DIAGRAM ACCOUNTS FOR ENGINEERING WORK.

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In engineering establishments few things are of more importance than a ready and accurate system of Prime Cost Accounts. By promptness and accuracy in ascertaining cost, the net result on the completion of every contract or piece of work done is at once brought clearly before the management; and the profit or loss shown serves as a guide for the acceptance or rejection of other contracts or other work. Usually the elimination of unprofitable orders and the cultivation of profitable work, directed by actual knowledge of cost, are alone more than sufficient to justify the comparatively small expenditure involved. The requisites of a good cost system may be summarised as follows; and they form the foundation of such a plan of Diagram Accounts as it is the purpose of the present paper to describe.

Firstly, costs should always be posted closely up to date. The requisite data are practically complete at the close of every day's work. They should therefore be posted under all their subdivided heads not later than the next day. The posting is more easily done the next day than at any subsequent time; and mistakes promptly discovered may be corrected with far less trouble and loss of time than if a week has elapsed since their occurrence.

Secondly, the system should be one of balance. The total wages and total store issues and incidental expenses should balance the prime cost of all the work done for customers, for repair and maintenance, and for improvement or extension; and each of these items should be quite distinct by itself.

Thirdly, it should indicate at a glance probability of error, if error exists; and much may be done in this way, in regard both to

labour and to store issues. The ability to detect errors is of far more value than the mere correction of an individual error as it occurs. The occasional discovery of error by a process probably unknown except in the office, or even the occasional demand for an explanation of deviations from ordinary practice, produces a degree of care and a habit of accuracy in making the primary returns, which is a great benefit in itself, and which without such help it is difficult to secure.

Fourthly, a charge should be included for the use of every machine employed. Work which involves the use of costly machinery should not be simply compared with other work involving perhaps equal labour but not requiring the same use of machinery. The capital value of the machine, its depreciation, the power required to drive it, and the space it occupies in the shop, are all elements of cost, which should be apportioned with careful consideration of their incidence. Moreover machine time-boards present the further advantage of showing whether the machinery has been kept fairly employed while there was work suited for it to do. It can also be seen what class of machines may be deficient in number, as compared with other classes. The machinery employment diagram, Fig. 1, Plate 95, shows the percentage of the actual earnings of each class of machines, compared with their possible earnings. The straight line at top representing 100, it is seen that the lathes, indicated by the uppermost of the fluctuating lines, average here nearly 95 per cent. of their possible earnings; next below come the boring machines at about 70 per cent.; and lowest are the planing machines, averaging less than 50 per cent. of what they might do in full work.

Fifthly, manufacturing and commercial trading should be kept distinct. If certain work is to get the benefit of good purchases in a rising market, and other work to be handicapped by bad purchases in a falling market, an element is introduced into the costs which should not exist therein; variation and confusion are produced in what ought to be uniform and simple. Trading profits or losses should be confined to the commercial books; manufacturing profits or losses alone should be entered into the cost books.

Since the introduction of the steam-engine indicator the performances of engines have been exhibited diagrammatically; and from the indicator diagram the horse-power is reckoned out in figures. But for enabling engineers to judge of their economy, the form of the drawn diagram is of greater importance than the arithmetical figures deduced therefrom. The diagram reveals at one view the whole performance; and upon it may be superposed a theoretically perfect diagram, bringing out every deviation and its effect. Precisely what an indicator diagram does in exhibiting the performance of a steam engine, a set of properly constructed account diagrams will do in disclosing the economic working of a manufacturing concern, in all that pertains to the actual manufacturing costs.

From the several lines of an account diagram adequately filled up may be deduced a closely approximate single line pointing directly to a graduated scale of greater or less profit or loss. Waiting till the close of the year for a balance sheet, produced too late for practical effect, is by no means a satisfactory course; the balance of profit or loss at the year's end is merely an aggregate of items arising day by day. If the exact tendency of this aggregation is displayed day by day or at short intervals, for the guidance of the management, a most important advance is realised.

The varying results of five or ten years' work can be exhibited upon a single sheet in a few lines, the direction of which indicates their import. Thus the diagram, Fig. 2, Plate 95, presents a review of nine years' work, in which the top fluctuating line UU indicates the actual invoice price of the output, when corrected for variations in rate of wages, in price of materials, and in outward selling prices. Replacing this fluctuating line by a horizontal straight line denoting 100, the percentages which the several charges bear to the output are plotted from the zero or base line: namely the machinery charges MM, the establishment charges EE, the wages WW, and the stores issues SS. The sum of these added together gives the line TT of total costs; and the interval between this line and the straight line denoting 100 represents the percentage of profit where below

the straight output-line, and the percentage of loss where the total costs exceed the output, as they are here seen to do in the fourth and fifth years. Not only does such a review furnish data of great value for comparison with present operations, but it fixes in the mind broad general principles of practical importance in regulating future work.

In some exceptional cases these principles seem opposed to what appear to be the most obvious economic considerations. For instance, on a particular contract a heavy loss had been sustained in a bad year. Under such circumstances the first thought would naturally be that such a contract should be avoided in the future. When however the year's accounts were thrown into diagram form, and a comparison of results was instituted, it became at once apparent that without this losing contract the bad year's loss would actually have been increased. An illustration of the possibility of such an occurrence is shown in the diagram, Fig. 3, Plate 96. Here the line UU represents the invoice price of the output, and TT the total costs including establishment charges. The proportion of establishment charges absorbed by each contract is shown by the line AA; and the apparent profit or loss shown by the cost books is plotted in the line LP. A circle drawn from the datum line at the first contract and again at the fifth shows the relation which the charges absorbed bear to the apparent loss on each of these contracts; and discloses the fact that, while an absolute loss was sustained on the first contract, a relative loss only was incurred on the fifth, on which the establishment charges bore a larger proportion to the whole. That is to say, in the absence of this fifth contract the establishment charges absorbed by it would to a large extent have fallen upon the other contracts, diminishing the profit or increasing the loss on each, and resulting in a worse total for the year than that produced when the fifth contract is included.

If a case could exist in which the profits of manufacturing some special article were approximately uniform, manifestly the absolute amount of profit would depend on the output of work; but then, the sunk capital being a fixed quantity, the rate of profit would obviously

not be uniform. Similarly it might perhaps be imagined that, if half the normal quantity of work be done, an approximation to accuracy of estimate might be obtained by doubling the proportion of the fixed charges for rent, rates, insurance, depreciation, salaries, and other incidental expenses; but almost any one who has not made a special study of the matter would be surprised to find how wide of the mark such an estimate would be. The following illustration is derived from facts of actual experience. In successive periods of abundance and slackness of work, where the work and management continued of the same character, less than £30 of wages usually completed £100 of finished work in the brisk times, 'as shown for the first period plotted in Fig. 4, Plate 96. Here the actual invoice price of the output is indicated by the line UU; and replacing it by the horizontal straight line marked 100, the line WW is plotted to represent the percentage of wages on output. The vertical scale for the output has been altered, and the years have been transposed and combined, so as to get a continuously falling line for the output; and corrections have also been made for varying conditions. The wages line WW is then a continuously rising line, until in the slackest period the wages were more than doubled for the same value of output, while the rate paid per man in the slackest period was actually less than in the busiest. In other words, in the same factory and under practically the same conditions a workman turned out five finished articles at higher prices when there was plenty of work, as against little more than half the quantity at lower prices when work was slack. In the latter case loss is almost inevitable.

In this connection there is one consideration which must not be lost sight of: namely, that the percentage of labour cost to the total cost of finished work is dependent both on the wages paid and on the works charges and on the store issues; and that the percentage of the works charges is diminished in brisk times, while that of the store issues may be considerably increased. For instance, it is possible to buy forgings either finished or rough. With abundance of work in hand it may be expedient to buy in as finished a state as possible; and in slack times to

do all possible work in one's own shop. The effect is to pass through the store issues to finished-work account a high-priced article when bought in the finished state, and the same article at a low price when bought in the rough; and thus to disturb the percentage of labour. Having examined individual cases however, the author is satisfied that this consideration by no means accounts for the discrepancy pointed out. To what extent the latter may be explained by the supposition that workmen do not like to complete a job without prospect of more to follow—or how far it may arise from the necessity, when there is little work, for more change of job, by employing a man upon a variety of work instead of continuously upon one kind; or how far the mere emptiness of the shop may give increased opportunity for skulking; or how far disheartening influences may unconsciously sap normal energy—it is perhaps both hopeless and useless to enquire. Under these circumstances it may probably be hopeless to ask for higher prices; but it is worse than hopeless, it is ruinous, to attempt to reduce loss by restriction of output. The remedy, whether practicable or not, would lie in the opposite direction. At all times therefore it is of the highest importance that the manager should have before him in the most simple and intelligible form the facts which day by day go to form an aggregate of prosperity or adversity. Before even the best management can have any chance of success, there must be provided an adequate supply of work to do reasonable justice towards the sunk capital and the staff. If the supply of work be inadequate, and therefore unfair in this respect, no management can prevent disaster. If the manager be an expert book-keeper and devote a good deal of time to the study of the books, he may acquire all the knowledge which can be embodied in a diagram. But a clerk once instructed in the method of procedure would probably in most cases produce more expeditiously, more correctly, and much more cheaply, a diagram containing all the information in the best form. The author's idea is to present to the management, with the utmost clearness and the least possible trouble, an exact record of progress in any desired detail.

One other advantage in a good series of diagram accounts extending over a period of years lies in its showing that extreme over-pressure of work is too costly; extreme deficiency of work is ruinous; between them somewhere lies a mean, at which the highest profit may be made. It is important therefore that this mean should be ascertained, and then that it should at all times be as nearly as possible maintained. Good management should be judged, not by the mere profit made, but by the profit viewed in the light of the favourable or adverse circumstances under which it has been made. Moreover when the capacity of works for profit-making has been ascertained by the review of past operations, the practical result of each year should be gauged, not so much by the percentage gained on capital, which is the ordinary gauge, but by the result which past experience has proved the works are capable of producing. That is to say, if £30,000 can be gained in a typical year and only £20,000 has been gained in a particular year, there has been in this year, whether brought out in figures or not, a loss of £10,000, which would be shown in such a diagram as Fig. 2, Plate 95, if one extra line were added.

The facts which apply to the general conduct of works apply in different degrees to all the separate departments in which profit or loss may be made. In many cases it would doubtless be found advantageous to construct diagrams of departments, so as to show what each department is doing towards the general result, and also to show from time to time its own progress towards economy or towards increased expenditure. In Fig. 6, Plate 98, for instance, is shown a diagram of the actual consumption of water in a factory on Tyneside during the four years 1893-6. The water account being kept in this diagram form, attention was at once drawn to the great rise in the second and third quarters of 1895, thus leading to an investigation which disclosed a serious leakage due to two broken pipes, whereby for the third quarter of the year 19,700 gallons were escaping daily through a neighbouring drain pipe. The discovery and stoppage of the first leak produced the first fall in the diagram; but as the consumption was still too high, the pipes were further laid

bare, and the second leak was then discovered and stopped. The improbability of the loss of water being detected by the mere payment of the water account was here increased by the fact that the turn-over of the firm contributing this diagram exceeds £700,000 a year.

In Fig. 5, Plate 97, is shown a diagram representing the plotting of twenty-nine out of a hundred consecutive orders executed in a foundry. These have been selected and arranged, simply so as to get the line of invoice prices to fall continuously from left to right, as shown by the descending stepped profile; and also to omit orders which were too small in amount to be plotted clearly on the scale of the diagram. The cost line, also stepped and mainly falling in the same direction, is not continuously descending, but occasionally rises. The space between the two lines represents the apparent profit, exclusive of establishment charges. The diagram in this form is considered by the author to be a readier guide for revealing anomalous results than a double array of figures would be. For illustration only, the wavy line XX is plotted separately, representing the percentage which the apparent profit forms of the costs, apart from establishment charges; and in the lower line YY the establishment charges are distributed in proportion to the costs. It is seen that this lower line YY is not parallel to the upper line XX; but the lower line YY represents the accurate results of the work done, and this line it should be the duty of the cost clerk to present to the management at short intervals. In two instances within the author's knowledge surprising results have arisen from working out this line, showing unexpected and considerable differences between tariff rates for various classes of castings and their actual costs.

Discussion.

The PRESIDENT said that the present paper was somewhat out of the usual course of those read and discussed at this Institution. It would no doubt be considered valuable and useful, especially where employers were really the masters of their own workshops. Naturally it had not taken into consideration the labour disturbances which had occurred in this country since it was written; and he was afraid it would be found that all the calculations it dealt with would be more or less upset, and of little value to manufacturers and engineers at large, unless they remained masters of their own businesses.

Mr. DAVID JOY, while not prepared to discuss the details of the paper, recalled that some years ago, when acting as secretary of the Barrow Shipbuilding Company, which even then was a firm of no small magnitude, he had been rallied by the managing director, the late Sir James Ramsden, upon occupying such a position after having been all his life an engineer. His answer had been to the effect that the accounts of a company, especially of a large engineering company like that, were simply a big machine to be handled by the head of the concern through the secretary and the cost clerks under him, with a view to the profitable management of the business. That experience had taught him a great deal about the question of costs; and he had been constantly in the habit of placing information in this way before the directors, by diagrams which could be read at a glance, as well as by the figures copied from the books which confirmed those diagrams, as no doubt had been done by many engineers in other concerns. Taking for instance the aggregate of the general costs, this formed one high curve, which was pitted against another high curve representing the output. The two curves together showed clearly at a glance that a certain output was required before any profit at all could be made; and anything beyond that output meant profit according to the amount of work. Similarly on an earlier occasion his own practice had independently been in the direction taken by the author. A railway, of which he had the

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control many years ago, was equipped with excellent engines and rolling stock, but with such scanty appliances for repair, that he had to watch every wheel and almost every rivet of the engines so as to keep them all going, in order that the demands of the traffic department might be always fulfilled to the time. For this purpose he had constructed the simple form of diagram shown in Fig. 7, Plate 98, for enabling him to see constantly, not by figures which took a great deal of time to watch, but by a glance at a moment, what was the condition of the engines at any time, and not only of any single engine but also of the whole stock. The diagram in Fig. 7 was only a portion of a large sheet, which had been kept constantly posted up to date. The vertical columns represented successive weeks in the three months, June, July, and August. Each horizontal line represented an engine, the individual number of which was prefixed to the line. The full portions of the horizontal lines represented full running engines in perfect condition, and the dotted portions represented shaky engines which would do for shunting and perhaps for piloting. A gap in a line, following a dotted portion, as in line 6, denoted that a shaky engine had been sent into the shop, and after being repaired had been turned out perfect. Line 7 showed that a perfect engine had gone into the shop for a week or ten days, perhaps for turning tires, and on coming out again had been in perfect condition for full work. The whole sheet extended of course much further in both directions than the fragment here shown; and in this way it was easy to gather for any month or week how many engines there were in a perfect condition. This was the form in which he had had the information put together for his own use, and he had found it thoroughly handy.

Mr. E. J. CHAMBERS considered that, although the use of such diagrams for many purposes in reference to profit making was not wholly new to engineers, yet unfortunately they were generally educated with too little knowledge of accountant's work, being too much interested in the engineering part of their business to devote a sufficient time to accounts. They were so much in the habit of expressing their ideas in graphic form that these diagrams appealed

to them in a way in which they certainly would not appeal to an ordinary accountant. With the suggestion in page 505 to construct diagrams of departments he fully concurred, having himself made each of his departments a business in itself, as much independent of the other departments as if each had to buy from the general fund and sell to it, the general charges being distributed over the various departments. It would be a great advantage he was sure to have all these accounts shown by diagrams. But in order that the diagrams might be of real value, he considered the several costs should be classified somewhat as follows. First of all, whatever belonged entirely to manufacturing should be classed under the heading of "manufacturing": namely the labour and the material which were shown in the finished article. Second, as "manufacturing charges" should be classed things which did not appear in the finished casting or forging or other finished article, but were consumed in its production: such as fuel used, coke or limestone in a cupola, coke in a smith's fire, coal or gas in a heating furnace, and whatever else vanished in the process of manufacture. The third heading would be "establishment charges," that is, the dead charges of the works, such as the clerks' and foremen's wages, telegrams, postages, and various other charges connected with the establishment. About the foremen he was not quite sure; it was just possible that their wages should be classed under manufacturing charges in their several departments. The fourth class should be the "distributing charges," which being entirely outside the works, and having nothing whatever to do with the cost of manufacture, should be kept entirely separate. The cost of an article was its cost when loaded into the railway wagon or carrier's van or canal barge at the works; and anything beyond, or any circumstances in connection with the sale of the article at market price or with the rise or fall of the market, had nothing whatever to do with the cost of making the article. Fifth came the "outside charges": such as the expenses of travellers to secure orders, or of directors, or fees for advice. Diagrams such as those exhibited should be used to represent each of these five separate headings, and should be brought before the manager each month or oftener. They would enable him to take into his counsel the heads

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of each one of his departments, making a point of consulting with them ; because he would be at a great disadvantage if he had to effect all the saving and all the economies himself ; if he merely gave orders for economies, he was not likely to see the full result of them, and therefore he should make a point of showing to the heads of the various departments the result of their respective labours. To a mechanic nothing would appeal better than a diagram showing the rise and fall of these various charges as each month went round. In this way he believed that, although not trained as accountants, engineers would be able to exercise their engineering skill to the best advantage. For though it might be a great thing for a man to be an able engineer, who could design machines that would work perfectly, yet, if he could not make the work pay, his ability would not be of a sterling quality.

Mr. JAMESON fully agreed with the remarks of Mr. Chambers as to the importance of keeping separate the different kinds of charges, such as the manufacturing charges, the establishment charges, and the outside charges. In the preparation however of the diagrams illustrating the paper, in order to prevent having too many lines upon them, he had grouped these charges together and shown them all by a single line ; smaller diagrams bearing these separate detail lines he should be happy to show to members desiring further information. Usually all the manufacturing charges were kept by themselves, detailed in the first instance and grouped at last ; while such items as debenture interest went into establishment charges, which should also be detailed and grouped. A separate heading was also made for all petty-cash expenses, so that it could be seen exactly, at the close of each month or other period, whether the petty-cash expenditure was tolerably uniform, or whether it was rising or falling abnormally. Although in the paper he had principally urged the importance to the general manager of having before him the result of the work throughout the whole establishment, he fully appreciated also the importance and value of his being able to secure the intelligent co-operation of the heads of departments, by showing them in a simple form the detail results of their

departmental work. As pointed out by Mr. Chambers, this was of great importance. Within his own knowledge a subordinate, having been shown from time to time diagrams of the results of his work, had started a system of diagrams for his own guidance, so as to keep constantly before himself any departure from the ideal result, and to be able to correct it as far as possible at once.

The paper was not meant to convey the idea that diagram accounts were in any respect a novelty of his own devising. They had been in extensive use for many years past in works of various kinds, and, where the diagrams were well designed, with the greatest advantage to those who had introduced them, as observed in one particular by Mr. Joy. What the paper was intended to make clear, as having come within his own experience, was the special advantage derivable from diagram accounts in engineering establishments, where fluctuations were so liable to occur in purchasing and selling prices, in wages, and especially in the amount of output; and where, too often, the results of these variations, in the relation of the percentage cost of labour and other matters, were to a large extent unobserved or misunderstood.

Mr. CHAMBERS asked why debenture interest should be included in the cost of an article made in the works. Instead of appearing as part of the cost, ought it not really to be charged to the capital account? And if debenture interest were included, why not interest on capital?

Mr. JAMESON was of opinion that, where debentures had been created, seeing that the interest thereon must under all circumstances be paid, it became in fact equivalent to such a charge as rent; and therefore in estimating the amount of profit or loss in the works it was necessary for a corresponding percentage to be added to the cost of whatever was done, in order to show the net result of the work. In a slack time, for instance, if too small a quantity of work was being done, the debenture interest might even be so great in proportion that it would really absorb the profit altogether. What engineers and manufacturers required to have

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brought before them was the net result of the work which they were doing; and therefore he should himself include debenture interest with establishment charges as an item of cost. Interest on capital however he would omit, because that was a matter of profit. Foremen's wages he would not include in the establishment charges, but in the "manufacturing" of their respective departments.

The PRESIDENT had great pleasure in proposing a vote of thanks to Mr. Jameson for his interesting and useful paper.

Fig. 1. Machinery Employment in 1897.

Fig. 3. *Eight Contracts in Bad year.*

Fig. 4. *Five periods of Work.*

Fig. 5. Twenty-nine Foundry Orders.

Fig 6. *Quarterly Water Consumption.*

Fig 7. *Condition of Locomotive Stock.*