular machine, so that the rates set are in accordance with the facts in each case. Whatever fluctuations there may be in operating expense are likely to balance each other above and below the calculated charges. But as there will be some variation in any event, it is permissible to obtain the advantage of easy calculation by equalizing the machine rates into two, three or more round figures, each covering productive units whose exact rates fall near together. On the job-tickets by which the time or piece price of the labor is computed, a space should be provided for the burden figure, so that the completed job-tickets will give both elements of the cost. Any change in methods or men will now indicate its complete result by a comparison of the job-tickets for the same work done under former and present conditions.

The accounting detail of the expense burden distribution is simple and effective. A burden distribution account is opened, to which is charged the calculated amounts of Table I. The account is credited with the total of burden charges to cost of work, by weekly or monthly periods. The balance indicates the loss by failure to utilize the full capacity of the factory; while a credit balance, if one should occur, indicates a condition of unexpectedly good management, or good luck, by which the factory has worked to better advantage than was believed probable. A standardizing account of this kind is very useful to the management. All the variable expense accounts can, if desired, be handled as suggested for power and repairs, so that uniform credits offset the varying debits, and the balances afford gages for the efficiency of the control of the departments originating the accounts.

A constantly increasing balance in one of the expense accounts will occur if there has been a permanent change in policy with respect to this item. In such a case, it will be necessary to change the equipment rates affected by this change. While it is not at all difficult to go over a column of the tabulation and revise the figures, it will generally be sufficient to change the rates by proportion, enough to absorb the difference. But it is not necessary to distribute all the burden by machine rates. The overhead of salaries and office expense, the cost of storage and handling, and, if desired, any small difference in burden actual and distributed, may be distributed as a rate per pound on a homogeneous product, or as a rate per order if orders are all of the same size, or as a percentage of gross cost, if that seems the most reasonable method. In every factory, careful analysis of the facts will point out the true incidence of expense due to factory operation, or factory product as a whole, rather than individual production centers.

A valuable result of localizing variations in expense burden is stability in the cost of the manufactured product. Because a repair force is discharged to save expense, and everything is allowed to fall into bad order, is no reason why the cost of goods made during the period should appear to decrease. The management is in effect borrowing part of the cost from the stored energy of the organization, or discounting the future. All fluctuations not directly due to a change in manufacturing methods are objectionable if carried into cost of product. Where the cost of similar articles varies uncertainly from day to day, each fluctuation is likely to have a different cause, much time is taken in searching for the causes, and incorrect conclusions are often drawn, or it is assumed that some unknown and unusual condition is responsible, and the attempt to trace the cause is given up. Increased labor cost is easily discernible and can be traced directly to its origin. Variations of material cost are quite as easy to explain; but where burden charges vary with labor charges, under the old percentage or hourly rate methods, a change in cost of labor involves a totally unrelated change in the burden charge, and no clear conclusion can be drawn.

Exact calculations are at the base of all well-planned engineering work. Exact uniform methods of cost calculation should be at the base of all factory accounting systems. Wherever associations of manufacturers operating on similar work have investigated the cost-keeping methods of the various factories, the investigators have been surprised to note the wide variation between the apparent or book cost of the same products, made under the same conditions, but figured in different ways. The inevitable result is that some factories bid for work below cost, and thereby injure the business chances of all. The remedy is not the maintenance of unduly high prices by agreement, thereby inviting competition from every outside shop; but an exact analysis and apportionment of the expense burden in such a way that each item of factory work will be properly charged for the use of that portion of the shop equipment and facilities which is devoted to it, and the true margin of profit between cost and selling price will be clearly apparent.

# CONVEYING AND ELEVATING MACHINERY, ITS COST AND COMMERCIAL VALUE[1]

BY REGINALD TRAUTSCHOLD, M. E.[2]

## IV.—BUCKET ELEVATORS

### Capacities—Economic Speeds—Horsepower Requirements—Cost of Operation—Maintenance and Burden—Net Operating Costs

The oldest, commonest and perhaps the most logical method employed for elevating materials is the bucket elevator, a system consisting fundamentally of an endless chain or belt to which buckets are attached at various points—sometimes spaced at appreciable distances and again in close succession. Such systems are in universal use for handling materials in bulk, such as coal, grain, stone and other building materials, and in fact almost every conceivable substance—not excluding water and other liquids. Modifications of these simple types are also used for handling materials in boxes, barrels, packages, etc. These more elaborate systems are often equipped with various devices for loading, delivering and handling the load in ways fitted to particular or local conditions. In this discussion, however, only the simpler forms of bucket elevators will be considered —those for handling grain, coal and other materials in bulk.

These simpler forms of elevators may be divided into three classes: (1) Those in which the buckets are attached to a single strand of chain; (2) those in which the buckets are attached to two matched strands of chain; and (3) those in which the buckets


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