EFFICIENCY OF PRODUCTION IN INDUSTRIAL PLANTS

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Thesis submitted for the degree of M. Sc.

by

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April 15th, 1911.

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I.

A P O L O G Y

Principally concerned in the sale of any manufactured article are three parties:-
The capitalist, whose energies are mainly directed to securing a maximum profit; the workers, who naturally desire, above all else, the highest possible wages for their time; and the consumer, whose principal concern is to obtain the article at minimum cost.

At first blush, it might well seem futile to attempt to harmonise any two of these apparently conflicting ideals. There are but two methods by which the capitalist may increase his profit per piece produced - (1) by increasing his selling price, or (2) by reducing the cost of production.

Hitherto the former has proved by far the more attractive; its profits in many lines of manufacture are certain, and agreements between competing firms to combine to the extent of advancing their selling prices uniformly, are the order of the day. The resultant increase in the cost of living is soon followed by strikes or demands for higher wages, which being granted, the cost of production increases, and the cycle commences again. The close of each cycle, however, does not entirely restore the initial conditions. There are in every

community a large number of persons not directly connected with production (the idle rich, the professional classes and a great deal of labour that is not organised into unions), and, while their cost of living advances, there is no automatic increase in their salary. Moreover, as the change in wages to his employés necessarily lags behind the increment of prices, every manufacturer stands to make a distinct gain by every such increment, unless it be made so injudiciously as to stifle the demand for his product. Hence the profession of raising prices has become highly remunerative, and is attracting the most desirable men from the field of production, so that we are now suffering from "a surplus of prices and a deficit of products"#.

Now, however, there is an increasing tendency to bring these combines under governmental regulation, so that manufacturers bent on increasing their profits are now being reduced to the necessity of concentrating upon lowering their costs of production.

With this end in view, the ideal to strive after is the employment of each element in the plant to maximum advantage - i. e. the elimination of preventable waste whether of machines or of labour. No doubt employers always have striven after this ideal, but generally so blindly or desultorily as to have

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H. L. GANTT - WORK, WAGES AND PROFITS.

rendered their efforts ineffectual. They have made the fatal initial mistake of keeping the status of shop workers below that of office workers, and, until this condition has been changed and more capable men attracted to the field of reducing costs, progress is vain.

That the three apparently irreconcilable ideals of maximum profit to the capitalist, maximum wage to the worker, and minimum cost to the consumer may be harmonised in almost any industry by scientific management has been proved, time and again. Instances might be cited ad nauseam, but one or two typical examples will suffice for the present, to indicate the possibilities of modern management:-

(1)# Prior to the reorganisation of the Symonds Rolling Machine Co., Fitchburg, Mass., 120 girls were employed in inspecting steel balls for bearings. They worked 6 days per week of 10 1/2 hours each, and were paid from $3.50 to $4.50 per week. Afterwards, the whole work was not only handled by 35 girls working 8 1/2 hours per day with a Saturday half holiday, but the accuracy of inspection (proportion of defective balls rejected) was proved to be 37% greater, and the girls now earned from $6.50 to $9.00 per week. Even assuming that each girl's wage was doubled, the relative efficiency of their wages after and before reorganisation =

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$$\frac{1}{2} \times \frac{65}{47} \times \frac{120}{35} \times 1.37 = 3.25$$

That is, an increase in efficiency of 225%.

(2)# To show that similar methods may be applied equally effectively to construction work, a contracter (Mr. F. B. Gildreth) some years ago analysed the motions involved in laying bricks. By eliminating the useless motions and modifying the disagreeable ones he found that the number of motions made in laying a brick might easily be reduced from eighteen to five by the institution of some simple changes in the method of delivering the bricks to the brick layer. By promising to each workman who followed his directions a large increase of pay, Mr. Gildreth succeeded in increasing the daily output per man from about a thousand to twenty-seven hundred bricks, and actually enabled the workmen to do their much larger daily task with less fatigue than formerly accompanied the performance of the smaller task.

In these examples the gain to the working force is obvious. The advantage to the capitalist results from the distribution of the overhead expense (taxes, insurance, rent, depreciation, interest, office expenses, superintendence and other apparently unproductive labour) which is approximately independent of the rate of production, over a larger volume of

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output - thus lowering the cost of producing each article. It is thus possible for the capitalist to gain a much larger profit, and at the same time, in order to stimulate sales and gain a larger market, it may be profitable to him to reduce the price to the consumer.

In many lines of manufacture, the overhead expense not only exceeds the labour cost, but remains practically constant whether the output is large or small. Yet many manufacturers in considering the cost of production fail to realise the enormous extent to which this sum is affected by the volume of output. For simplicity, let us consider a concrete operation on a casting worth say $3. Suppose that it is performed upon a machine for the use of which all work is charged 40 ¢ per hour (one method of apportioning the overhead burden), by a mechanic who is paid at the same rate. Then assuming that we can persuade the machinist to reduce the time for the operation, which generally takes 10 hours, without an increase of his usual hourly rate of 40 ¢ per hour, the cost of product would be reduced as shown on the following table:

HOURS	MAT'L COST	LABOUR COST	OVERHEAD EXPENSE	TOTAL COST
10	3.00	4.00	4.00	11.00
9	3.00	3.60	3.60	10.20
8	3.00	3.20	3.20	9.40
7	3.00	2.80	2.80	8.60
6	3.00	2.40	2.40	7.80
5	3.00	2.00	2.00	7.00
4	3.00	1.60	1.60	6.20
3	3.00	1.20	1.20	5.40
2	3.00	.80	.80	4.60
1	3.00	.40	.40	3.80

As will be shown in Chapter VIII, it is not at all improbable that this manufacturer, having a defective cost accounting system, will have been selling this article at $10. under the impression that any sum over $7. would bring him a profit, whereas sale at that price actually involved a loss. But if the workman were induced to curtail the time of the operation by two hours, a selling price of $10. would now bring a profit of 6 1/2%, and the 20% increase of output would involve a corresponding increment in his total turnover. And if, as is so often possible, the time of the operation be reduced to 5 or even 3 hours, the margin of profit will obviously enable the employer to offer the machinist a substantial incentive for maintaining the high speed, as well

as to reduce the selling price of his product, if close competition or the desire for a larger market should make it advisable.

As a result of the reorganisation of a New England textile mill, the output was increased by 80%, average wages increased by 40%, without increase of staff, and the wage cost per piece reduced by 40% #. In some plants the output has been doubled, in others more than trebled. To indicate the advantage of increasing the efficiency of existing plant over proportionately increasing its capacity ~~of existing plant~~ without adding to its efficiency - where the market will justify such extension - I quote the following hypothetical but conservative figures from "WORK, WAGES and PROFITS":-

	Initial Costs
Material	$3000
Wages	1000
Expense Burden	1000
	5000
Selling Price	5500
Profit	= $ 500 = 10% of cost.

Suppose then that in order to double the output (1) the plant is doubled and (2) the efficiency of existing plant is doubled without increasing size of plant or the number of workmen.

H. L. GANTT - ENG. MAG. MAY 1910.

(1) means the doubling of all expenses except the expense burden, which will be nearly doubled. We then get something like the following:-

	(1)	(2)
Material	$ 6000	$ 6000
Wages	2000	1400
Expense Burden	1800	1200
Total Cost	9800	8600
Selling Price	11000	11000
Profit	1200	2400
Profit % of cost	12.25	28

It is truly astonishing how seldom the problem of increasing the output of a given plant is attacked in the logical and intelligent manner which would befit its obvious importance. Under the usual organisation, the manager simply "puts it up to" the superintendent to speed up production. The latter then repeats the process on the foremen, and these very important individuals either succeed in making their men angry or resentful, and, possibly, in precipitating a strike, or - if their sympathies are with the men, or if they resent the superintendent's statements as reflecting upon their ability or integrity - they are more than liable to present a number of plausible excuses for failure to increase the output, which, as the foremen are largely "the source and conservers

of industrial knowledge" in any plant, no one else is able to refute. And so the conditions remain unchanged, except for the creation of a wider breach between employers and workers.

The foregoing is but one of the very many manufacturing problems which might be cited to demonstrate the necessity of more serious attention being directed to the establishment of the Art of Shop Management upon a sound and scientific basis. It, or the equivalent, has been said by so many people who have thoroughly studied the question, as to have become almost axiomatic, that "the greatest risk in the manufacturing business is that of bad management, and of the three managing departments - commercial, financing and productive, the latter generally received least attention while containing the greatest elements of risk"#. The Manager usually goes minutely into every detail of buying, selling and financing, while absolute authority over the actual manufacturing is relegated to a Superintendent, with little restriction as to the policy he is to follow either in management of men or care of plant. It is the problem of discovering how best to obviate these risks that I propose to study. And, reduced to its lowest terms the path to salvation will be shown to consist in leavening the methods of common commercial production with scientific and searching analysis of individual operations;

#.TAYLOR - SHOP MANAGEMENT. TRANS. A. S. M. E. VOL. XXIV.

supplemented by the application of something more than an elementary knowledge of human nature and of the fundamental principles of economics.

II.

THE IDEAL PLANT AND THE REAL.

The term "Industrial Plant" is subject to very broad definition as "a place where productive work of the same general nature is carried on regularly":- but, for simplicity, and in order to confine the length of this thesis to reasonable proportions, it will be most profitable to concentrate upon the means of securing maximum efficiency in that important and most intricate type - the metal working plant. Although the underlying principles are identical, the problem of increasing the efficiency of such a plant, with its complete dependence upon the co-operation of the human element, is vastly more complicated than in a hat factory or similar strictly manufacturing concern with its simple organisation, repetitive work and advanced division of labour. Therefore an understanding of the principles whereby it is possible to attain the former end will readily enable us to solve the problem of cheapening production in our hat factory.

In order to make the remainder of the thesis intelligible, it would seem both logical and desirable to decide at once upon some more or less attainable condition as our ideal of industrial efficiency. Even accepting as an axiom the proposition that no plant will ever be operated at an efficiency

of 100%, it will hardly be disputed that ceaseless and well ordered striving after a condition analogous to a mathematical limit, which may be continually approached but only reached at infinity, is more conducive to continuous progress than to aim at a series of accessible, will o' the wisp ideals, which are apt to confuse and discourage everyone by receding whenever caught. But it is immeasurably better to have attainable ideals than none at all.

As a prelude to depicting the conditions in our hypothetical ideal plant, let us spend a moment in examining the organisation of the average joint stock manufacturing company.

The direction of the company's broad policy is delegated by vote of the shareholders to a less unwieldy and better informed body than themselves called the "Board of Directors", of which the General Manager of the Company is usually though not necessarily chairman. His responsibilities are generally purely financial, and the extent to which he influences and directs the internal affairs of the company is largely a function of his personality.

Elected, with him, by the Board of Directors are the Secretary and Treasurer, whose duties are somewhat elastic but have little to do with the internal mechanism of the company. They may perform part of the functions of a Sales Department, or the Secretary may confine himself to dealing with

correspondence affecting the Board, and the Treasurer simply to supervising and recording all payments in and out of the Company's Treasury.

In addition to the above officers elected by the representatives of the Shareholders, the latter appoint directly an Auditor who has access to the books of the company at all times, and inspects them at stated intervals.

In charge of these books is an Accountant, part of whose duty it is to compile reports of more or less practical value, for presentation to the Board of Directors.

The functions of the sales department are obvious, and as they will be discussed later, require no present elaboration.

Coming then to the actual manufacturing department, we find the plant in charge of a Superintendent or Works Manager, who is directly responsible to the General Manager for the satisfactory operation of the plant as regards efficiency, discipline, maintenance, renewals, etc.

Next under him, and responsible to him for the condition of their various departments are the storekeeper and foremen of the various shops and tool room. And, under these, in order, are the assistant foremen, gang-bosses or charge-hands, and the rank and file.

Among other duties, a foreman is supposed to exercise continual supervision over his men, especially when the latter are paid by the hour; he must be a master of his trade; he must

be on hand for consultation with them at all times; he should know the capabilities and trustworthiness of each of his men; should plan work ahead to prevent idleness; should be sufficiently acquainted with the potentialities of every machine in the shop to see that it is continually driven at its highest economical speed; should inspect each job when completed; and is often expected to endorse the time sheets, investigate absences, discharge men when advisable, and engage new ones.

Another important official whose responsibilities are less clearly defined than the foregoing is the Purchasing Agent. His duty is not only to keep the plant supplied with all necessary raw materials, but to purchase only the most suitable grades, and to do so economically.

The above sketch is briefly descriptive of what is generally referred to as "military or line organisation". Each man is directly responsible to someone immediately above him, and promotion is along a clearly defined channel. Line organisation makes for discipline and for permanence of existing conditions and methods. It is in operation wherever there is an industrial plant.

The Drafting Office has no place in a pure line organisation, but represents the first encroachment of what is coming to be known as "Staff Organisation" into the industrial sphere. Its labour is not directly productive, and one can

well imagine the indignation and contempt with which the practical men who had prospered without it must have greeted its introduction. But it is long since the last order for an engine, say, was handed direct to a foreman, and filled by him without other drawings than a few rude sketches made by himself in consultation with two or three of his best tradesmen. It is long since employers became convinced of the saving in time of foremen, skilled workers and machines attainable by relieving the former of the responsibility of being his own designer. The appreciation of this change and of the resultant improvement in product was the first intimation of the economies which might be rendered feasible by relieving the manual workers of the necessity of planning their work - i. e. the economy of "separating the brain from the brawn".

Since then, in many large plants, the Superintendent has been provided with an assistant who often devotes his attention and energy mainly to the amelioration and co-ordination of shop conditions and methods with the object of increasing the efficiency of production. And the employment of a corps of inspectors, in order to lighten the foremen's burden, is now the rule rather than the exception.

Partly through the conservatism, but mainly due to the preternatural terror of anything resembling extravagance that characterises the average manufacturer, only a few of the more enlightened have permitted the staff organisation idea to

permeate their establishments to a greater extent than this. Thanks to F. W. Taylor, H. L. Gantt, and other enthusiastic specialists, the seed of staff control has germinated in many apparently hopeless soils, but has thrived, grown and borne ample fruit. And now the moral effect of the prosperity apparently though perhaps inexplicably consequent upon an increase in numbers of the non- productive staff is convincing a rapidly increasing field of manufacturers of the desirability of supplementing the knowledge and facilitating the work of the line by the employment of a special staff.

The staff consists of highly trained experts for the brain work, and ordinarily intelligent and reliable clerks and machinists for the routine; and each member of it has a clearly defined function, for whose satisfactory performance he alone is responsible. For instance, the vagaries of belting, when each machinist attends to his own belt, are often a source of irritating and expensive delays. So a special staff, under the supervision of an experienced man, is formed for the purpose of making periodical inspections of all belting in the shop, adjusting the belt tensions and making repairs and renewals where necessary. A comparatively insignificant staff is ample for this purpose. Their work is practically all done while the shop is not working, and adoption of this idea obviates practically all further

possibility of stoppages through belt troubles. The essential feature of the staff is thus that it tends to increase the overall efficiency of a shop.

We are now in a position to pry more or less superficially into the details of our ideal plant. And, instead of entering into a separate discussion later of the defects characteristic of the ordinary existent plant, which would be little more than a negation of the features of an ideal works, I shall simply append a note to each peculiarity of the latter, showing wherein many of the former fail.

(1) LOCATION. The plant is located in close proximity to at least one trunk railway line, to which it is connected by at least one siding, and also to a river or canal. This renders the manager largely independent of the vagaries of any one means of importing supplies and of shipping his product.

In order that a fire in one part of the plant may not destroy the rest, and to allow for extensions of the more important departments without cramping the others, the plant consists of not one large building, but several smaller ones connected to each other by cranes and narrow gauge tracks. For administrative convenience, the buildings are arranged in compact form, allowing only reasonable yard areas, but providing for most probable extensions.

The relative location of the various buildings is such that those departments whose heads most often find it necessary to confer with each other, are closest together. Thus the drafting office is situated as close as possible to the General Office, Pattern Shop and Machine Shop, and the Pattern Shop is near the Foundry, etc. The Store Room is conveniently placed both for receiving supplies from railway cars and for redistributing them as required, to the men.

(1a) As will be shown in Chapter III, this important element in efficient outlay of capital is receiving considerably more attention now than a few years ago, when the procedure was first to purchase a piece of land and then to engage an architect unacquainted with manufacturing methods to design a plant to fit the site. A very large number of plants so designed are still in existence, but the defect is fortunately becoming ~~obsolescent~~ obsolete.

(2) TOPOGRAPHY OF SHOP:-

The machines in each department are so arranged that the work travels through it in as straight a line as possible from the point of receipt to its final destination, and without retrogression. There are plenty of trucks, so that no time is lost in loading or unloading before and after each operation, and work is taken direct from one machine to the next.

The internal arrangements of the store and tool rooms

are such as to facilitate rapid location of whatever article is required, thus reducing to a minimum the time lost by workers in the shop, and to show at a glance when it is advisable to order a fresh supply of any stock material.

(2a) A common phenomenon generally as a result of growth for which there was insufficient original provision in designing the plant, is an arrangement of equipment which renders it impossible for the product in course of manufacture to pass in anything approaching a straight line through the shop. This defect naturally makes the cost of production unnecessarily high, through excessive handling, and imposes a very real limitation upon the rapidity of production, through congestion on the shop tracks etc.

The consideration given to store and tool room systems varies considerably in different plants, and it is not at all uncommon to see a queue of three or four high priced mechanics awaiting their turn at the store or tool room window - their machines standing idle the while.

(3) EQUIPMENT:-

It is perhaps superfluous to state that the equipment of the ideal plant is maintained in as good condition as is consistent with best economical operation. All machines on each class of work are, as far as possible, of the same modern standard type, so that the performances of the various

machinists can be measured against each other.

(3a) The operations of most plants are severely handicapped by inferior equipment - probably insufficient allowance has been made for depreciation, and there is no provision for the replacement at the right time, of old machine tools, few of which, since the advent of high speed steels, have been sufficiently rigid. And when they are replaced, not nearly sufficient attention is paid, in selecting new machines, to recent discoveries and developements in the art of cutting metals. As regards best economical operation, the rate of driving these machine tools, and speed and feed combinations, when not actually left to the discretion of the machinist are generally decided by a foreman who knows little or nothing of the above discoveries, and who has little opportunity of studying the capabilities of each, or even of any machine in his department.

(4) TOOLS:-

Only modern high speed tool steel is used, and as few grades of it as necessity dictates. The tools are ground to the predetermined most suitable standard angles, by a special staff in the tool room, and on an automatic grinder. A special staff of toolmakers and draftsmen relieves the machinist of the responsibility of improvising tools and fixtures for his work.

(4a) The tool room is generally handled by a staff only about half large enough for the purpose. The machine tools are ill maintained and each machinist grinds his own cutting tools to whatever angles best suit his own particular fancy. Neither tools nor fixtures are standardised, and hours are wasted daily in every shop through machines standing idle while machinists make plans for handling their work. Absence or neglect of any system of checking men who return broken or damaged tools has resulted in the average workman losing whatever compunction he once had about handling tools carelessly.

Several grades of tool steel are used - in fact some firms buy samples of every kind of steel that is placed on the market, and use simultaneously all grades from carbon to modern high speed steel, without ever troubling to discover the best economical conditions for the use of each, or even to compare their performances under similar conditions. Consequently it is reasonably certain that no tool in the shop is ever being employed to best advantage.

(5) FOREMEN:-

A man endowed with sufficient intelligence, vitality and initiative to be capable of faithfully performing all the functions which are commonly relegated to the foreman, would be able to command almost any position and salary in the industrial world. But the task is superhuman, and, in our

ideal plant, is whittled away at one end by ceasing to credit the foreman with knowledge that he does not and cannot possess, and at the other by relieving him of such routine duties as an intelligent clerk can handle. His task then assumes humanly attainable proportions, and requires but little more than executive ability, common sense, and a special knowledge of his trade. The responsibility of planning work ahead to prevent idleness is taken over by a special staff for the whole plant. The inspection of work is carried out by a group of inspectors. Each machinist is relieved of worry as to how best to attack each new job, by a card which accompanies the work and gives detailed instructions showing the simplest and most rapid method of doing it. These cards are made out or checked by an expert possessing a special knowledge of most recent experiments in the Art of Cutting Metals, and of the capabilities of each machine in the shop; and the foreman or other officials see that the instructions are followed to the letter, advising and assisting the workmen when necessary. They also see that the next job is ready beside his machine before completion of the job in progress; and that he is provided with all necessary facilities for hoisting it into position, and fixing it there, and with all the tools required for its performance. The officials responsible for the performance of the above functions together form an institution of paramount importance in relieving the foremen of their most

vexing duties, and of the necessity of simulating a knowledge which they do not possess or in completely supplanting the foremen, while, at the same time, reducing manufacturing costs to a minimum by doing all work in the best and most rapid way, and by eliminating idleness of machines and machinists.

(5a) The foreman is immeasurably the most important link in the usual organisation. With conscientious and efficient foremen, almost all things are possible, and the relative efficiency of each department in any plant is almost infallibly a measure of its foreman's ability. An inefficient foreman, however, will inevitably be the cause of poor workmanship, high manufacturing costs, tardy production and labour troubles; and an analysis of the extraordinary collection of virtues and qualities without which no man can be an efficient foreman leaves no doubt as to the impossibility of securing such a man for the salary of a foreman. However, some are less inefficient than others. Very often he is simply a machinist who has been promoted for his apparent intelligence and integrity, but who is versed in the methods and routine of only one shop. Such a man can seldom rise superior to the limitations of his experience to the extent of formulating or even following a bold, broad and logical policy of progress. As the foremen are the direct representatives of the management to the men, the latter are extremely prone

to base their opinion of the management upon the qualifications and behaviour of the foremen; and, in light of this fact, far too little caution is at present exercised in selecting the occupants of these very important positions.

(6) WAGES:-

For the performance of each job is set a time in which a first class workman could complete it under the conditions of the shop. Each employé is then stimulated to strive after maximum production by some automatic method of increasing his remuneration whenever he succeeds in completing the job within the stated "standard" time. And not only are each man's immediate earnings a measure of his efficiency, but prolonged high efficiency is still further rewarded by promotion.

(6a) Of all conditions directly concerning the workmen and influencing their support in attaining the ideal of most efficient production, it may well be doubted if any element is of such vital importance as the payment system. And yet, as will be explained in Chapter IV, the two systems favoured by most widespread application - day-work and piece-work are frequently so clumsily or so craftily administered as to level all workmen of the same trade in a shop down to the standard of the least efficient. The natural and inevitable effect of this maladministration is to alienate the sympathy

of the workers from the maintenance of the status quo; and it may be accepted as axiomatic that a dissatisfied worker is an inefficient one.

Probably no other industrial phenomenon is half so disastrous to the capitalist, the worker and the general public as a strike or lock-out; and the vast majority of these are directly traceable either to an unsatisfactory payment system or an inexperienced, blustering, tactless foreman, or to a combination of the two.

(7) HOMOGENEITY:-

The various departments are so organised and developed that each is kept working at full capacity, while their several products are very nearly the exact quantity required for the general output of the plant.

The foremen of the more important shops, the chief draftsmen, and a representative of the sales department are kept in touch with each other and with the superintendent by forming a committee ~~of them~~, over which the superintendent presides at periodical meetings, when questions of general interest are discussed. This serves to fix responsibility for delays, and keeps the foremen more nearly up to a uniformly high standard.

(7a) In the average plant the predominant characteristic is that of unevenness. In hardly a single plant is any

department equally efficient with any other.

The method of management usually adopted is to place all the responsibility on the shoulders of one superintendent, and to make no automatic or other provision for surrounding and strengthening him with an advisory board of the most efficient foremen. In so doing, the management deliberately lays itself open to a double loss. In addition to sacrificing the incalculable benefit derivable from periodical conferences between the superintendent and the most important foremen, which would serve to keep the former continuously in intimate touch with the actual conditions and obstacles to progress in each department of the shop, it also loses a splendid opportunity of educating and broadening the foremen, and of so far conquering their jealousy of the superintendent and of each other as to stimulate them all to hearty co-operation with the firm.

Too frequently the head of the drafting office is a man of limited shop experience, with little idea if left to himself of adapting designs to economical methods of manufacture, and with no appreciation of the economy of standardisation or of the use of stock parts in designs. And he is often too jealous of the shop foremen and of the sales manager to adopt suggestions from either as to improvements.

(8) ACCOUNTING:-

A feature of the ideal plant is the use of an accounting system whereby any piece of work may be at once located, and the cost of, and time required for filling each production order is easily determinable in advance.

(8a) Even at the present day, numerous manufacturers are blissfully unconscious of, or even sceptical as to the economies of simple systems for such purposes as inventorying stock, tracing work through the shop, and for ascertaining the approximate cost of each operation on each piece of their product. The importance of these will be discussed in a later chapter, but it might be well to emphasize now that their complete ignorance of the actual manufacturing cost of any piece of their product and of the capabilities of the shop must inevitably keep the sales department continually groping in the dark. The production of orders is an essential link in the chain; ~~and~~ a sales organisation which is quite unable to guarantee delivery before a certain reasonable date is already half beaten by competing organisations in the race for orders. Ignorance of the actual cost of manufacturing the product effectually debars them from concentrating on the sale of their most profitable lines.

Very often, too, the salesmen being jealous and distrustful of each other, and having only an incomplete knowledge of their own and their competitors' products, do not co-operate even to the extent of pooling their knowledge.

CONCLUSIONS:-

Such, then, are the more noticeable distinctions between the ideal plant and the actual. Not even the most efficient plant is completely inoculated against all of the defects which characterise, in greater or less degree, the average works; and probably no plant is so clumsily managed as to suffer from all. The manager of almost every plant is a specialist in some element of management whether it be in sales work or in the actual machine operations etc., and the department with whose needs and problems he is conversant will likely be extremely efficient - perhaps even over developed at the expense of the others. That is, he cannot see the necessity of employing a non-productive staff in the departments which he does not understand, because his own particular department appears to have become very efficient without one - though in that case he himself is the staff. The ideals and limitations of the manager, therefore, are largely responsible for the unevenness of the average plant.

Although the multiplicity of apparently non-productive labour engaged in the ideal plant would go to the heart of an orthodox manufacturer, I hope to show, in the course of the Thesis, that industrial inefficiency is largely a measure of the numerical paucity of non-productive in proportion to productive workers. Apart from the drafting office, staff organisation is conspicuous in most plants mainly by its insignificance.

Of a truth, many firms employ what is termed a "production engineer", but his principal functions often consist mainly in tying red labels marked "RUSH", on work which has been lost or forgotten, and in irritating foremen.

Another important contributing factor to present inefficiency springs from the necessity in almost every known plant for weighing and compromising between several desirable but conflicting ends.

Consider the problem confronting a railroad organisation in deciding upon the details of a new locomotive repair shop. As all time spent by an engine in the shops represents a dead loss to the company, estimated at from $35 to $100 per day, they will naturally desire to execute all repairs in the least possible time - that is by always keeping in stock a duplicate of every locomotive part which could be damaged.

~~However,~~ The number of standard types of locomotive owned by the Canadian Pacific Railway Co. for instance is 66. Thus the interest on unproductive capital represented by the accumulated cost of only one duplicate of each standard locomotive part might far more than counterbalance the loss occasioned by keeping each engine in the shop while its repair parts are actually being made. And so a compromise is reached, whereby a number of standard parts most frequently required - piston rings, cylinders etc., - are made in large quantities and stored; while less popular parts are simply made as actually

required. Some such compromise as this has to be made in almost every industrial plant, and necessarily results in a certain waste which however is less than if no compromise were made at all.

III.

THE DESIGN AND CONSTRUCTION OF PLANTS FOR BEST ULTIMATE EFFICIENCY.

The appreciation of the limitations which can be permanently imposed upon the ultimate efficiency of a plant during the periods of design and construction is a comparatively recent developement. The old method of procedure, beginning with the selection and purchase of a site, and the employment of an architect to design and locate the buildings, frequently resulted in excessive investment charges through the subsequent necessity of demolishing sound structures or of purchasing more land for subsequent extensions. And the conditions of manufacture were often such as to have doomed the enterprise from the start, had not its competitors been similarly handicapped

The change to modern methods is so complete and revolutionary as to be responsible for the existence of a new and flourishing branch of the profession, whose members devote themselves almost exclusively to the scientific design of new plants, and of extensions to existent ones.

Now, [redacted], the work begins with an examination of the finished product, and an analytical determination of the processes and equipment necessary or desirable for its economical

production. From this, and considerations of the capacity of the market for the product, a tentative design of the plant is completed, and a search is then begun for a suitable section of real estate to fit the plant - a complete reversal of the established practice of only a decade ago.

In the operation of designing a proposed new plant, there are certain broad principles to be observed, according to the nature of the products which it is intended to manufacture. Beyond a mere statement of these broad principles it will hardly be profitable to trespass in a thesis of so general a nature.

Thus, in a metal working plant, the machine shop must be placed for convenience in receiving raw material and rough stock from the store, foundry and blacksmiths' shop, and for shipping the finished product as soon as it has been completed. Therefore, in designing such a plant, first consideration must generally be given to the machine shop, and the other departments grouped about it according to their uses and administrative convenience.

The Store Room must be convenient both to the workmen who are to draw supplies from it, and to a railroad track and other points of delivery of raw materials.

The Drafting Office varies both in status and position with the size of the plant, and the kind of work which it handles.

Thus# in plants employing less than 500 men, working on a regular product, the drafting room should be near the superintendent's office, and under his control; and should communicate directly with both pattern and machine shops. Where the staff numbers from 500 - 1000, the drafting room should be near the general office, for convenience in supplying drawings and estimates for prospective customers, - and it must also be within easy reach of the pattern and machine shops. Practically all plants larger then this do a fairly general business, and their drafting room becomes an engineering department. It should now communicate with both general and sales offices, one of its principal functions being to make preliminary plans, and estimates for bidding on tenders. If possible it should still be fairly convenient to the pattern and machine shops.

The method of power transmission is of extreme importance, and appreciably influences the design of buildings. Employment of motor drives may be justifiable through the resultant reduction in cost of the buildings, which are then released from their function of forming part of the equipment, and has the further advantages of clear head-room for crane service, best location of machine, convenience in detached buildings, better speed control, and probable reduction in the

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O. E. PERRIGO - IRON TRADE REVIEW - OCT. 3, 1907.

frequency of shut-downs.

The problem of design is generally still further complicated by the necessity for compromising between the ideal arrangement of available transportation facilities and the actual - and, in adding extensions to an existent plant, by the location of the older buildings.

Generally speaking each industrial plant belongs to one of three groups according to the nature of the work which is performed in it:-#

(1) Manufacturing work for the purpose of producing a single product or line of products e. g. sewing machines, cash registers. typewriters, textile goods, paper boxes, soap, etc.

(2) A definite line of comparatively heavy work - e. g. locomotives, automobiles, turbines, electric generators, railway cars, etc.

(3) General machine work - including repairs and jobbing work.

The design of each is affected by the following broad considerations:-

(1) The work being light, an overhead space sufficient for proper lighting and ventilation is adequate for manufacture. Thus the structure plays no part in the actual manufacturing

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processes, and may be suitable to many types of occupancy. For financial reasons, it is often desirable to ensure this last consideration, possible slight disadvantages notwithstanding.

The materials purchased by concerns of this type are characterised by comparative lightness, and it pays to buy them in large quantities at a time. The stores department may thus be accurately laid out, and special bins provided for the storage of material, and for transporting it in lots through the shop.

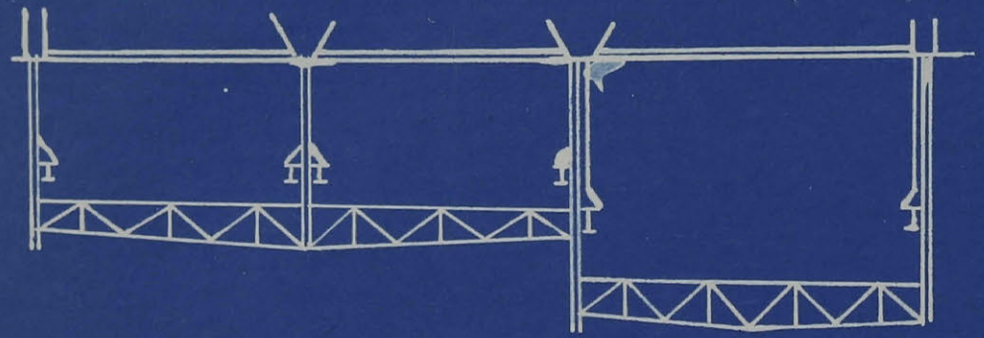
The equipment is generally special, and each machine may be designed to perform only one operation. The demand for such machines may be sufficiently great for several companies to build them in standard sizes - e. g. box-making machines, etc. - but they must often be built to order to special designs. The ability of designers thus becomes an integral element in the efficiency of plant.

As the buildings are standard (FIG. I) extensions are easily provided for through the possibility of adding similar units; but, in the event of an extension being made, a reapportionment of space among the various departments in the original plant is generally advisable.

The question of routing is simple, and the routing plan apparent from lay-out of machinery.

Thus an accurate lay-out is possible. The performance

III



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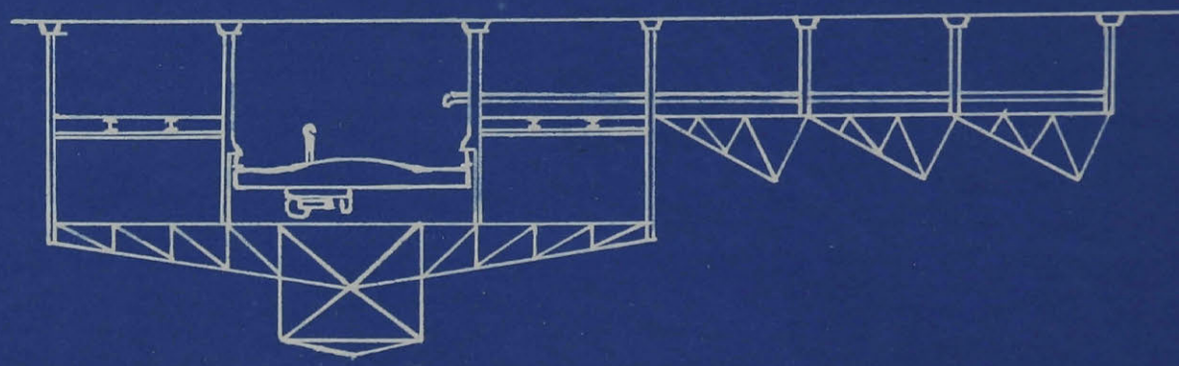

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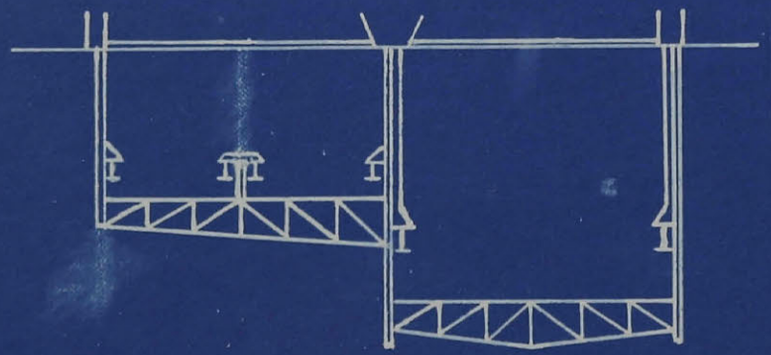

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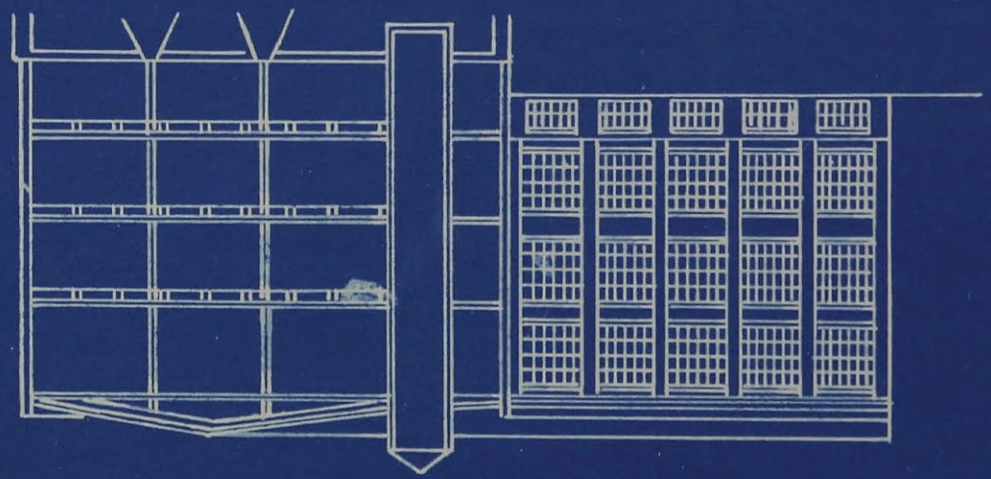

of equipment is definite, and the amount of equipment required is therefore easily calculable. The total requisite enclosed floor space is readily ascertainable after completion of lay-out.

(2) The lay-out of a store department is fairly simple granted some knowledge concerning the quantity of each material which will be purchased at a time. The raw material is large and heavy, requiring special transportation equipment, and often special building features such as reinforced floors, and unusually large door and elevator openings.

The equipment has generally been designed for a diversified line of work, though the modern tendency is to diminish its range. Each type is suited for the performance of certain operations on a large number of different parts.

Travelling cranes are generally essential, so that buildings are a part of the equipment. High head room under the cranes will probably be required for the erection of large machinery. Heavy floor loads may necessitate the provision of especial reinforcement.

It is impossible to select the character and amount of equipment with anything like the degree of certainty possible in a manufacturing plant. The type of building is fixed by equipment, which can itself only be approximated, so that the best solution concerning the building proper is hardly likely to be obtained - (standard types Figs. 2 and 3).

The routing problem is a difficult one, and can only be solved by a compromise to secure the best average routing of all parts. It is sometimes advisable to install additional equipment, rather than transport parts a considerable distance to a point where machines of the desired character are available. The point at which such extra equipment becomes desirable is determined by balancing the probable cost of extra handling against the interest and depreciation on extra machines.

As it is impossible to foretell exactly what the future requirements will be the need of subsequent rearrangement of equipment is probable, and the buildings must be specially designed to house several radically different kinds of work.

(3) In jobbing plants the present and future requirements are only roughly approximable. These plants are built for diversified lines of performance, and only those stocks of raw materials adaptable to several uses are carried. Provision must be made for handling and temporarily storing special materials when ordered.

The types of building suitable for this work are practically independent of the product and are well standardised (Fig. 4). They may differ widely in character, but their design is governed by considerations of requisite floor space and floor loads. If much variation is anticipated

in the size of work handled, there must be a section with overhead space for a travelling crane, and a lower section suitable for shafting.

The equipment is standard, with a wide range of duty. Wide range involves low efficiency on most jobs, but this arrangement is more economical than to have a number of small range machines, and keep all but one of each type lying idle. Many questions apart from the efficiency of individual operations must therefore be considered. Thus many operations are performed by hand and certain machines may be employed for a double purpose, e. g. slotting machine for planer, etc.

ACTUAL DESIGN.

Whether or not the work of designing the plant, or extensions thereof, is relegated to a specialist, the procedure should be somewhat as follows:- #

(1) "Ascertain the specific manufacturing requirements, and compile data relating to present and future needs". This includes an exhaustive study of existing methods, and of the purposes which have prompted the enterprise or extension. Where the plant is being designed by a specialist, it is essential that the owner should co-operate to the extent of supplying him with this and all other necessary information.

The compilation of data is largely directed to the end of

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reducing information to a unit basis. Such quantities as floor area per operator in each department, floor area per ton of finished product etc., are of great assistance in constructing a preliminary design, or a tentative subdivision into departments.

(2) Consider the system of shop management which the owner intends to adopt, and its effect upon the design of a tool room, the number, size and location of offices in the shop etc.

(3) Supplement the information already gathered with data as to the practice of similar plants, - more especially of those recently built. Such practice, however, must be adopted with extreme caution, as it may have been dictated by local or special conditions.

(4) Determine the kind and number of machines that should be purchased immediately. The probable future requirements should also be estimated, in order that ample yard areas may be left in the right place to allow for extensions that may become expedient.

(5) Decide upon whether the plant shall be built in a business or suburban district. The locality of the plant exerts one of the strongest influences that affect its design, as explained under (8).

(6) "Decide preliminarily on the arrangement of equipment and processes, based on elemental routing and administration requirements". Day recommends that a theoretical arrangement of machinery, with a view to minimising the travel of material, be made with the assistance of accurate templets of the various machines, and of the spaces required for process work. The broad relationship of the templets will be dictated by previous conclusions as to the best general plan of manufacture, but a number of alternate and equally satisfactory arrangements may suggest themselves. Except in the few cases where the routing diagram is obvious, a compromise will be found necessary to bring the best working result from a mass of conflicting desiderata.

(7) Determine the floor areas required for the manufacturing department, stores, assembly rooms, offices etc., and estimate probable future requirements for each. The equipment having been arranged for minimum cost of handling, decide what space to allow beside each machine for the temporary storage of partly finished product, tool cupboard etc. At the same time decide how the product shall be stacked - whether piled on the floor, placed in boxes, on trucks or other special appliances - and whether it shall be transported by manual labour, or by what other means.

The machine and temporary storage spaces having been approximated, the areas requisite for passages, general storage

departments and special enclosures (inspection and tool rooms) must be estimated. This calculation is only possible when assisted by a combination of experience and elaborate data.

(8) Determine which departments must be accomodated on the ground floor, and which may be located on an upper storey. The cost of real estate may necessitate the restriction of the area purchased to a minimum, in which case all possible processes are performed on upper floors. Work requiring heavy machinery or crane service must be performed on the ground floor, as solid foundations are essential to the successful operation of the former.

The results of this investigation largely govern the final decision as to what building types and construction details shall be adopted.

(9) Determine the total property area that will be needed at once, and the amount that should be reserved for future expansion. Tabulate the areas needed for each class of work - storage, yard requirements etc., segregating immediate from future needs. Total the open and enclosed areas separately, and note what floor area may be upstairs.

(10) Select the most suitable available site, but, if possible, defer purchase until completion of the design. If the location were fixed in advance, the procedure would be slightly different, as the actual limitations of the site could then be considered

from the outset.

Generally more than one site possesses several of the predetermined requisites, while none possesses all. Therefore several should be taken under consideration pending completion of building sketches, and the estimate of costs. Data bearing on the desirability of each site should be separately tabulated, in order to isolate the less suitable ones. The essential data comprise a knowledge of the suitability of the various soils for foundations, the cost, including expenditure necessary to make the site available, sanitary facilities, fire protection, availability of water, coal, electric power, gas and raw materials. and railroad and trucking facilities for the receipt of materials and shipment of products.

The most suitable site having been singled out and its purchase practically decided upon, the next step is to survey it. A map should then be drawn, showing, among other things, the boundaries of the site, the location and character of neighbouring buildings, the railway sidings, and canals in the vicinity, sewers, gas and water pipes and electric circuits near the site.

(11) Prepare alternate lay-outs of departments. taking into account all foregoing factors, including the site. Information already compiled will have defined where particular care must

be taken to prevent the building details from interfering with manufacture. There should now be frequent conferences between owner and engineer, as many points are bound to arise, in dealing with which two experienced heads will be far more successful than one.

(12) Reconsider all the work so far done, and prepare a revised lay-out incorporating the best features of the preliminary studies. Then make an accurate outline drawing showing the essential dimensions of the various buildings, departments and enclosures. This is necessary for estimating the cost, and for obtaining the owner's final sanction to the proposed arrangement.

The final decision as to whether the type of building shall be reinforced concrete, mill construction or steel frame depends upon specific requirements and climatic conditions in the locality. Different portions of the plant may be constructed of different materials if this arrangement is considered to be more economical without threatening the efficiency of operation.

Generally there is a logical front to the site, and the question of appearance affects this side only.

(13) Prepare a classified estimate of costs. This will be based on unit cost statistics, as the exact quantities and the amount of labour necessary have not yet been estimated.

The estimate should be classified to facilitate separate consideration of each item.

(14) Determine whether the probable business will be able to support the estimated necessary investment charges. If the owner considers the proposed expenditure to be excessive after conferring with the engineer, the plan must be consistently modified to curtail the first cost. This serves to illustrate the importance of accumulating data of unit costs.

The lay-out should then be revised, and the final plans prepared.

Steps should now be taken to secure the approval of the trunk-line railroad, so that there may be no later difficulty about the location of sidings; and other tentative decisions must be made final.

The subsequent work of financing the enterprise; preparing detail plans and specifications, superintending construction work and installation of equipment; and of commencing operation may or may not be performed by the consulting firm. The engineer seldom participates in the actual financing of an enterprise, as his engagement terminates on completion of the plant, and he is consequently unable to guarantee earnings.

In the preparation of plans and specifications, it is generally found profitable to subdivide the work as follows:-

(1) Special Machinery - Specifications for special equipment

must be in considerably greater detail than for standard machines. Either detail designs must be worked out, or an exact definition of the work to be done made, and the function of designing suitable machines left to the bidders. The owner, who possesses a unique experience, may undertake to procure such equipment independently of the engineer.

(2) Standard Equipment, - generally a large number of machines are built for doing exactly the same type of work, each working between certain well defined limits as to size of work, accuracy and speed. Reliable data may be secured from the leading machine tool builders as to the rapidity of performance of the machine which each would recommend for the given conditions. A comparison of these data with the specifications will generally isolate one as having peculiar advantages over all the others under the prescribed conditions.

(3) Power Plant Equipment, - these specifications are well standardised. The steam piping, wiring and line shafting should be designed before soliciting tenders, partly to facilitate comparison of bids and partly to prevent them from being arranged in a manner prejudicial to the overall efficiency of the plant.

(4) Artificial Lighting Equipment, - the shop generally should be illuminated by arc lamps, and supplied in addition with incandescent lamps wherever desirable.

(5) Heating, Ventilating, Sanitary and Fire Prevention Apparatus etc., - standards of insurance bureaux should be accepted as a guide in preparing specifications for the last. The specifications in all cases should be sufficiently complete to facilitate comparison of bids.

(6) Complete Buildings, - in this connection it is advisable to specify for a maximum of fabrication of the building materials prior to shipment, in order to limit the ordinarily exorbitant field costs.

(7) Necessary Yard Equipment,- this includes railway tracks, platforms, storage and scrap sheds etc.

It is generally advisable to secure tenders for the work as a whole, in order to centre all responsibility in a single company, and care should be exercised to allow bidders ample time for the preparation of their estimates. Otherwise they will naturally leave a margin over the hastily completed estimate for each section, in order to make the total price beyond question safe.

The procedure just outlined perhaps seems unnecessarily replete with precautions, but no care must be spared to make the design of an industrial plant the best possible. In the case of a manufactured article, errors of initial design can at any time be rectified for a comparatively trifling expenditure;

but, as regards the industrial plant, "a design for something that has never been built before and will probably never be built again, must be made right the first time". Errors in such a design impose a handicap on economical production, that will last as long as the plant itself. Therefore the comparatively insignificant cost of ensuring the best possible design is more than justified.

IV

SYSTEMS OF SHOP MANAGEMENT OTHER THAN THOSE EMPLOYED BY TAYLOR AND HIS DISCIPLES.

As indicated in Chapter II., many plants are still handled almost exclusively by an organisation of the military type; and, where competition is close, the owner is pitifully dependent for continued prosperity upon the success of his foremen in coercing or cajoling the rank and file into putting forth their best endeavours. The predominant cause of present general inefficiency is the almost culpable ignorance of employers as to the minimum time in which the various jobs performed in their plants could be done, or their inability to induce the workmen to perform the jobs in these times, in the rare cases where they are known. Naturally resultant upon this ignorance comes the prevalent phenomenon of loafing - partly because it is both congenial and safe, and quite often just as much in order to keep the employers in the dark as to the capabilities of their machines and workmen.

Hitherto industrial progress has been heavily handicapped by an overestimation of the difficulty of harmonising the workmen's desire to receive maximum wages for their time, with that of the employers to receive a maximum return for wages paid.

Prior to attacking this problem, we must first accept the following propositions as axiomatic:-

(1) That the workmen in nearly every trade can and will materially increase their present daily output, if assured of a permanent larger daily wage than they have previously received; and

(2) That employers can well afford to pay higher wages even permanently if each man and each machine in the shop turns out a proportionately larger amount of work. #

Until comparatively recently and now only in a less degree, the progress of the art of industrial management has been perpetually hindered by persistent failure of employers of labour to realize the potentialities of the payment system as an instrument for stimulating the workers to maximum efficiency. The system favoured by almost universal application was that extremely simple one of dividing the productive force of any one plant into classes, and paying the same standard hourly or daily wage to every member of each class. This plan has the fatal objection that any increase of effort by a superior workman over what is required from his class benefits the employer without affecting his own pay roll. Consequently, all the workers of each class in any shop, having no inducement to expend more than a standard minimum of energy, will soon be

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F. W. Taylor. A Piece Rate System. Trans. A.S.M.E. Vol. XVI.

found, almost invariably, to adopt the gait of the slowest.

Thus the workers lose interest in their work, and each man's fear of working harder than his neighbour produces a constant tendency to deterioration; his neglected reserve powers gradually atrophy; and, should the process have endured sufficiently long, no change of system, no amount of intimidation, and no dazzling offer of fabulous remuneration could stimulate the men to perform a really hard day's work. The effect of such surroundings upon a youth just entering a trade may be well imagined; and these conditions, if at all general in a country, would obviously constitute a grave national danger - as it is said even now to be doing in England.

In this connection Shadwell # tells of an English electrical works in which the men engaged in winding coils got slower and slower until the average time taken to wind a single coil was about 90 minutes. Girls were then put in charge of the work, and each girl now winds before breakfast more than a man was doing in a whole day.

Thus the employer who pays men for their time frequently gets little else in exchange for his money, and almost invariably pays extravagantly for the product.

Under this system the management at least recognises its obligation to maintain the equipment in a high state of

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Industrial Efficiency. Vol. II. p. 454.

efficiency. Every employer knows that no machine will work at even reasonable efficiency if it is driven continuously at the maximum speed at which it is capable of taking a cut - ruinous depreciation renders this course prohibitive. As employers of labour are generally credited with the possession of more than average intelligence, one would at least suppose them capable of inferring that the human machine is subject to exactly similar limitations; and yet the great majority of them consider that economical production is compatible only with the employment of a foreman who is also a skilled driver.

The daily rate of the workmen in each class is usually the lowest that will suffice to secure the requisite number of tradesmen of the desired grade, and depends simply upon the supply of and demand for such workers. Occasionally, however, a union may be sufficiently strong to insist upon the payment of a higher rate than this. In either case, unless accurate records are kept of each man's output, it is impossible for an efficient worker to be granted an increase without others claiming it also. As absence of records renders discussion fruitless, the rise is generally withheld to save trouble, and the efficient worker slows down.

The effect of this system is demoralising as well as levelling. The more ambitious workers, who see no profit in working hard turn their attention and devote their energies to other methods of improving their lot. and they take the lead

in forming labour unions for the purpose of wringing better pay or better conditions or both, from their employers by threatening to strike. The necessity for unions would disappear if free scope were granted the ambition of the better workmen by paying them according to their performance. It is relative, not absolute wages that stimulates exertion, and just so soon as the best men perceive a genuine inducement to discontinue restricting their output, they are only too eager to do so.

In order to circumvent the inherent defects of ordinary day work, the system has been developed in the direction of reducing the number of men in each group, and increasing the number of groups, involving a greater diversity of daily rates paid to the men on each kind of work. Under the highest form of day work, when accurate records are kept, and when each man's wage is increased as he improves, the restriction of output can be largely overcome, providing that the men are convinced that the system will not be eventually superseded by piece work - otherwise the fear of making a record that might be used as a piece price basis will probably impel them to loaf as much as they dare. Only with these innovations can any plant be operated efficiently under day work for any length of time. The records justify any increase of pay, and, if high individual efficiency be liberally compensated, the workers will soon prefer this system.

For jobbing shops, day work is about the only feasible

system, but needs a first class foreman and a uniformly high grade of workmen.

PIECE WORK.

From the best type of day work to piece work is a short step, although the latter is in many respects the antithesis of ordinary day work. The avowed object of the piece work system is purely and simply to obtain a larger output from a given plant, and generally though not necessarily for a smaller labour cost per piece than under day work. Even supposing that the labour cost per piece remained the same, the distribution of the overhead burden over a larger volume of product is virtually tantamount to a material reduction in the cost of producing each individual piece.

Fundamentally, the piece work system contemplates effecting the material recognition of unusual industry by the payment of an unusual wage. It purports to attain the ideal of paying each man in proportion to the worth of his performance, and thus to stimulate maximum individual efficiency. As an instrument for increasing output, it should invariably prove attractive to employers of labour; and, by affording him an opportunity to improve his lot, it should be welcomed by every workman, better than the average of his trade. Why then do we find its introduction as a rule so bitterly opposed by the workers, whether organised into unions or not, as to have been productive of some of the most determined strikes in industrial

history? Piece work proper is the only exact justice, but the manipulation of the system is frequently so clumsy or so crafty as to have convinced the average workman that piece work and injustice are inseparable. The iniquity is inherent in the manner in which the piece prices are generally set.

The methods may be classified as follows:-

(1) From a foreman's estimate of the time which the job will take.

(2) From records of the best time in which each job has previously been performed; and

(3) From a detailed expert investigation of each piece of work, to find the best method and shortest time in which it can be done with available appliances. Thus develope a standard method for each series of operations, and set a standard time within which a good workman should be able to perform it.

Of these, perhaps, all are of equal importance - the first two because they are the methods generally employed, and (3) because it is the only exact and equitable one.

(1) is pure guess work. Sometimes the error is small, but often it is just as likely to be large, in which case a particular workman will receive a wage that is either ridiculously low or abnormally high in proportion to the earnings of his fellow workmen for a similar expenditure of energy. In either event there is a strong sense of injustice, and the management

loses prestige, whether it alters the rate or not. As a rule, however, it is only on new work that the foreman's estimate is used as a basis for a piece rate.

Quite frequently, on new work, a piece rate is set by a combination of a cursory time study of the first attempt at it, and the foreman's estimate. For this purpose the machinist or fitter who will afterwards have to perform the job is allowed to undertake the experimental performance upon which the piece price will be based, under whatever supervision the foreman has time to give. The man will naturally perform the job as slowly as he considers safe, and, when a price has been set according to this time, he can with discretion safely reap the fruit of his dishonesty whenever the job has to be repeated. Taylor states that he has time and again discovered cases like this where a man has successfully nursed a job for ten and fifteen years, performing it always in a ~~quarter to a third~~ twice or thrice the best time which he was capable of making, and still securing a handsome price.

(2) This is the method most generally employed in setting piece rates on work that has previously been standard. On the assumption that every workman is capable of performing a substantially greater amount of work per day than he has been doing under day work, the piece rates set are generally so calculated that, in order to earn the same wage, each employé will have to do 25% more work. Thus, those men (and there are

some) who, under day work, had regularly put forward their best endeavours, are rewarded for their integrity on a change of system by a 25% reduction in wages. On the other hand, those who have most grossly deceived and despoiled their employer under day work, are now tempted by the incentive to increase their output by two or three hundred per cent or even more, and are punished for their previous deception by a phenomenal increase in wages.

Consider a shop consisting simply of machine shop and assembly room, and suppose for simplicity that the staff under day work consisted of a number of first class machinists each working at half his maximum reasonable speed, and a number of similarly equal fitters. each working, under better supervision, at 4/5 the best speed which he is capable of maintaining. Suppose that day work be then superseded by piece work, prices being set as above. Then if each man work at his maximum reasonable efficiency, a fitter's wages remain the same, while those of a machinist are increased by 60%. The iniquity of so slipshod a system is evident.

The system as commonly applied is thus permeated by injustice; and should the firm attempt, as many do, to correct the discrepancies of the initial rate setting, it not only stands to lose the last shred of the confidence of its employés, but is almost certain to antagonise them as well. Beyond question, the cutting of piece rates is frequently justifiable. Consider the man, cited above, whose output increased enormously

at the inception of the piece work system. This is no rare phenomenon, but has occurred on a large scale almost wherever piece work has been introduced by either of the first two methods. However much the firm may have been to blame for failing to call forth this man's best efforts prior to the change of system, the fact that he had in all that time been systematically robbing his employer is apparently inconvertible. Consequently the man is now receiving far more than he earns, just as he had previously been doing, and a reduction in his piece rate is not only justifiable but just.

This argument, however, puts the case for the employers, where rate cutting is concerned, on an unnecessarily high plane. It ignores the incentive created by the prospect of greatly increased earnings, which impels an intelligent man to take a new interest in his work, and to cast about him for possibilities of improving upon prevailing methods of handling and machining it; and undoubtedly a fair piece rate does frequently effect these desirable ends, and so speed up production, apart from the crowding of the machines. It disregards the obligation of the management to treat its employés with uniform justice, and it can only do this by knowing the relative difficulty of every operation performed in the plant; and, moreover, it fails to refer in any way to what is really the underlying motive in all reductions of piece rates. The astute manufacturer, ever on the lookout for avoidable waste, can never entirely dissociate

his conceptions of piece work earnings and a daily rate. The discovery that a certain skilled mechanic, under piece work, is receiving $7 per day, while under day work he was earning perhaps only $4 for about half the output, and confidence in his own ability to secure for $5 per day an equally efficient substitute for this apparently overpaid mechanic, are a strong, and often irresistible temptation to him to reduce that man's rate so as to make his earnings $5 per day for the same output. And should the man be so ill-advised as to increase his output still further, under such management it is extremely probable that his rate will be further reduced. When this procedure is general in a plant, each employé soon discovers the maximum wage which he is to be allowed to earn; and thereafter no man will attempt to earn repeatedly more than a very small amount above this maximum.

Thus all that has been achieved is a replica of the conditions obtaining under day work, - but with the further disturbing circumstance that the management has succeeded in alienating from itself the sympathy and confidence of the staff. The fellow feeling, however lukewarm, prevailing under the old régime has been superseded by mutual antagonism, accentuating the distinctions between capital and labour, and providing ample scope for the blatant eloquence and plausible hyperbole of irresponsible demagogues and walking delegates, as well as for the more cogent and better informed counsels of

trade union leaders. On this continent, almost every important union (including the Mechanics' Union), that has considered the piece work system has denounced it, and declared that none of its members shall work under it.

Thus, however justifiable the cutting of piece rates may be, and however extravagantly a firm may be paying for its labour, the moral effect is so bad in most cases as to make the procedure extremely expensive. Earnings are somewhat higher, and cost of production is somewhat less than under day work, but the output is again restricted, and the possibility of further progress has been stifled.

Occasionally the strain is temporarily relieved after a cut in piece rates by guaranteeing continuity of the new schedule for a definite period. If the period be sufficiently long, the majority of the men will cease to restrict their output. Maintenance of accurate records of all standard work performed during this period will then enable the employer, at the end of it, to set up a more just and more logical price list.

(3) This, as I have said, is the only just and equal method of instituting a piece work system, in that it forms a ready means of standardising labour. It is really borrowed from the Taylor system and has only been applied to piece work since the developement of the former system. As the details of this method will be somewhat fully discussed in Chapter V, where it more properly belongs, I shall trespass here only to the extent

of indicating its most patent advantage.

Knowing the maximum reasonable amount of work that a first class man in any department can accomplish in a day without over-exertion, the management has a ready basis for comparing the efficiencies in the same plant of machinists, fitters, moulders, blacksmiths, painters, labourers etc., and for adjusting piece prices accordingly, though in the actual rate fixing other elements might have to be considered - such as supply of and demand for labourers of each particular class, strength of trade unions, etc.

Thus in the simple shop described under (2) it would be found before changing the system that the machinists were working at only half their best available speed, while the fitters were 80% efficient. Assuming that a first class fitter can be attracted and retained just as easily as a good mechanic, the piece rates could then be so adjusted that a machinist would have to work just as hard as a fitter in order to earn the same wage. For the purpose of inducing maximum output, it would probably be wise to pay to the fitters the same price per piece as was implied in their daily wage of so much per day for a given daily output. And, in this case, absolute interdepartmental equality and justice will be established by so fixing the machine shop piece prices, that, in order to suffer no reduction in wages, each machinist will have to increase his output by 60%.

Almost wherever piece work has been established along

these lines, and reasonable rates set, the workmen have proven not only willing, but glad to eschew loafing - and, if assured of a suitable permanent reward, to devote their energies to producing a much greater output than under day work. As regards the Angus Shops, the recent conversion of their most important standard operations from day to piece work, has already resulted in a saving of 5 to 8% in cost of labour, while the workmen earn more, and the feeling between Company and employes is much more friendly than heretofore. As evidence of the confidence which the men have in the Piece Work Department, the majority of the requests for piece rates on new work come direct from the men.

It is obvious, however, that piece prices can only be set on all work throughout a plant by this means where all the work and all the conditions are standard. Quite frequently strikes have resulted in piece work plants, directly from persistent variation in quality, or lack of uniformity of metal or other raw material supplied to the workers. Means should be also be taken to ensure that no worker need suffer loss through having to wait for new work to be delivered to him, or through having to waste time on trips to the stores or tool room. But as it is so clearly to each worker's interest to find a means of circumventing these unfavourable conditions, many firms are content to shuffle out of responsibilities which, under any other system they would naturally shoulder. Thus it is quite usual to

penalise each worker for temporary stoppages of his machine by corresponding stoppages of his piece rate. This largely relieves the management of responsibility for the condition of equipment; and Emerson is therefore somewhat justified in characterising piece work as a "lazy, haphazard method of shifting the responsibility and direction from employer to employe." #

Conclusions:-

Piece work is based upon the sound economic principle that each worker should be paid according to the value of his work. There is and can be no valid objection to the principle. In fact, given intelligent, ambitious workers, and honest, broad-minded employers, piece work is the fairest and most satisfactory of all systems. Even under existent industrial conditions, with no one interested in pushing or advertising it, per se, it is spreading on its merits as the most honest way of paying for repetitive work. Its troubles are not inherent to the system but are almost invariably due to ignorance, carelessness or cupidity in its application. The whole principle is often falsified by rate-cutting which is inevitably followed by restriction of output, and thus defeats the principal purpose for which piece work is generally introduced - i. e. the reduction in cost of production per

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Richards - "~~What Is~~ Is Anything the matter with Piece Work?"
Trans. A. S. M. E. Vol. XXV Discussion.

piece of product to a minimum by increasing the output to a maximum. It is often true that the excessive speed at which work is performed under this system is subversive to accurate workmanship. With thorough inspection, however, the amount of this deterioration can be fixed wherever desired and in many cases the quality of output actually improves through the necessity of greater intensity of attention to the work. "The industrial value of piece work is clearly shown by the fact that it obtains in those branches of industry in which England retains her superiority, (i. e. textile and engineering trades), whereas time work is more common in those wherein she has been caught up and surpassed#".

Piece work has not yet come to its own.

III. The Contract System.

The plan of contracting with an exceptionally competent workman to do a certain class of repetitive work, and employ his own men (subject to limitations) is very often successful. The fewer the men employed by the contractor, and the smaller the diversity of work performed by the gang, the more conspicuous will be the success of the system. The contractor makes so minute a study of the minimum time in which each operation can be performed that it is impossible for the men to loaf without the fact becoming known; and he effects a

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Shadwell. Industrial Efficiency. Vol. II. p.134.

further saving by teaching intelligent labourers to so as much as possible of the routine machine work - paying them more than a labourer's wage but considerably less than that of a mechanic.

The employment of this system in the erecting shop at Angus appears to work very satisfactorily. In this shop the general erecting work is done by a number of gangs each consisting of about five fitters, two or three helpers or apprentices, a driller and a labourer. In addition to these gangs, each under its own "boss", there are a number of "floating gangs", each performing only one operation or group of operations in the erection of all locomotives - such as setting up shoes and wedges, springs and brakes, brass mountings, valve motion, valve setting, steam fitting, painting, etc. A contract price is made with a "boss" or "charge hand" for the erection of each engine, and, except on the new Mallet articulated locomotives, these operations are fairly well standardised, and are paid for on a piece work basis out of the contract price. Consequently it is only on the general erecting work that the charge hand regularly finds it necessary to exercise his driving powers. Each man in the gang proper, including the charge hand. is paid a fixed hourly rate, whether the sum of the products of these rates and the number of hours spent by the corresponding men on the job amounts to more than the contract price or not. Where there is a

balance on the credit side of the gang between the contract price and the actual labour cost of general erection, the surplus is distributed among the members of the gang in proportion to the product of hourly rate and number of hours spent on job, of each man. Where the balance is a negative one, there may be some good reason which was unforeseen at the time of making the contract. If this is found to be the case the contract is usually cancelled, and the discrepancy adjusted by the substitution of another and more liberal one. But where no such unforeseen difficulty has arisen, and the failure is considered to be the fault of the men, the gang is simply debited with the deficit, which its members must cancel with subsequent surpluses before they again receive anything above time wages.

This system is peculiarly applicable to erecting work. In the machine shop it is generally the cause of extravagant deterioration of machine tools, and the employés are often exploited by the contractor.

Another defect of the system, on any kind of work, and especially on new work, is the tendency of the contractor to restrict the output of the gang in order to keep up prices; or to refuse to adopt improvements in machine methods or appliances after the contract has been made.

However, the relations between employer and employé under

this system are generally less constrained than under ordinary piece work, and the contract system might well be more generally employed.

IV. CO-OPERATION.

As a natural reaction against the half century or so of industrial anarchy in Europe and more especially in England after the industrial revolution, and against the gloomy doctrines anent the sanctity of individual selfishness, and freedom of contract, which were promulgated by the classical economists in justification thereof, many idealists commenced to turn their attention to the evolution of some means of unifying the interests of what have come to be called Capital and Labour, and so eradicating the injustice and acrimony which already characterised their relations. One cause to which many thinkers ascribed the increased exploitation of labour after the industrial revolution was the fact that tradesmen no longer owned the equipment with which they worked, and were therefore dependent for the right to live, upon the pleasure of the few who owned the tools, and whose terms they must accept or starve.

The only apparent means of obviating this degrading condition, apart from reforming the factory owners, was to have each plant collectively owned by the working force employed in it. In addition to ensuring for each worker his proportional share of the profits, it was thought that adoption

of this plan would inevitably involve a large increase in the amount of profit to be divided, through securing the active sympathy of every workman for the welfare of the plant as a whole. It would, it was confidently hoped, eliminate most of the loss then suffered in each plant through waste of material, and carelessness in the use of equipment, and by discouraging loafing.

Since 1849, some 250 co-operative associations have been formed in the United States but most have failed or been transferred into joint stock companies. In Europe there have been still more, but only the insignificant few have proven successful. The enormous capital required for the conduct of most industries has confined productive co-operation to relatively simple and undeveloped businesses, and it is in the field of distribution that co-operation has given most satisfaction. There are now about 50 co-operative associations in the United States and 149 in England, but investigation of any one will show that the co-operation is only nominal, and "that it consists of capital-members who are not workers, and of wage-workers who are not members"#.

Notwithstanding the repeated failures of productive co-operative associations, a modification of the system has

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Beatrice and Sydney Webb - "Problems of Modern Industry".

often succeeded, whereby the owner of a plant periodically distributes among his working force a certain proportion of the profits earned since the last distribution. Undoubtedly there is scope in most plants for increasing earnings by the elimination of waste in material, machines and time, and the best way to secure this is to share it with those who, by their efforts or care, have really effected it.

At first glance it looks as if the owner were proposing to pay "something more than the market rate of wages" for his labour "and receive something less than the market rate of profits;" # but, as the increment of profit would not be created by the workers except under the stimulus of the offer of a share in the profits this criticism is obviously no better than superficial. Starting with the Maison Leclaire, a house decorating firm in Paris, about 1840, this plan has worked smoothly and apparently satisfactorily in a large number of plants - particularly in France - but generally in small towns or in industries not subject to ordinary manufacturing conditions.

The following, briefly, are the outstanding defects of ordinary profit sharing systems:-

(1) The interest of each participator is largely affected by the actions of others whom he cannot control or influence.

J. S. Nicolson. "Profit Sharing" - Contemp. Rev. Jan. 1890.

Thus an increase in profits may be attributable to improved management, fluctuations in the raw material market, activity of a sales department, or to monopoly of a new product, etc. rather than to increased efficiency of labour, in which cases the workmen receive what they do not earn.

(2) The share of any particular workman, cannot possibly, under this system, be adjusted to his individual deserts. Consequently, as the men working under co-operation are generally paid by the hour, almost all are anxious to work no harder than any other man who is paid the same rate, and we have a repetition of the conditions obtaining under the worst form of day work.

(3) The uncertainty of a surplus, the comparative insignificance of a workman's share, and the remoteness of its receipt are generally so pronounced as to nullify the individual incentive. The temptation to "soldier" for an hour or two is often irresistible, when the reward of increased industry will have to be shared with a number of other workmen, six months or a year hence.

(4) The plan makes only partial provision for unprofitable years in that the workmen are neither asked nor prepared to participate in the losses.

(5) The workmen may be prone to doubt whether the employer is faithfully fulfilling his contract. In light of

their exaggerated ideas of industrial profits, the rewards must often appear disappointingly small. At first the workmen may regard their share as a bonus, which is better than nothing - and later as a ridiculously small wage for increased efficiency, when perhaps they will begin to doubt the honesty of the division.

Thus the agreement seems to be between "two parties, of whom one has every temptation and opportunity to cheat the second, while the second cannot tell if it has been cheated"#. This difficulty, however, may be circumvented by the engagement of a sworn accountant to audit the books of the company.

(6) Any one who is interested may calculate the rate of profit by discovering the amount of the share distributed to any employé. If this amount were relatively high, it would almost unavoidably have the effect of attracting new competitors into the field; while if it were known to be very low, the fact would probably be detrimental to the company's credit ##.

The Towne System:-

This is a refinement of the co-operative system, whereby the increment of profit, or reduction in manufacturing costs,

F. A. HALSEY - A Premium Plan, A. S. M. E. Vol. XII.

J. S. NICOLSON - Strikes and Social Problems.

and not the absolute profit, is shared by the employer and the group of workmen who created it.

It seems to differentiate between those factors in the creation of new profits which depend solely upon the industry and carefulness of the employés, and the following:-

(1) Those contributed or controlled by owner - capital, plant, equipment, organisation, experience of owner, etc.

(2) Those influenced by the mercantile staff - purchasing and selling agents, etc., and

(3) Fluctuations in the rate of interest, and in the market value of raw materials, and the finished product # .

Insofar as the plan succeeds in so doing, it is superior to the foregoing systems, but is still subject to all but the first of the defects enumerated on the two preceding pages.

In the works of Messrs. Yale and Towne, where this system was first introduced, the majority of the men were paid by the piece but some by the day. Of each $100 saved in the cost of production in any department, the company retained $50, paid the foreman $5 and distributed the remaining $45 to the men in proportion to the total amount of their earnings since the last distribution.

The plan is thus very simple, and has succeeded in reducing costs in many establishments, though always slowly and

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H. R. TOWNE - Gain Sharing - Trans. A. S. M. E. Vol. X.

irregularly. It retains the fatal defect of the foregoing co-operative systems, of failing to differentiate between workmen of varying merit; and "the drones who do the loafing and share the profits tend to drag the others down to their level" # . It therefore resembles day work in tending to herd the workmen into groups, and thus to promote unionism rather than to develope individuality.

Incidentally, the successful working of this system necessitates considerably more clerical labour for the maintenance of cost records than either of the foregoing co-operative systems. This labour, however, if properly applied, might soon become self supporting, as will be explained in Chapter VIII.

THE HALSEY PREMIUM PLAN:-

This plan contemplates the attainment of practical co-operation by enabling each workman in a plant to increase his earnings permanently by a corresponding increase in his daily output.

The lowest reasonable time required by an average workman for the performance of a given piece of work is "determined from previous experience", and each workman to whom the job is assigned is offered a premium for every hour by which he reduces

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F. W. Taylor - A Piece Rate System. A.S.M.E. Vol. XVI.

that time - "the amount of such premium being less than his hourly rate of wages" #.

Thus, in the case of a job considered to require 10 hours - wages 30 ¢ per hour and premium 10 ¢ per hour saved, we have

TIME CONSUMED	WAGES PER PIECE	PREMIUM	TOTAL LABOUR COST OF WORK	WORKMAN'S EARNINGS PER HOUR
10	$3.	0	$3.	$.30
9	2.70	10	2.80	.311
8	2.40	20	2.60	.325
7	2.10	30	2.40	.343
6	1.80	40	2.20	.366
5	1.50	50	2.00	.40

Thus, if the man's output were doubled, the labour cost per piece is reduced by a third, and the workman's hourly rate increased by a similar proportion.

Thus, if the incentive of the premium be just sufficient to stimulate the individual worker to work at his maximum power factor, the efficiency of the plant should increase greatly through the attainment of maximum production, and a reduction in labour cost per piece of product. And the manufacturing

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F. A. HALSEY - A Premium Plan. Trans. A. S. M. E. Vol. XII.

cost will be still further lowered by the distribution of the overhead charges over a larger volume of product.

An increase in the output of a machine shop is largely a matter of intelligence, and involves the crowding of machines rather than of the individual worker. In the blacksmith's shop or foundry, on the other hand, an increased output can be secured only by an actual increment in expenditure of muscular energy by the workers. Therefore a much higher premium will be required to stimulate maximum production from the two latter than from the machine shop. Thus the incentive may be graded according to the class of work.

Employment of this system involves the use of a written order for each job; and, where printed forms are employed, it is usual to have printed on the back

"According to previous experience, this work should require ----- hours. If completed in less time than that, a premium of ----- cents will be paid for each hour saved". On receiving his job order from the foreman's or other office, the workman will have stamped upon it the time of commencing the job. When he has completed the order he will have a space marked "Time finished" filled in correctly and the card will then bear all the information necessary for determining the man's wage (for the pay roll), the labour cost of the work, and the time it occupied (for determining manufacturing costs).

As every increase in wages is accompanied by a reduction

in labour cost, there is not the same temptation as under piece work to set a limit to any man's earnings. Rate cutting, while not impossible, is therefore unnecessary as well as unprofitable, and one of the most baneful features of piece work is thus completely obviated.

It is usual to inaugurate the system with only moderate premiums since, if they prove too low, no one can object to their being raised, - Halsey states that excellent results have been obtained on light machine work by a premium of only 10% of the men's hourly rate. When the rate proves to have been judiciously fixed, it should be made permanent, and no downward revision made until an improved process shall have changed the time base. However, the advantages of increased output are so great as to render any refined hair splitting of the rate of premium unnecessary.

Any system which thus simultaneously increases output, decreases cost and increases wages without friction undoubtedly commands attention. The transition to it from day work is easy and natural; and there seems no reasonable scope for opposition to it, as there is nothing compulsory about it, and nothing tangible to oppose. It is simply an offer to permit the men to earn higher wages if they care to work harder.

This system is still employed in a large number of

plants, and a modification of it was notably successful in the Santa Fé Railroad Shops. Yet "in the year 1903, in New York alone it was the cause of two determined strikes"#.

The defects and troubles of this system spring almost invariably from the fact that the basic times for the various jobs in a shop do not represent the performance of a uniform grade of labour. Where the times are not set from an accurate knowledge of the maximum reasonable daily performance of a first class workman, they are the outcome of guess work - where they are so set, it would generally be simpler and more efficient to institute pure piece work. As it is the new rates are almost inevitably unequal, and, in deciding whether or not to give their support to a new system, workmen are invariably influenced by object lessons rather than theories.

Consider the case in which the first performance of a new operation under incomplete supervision forms the basis of the time allowance. Suppose ## that two men receive two new jobs, each of which can be performed in one hour, and that each man is paid 20 ¢ per hour. Suppose further that A takes 4 hours and B 1 1/2 hours on the trial performance, but that each ultimately reduces his time to 1 hour. Then if the premium be

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F. RICHARDS - Is Anything the Matter with Piece Work?
Trans. A. S. M. E. Vol. XXV.

F. W. TAYLOR - Shop Management. Trans. A. S. M. E. Vol. XXIV.

33 1/3 %

A receives $20 + \frac{3 \times 20}{3} = 40$ cents per hour

and B " $20 + \frac{1}{2} \times \frac{20}{3} = 23\ 1/3$ cents per hour.

Thus most men will be strongly tempted to follow A's policy, and spend as long as possible on the standard performance. Where the times for previous standard operations are based upon records, there is likely to be a similar injustice, as the man who deliberately wasted his time under day work will be seen to make a much greater proportional gain on the introduction of the new system. It is therefore to be apprehended that every man will be influenced in his work by a sense of resentment against the injustice which will seem to permeate the system.

In comparison with systems to be described in the next two chapters, it will be seen that the Halsey plan

(1) Is slow and irregular in reducing costs, being dependent largely upon the whims of the workmen,

(2) Fails to attract first class workmen to a plant, and discourage inferior ones,

(3) Does not automatically ensure maximum output per man and machine.

- V. -

THE TAYLOR SYSTEM OF SHOP MANAGEMENT.

In dwelling at such length upon the characteristics and more especially upon the defects of the ordinary systems of shop management, I have perhaps become tedious, but a proper perspective of these seems essential to an understanding of the means taken by the Taylor system for coping with the problems which they fail to solve. If a moment's recapitulation were permissible, it might be well to emphasize that not one of them is capable of inducing even an approximation to maximum production combined with minimum manufacturing cost. The defects whose existence vetoes the attainment of this industrial ideal are inherent in every form of each system, except perhaps the third type of piece work, granted a working force far more intelligent and ambitious than is conceivable. The fact that all the other systems are founded and conducted without serious reference to what might be termed the labour unit, - i. e. the maximum reasonable amount of work which a first class man can perform per day on a good machine and under the most favourable circumstances, without over exertion - the almost absolute futility of attempting to make the application of any of them uniformly fair, and the dependence for complete success upon

whether or not the foremen are endowed with a superhuman combination of qualities, foredoom each of the systems to only partial success. The best that can be said of any from piece work to the Halsey system is that they tend to eliminate a portion of the loafing which characterises day work.

The Taylor system of shop management is far more ambitious, and, starting from an accurate determination of the labour unit on all kinds of work performed in the plant, it takes measures to obtain with certainty the maximum reasonable output every day from each man and each machine in the shop. To its proper application the following are the primary essentials:-

(1) A knowledge of, or ability to apply the results of the remarkably exhaustive series of experiments to determine the laws governing the art of cutting metals performed by Messrs. Taylor, Gantt, White, Barth, etc.;

(2) An accurate or very approximate determination of the labour unit on all kinds of work performed in the plant;

(3) The assignment every day, to each man in the shop, of a clearly defined task so large as to tax the powers even of a first class workman in order to effect its accomplishment within the compass of a working day;

(4) The establishment of such conditions that the daily task can always be accomplished; and

(5) A differential piece rate system, whereby an unusually

high daily wage is paid on successful completion of the task in the allotted time - and only a comparatively low wage in the event of failure.

The possibilities of the system are dependent mainly upon the enormous difference between the amount of work done by the average man under ordinary circumstances, and the quantity which a first class man can perform, granted favourable conditions, without over exertion; and also upon the fact that first class men are not only willing but glad to work at their maximum reasonable speed if paid from 30 to 100% more than the average wages of their fellow tradesmen. On a superficial examination of the system, the last condition may appear the most striking and novel of all five - yet it is perhaps the least essential to the system of all the elements. Without (1), (2) and (4), conditions (3) and (5) would be both impracticable and ridiculous. These three, may consequently be regarded as the foundation of the system, for, without them, the whole intricate superstructure would be so much scrap. I propose, therefore, to devote somewhat detailed attention to conditions (1), (2) and (4), before proceeding to describe the system in actual operation, or to discover its more noticeable defects.

(1) In his paper "On the Art of Cutting Metals," (Trans.

A. S. M. E. Vol. XXVIII)# Taylor describes a classical series of some 30,000 experiments, undertaken almost solely for the purpose of obtaining sufficient reliable data for the establishment of the system upon a solid foundation. His ultimate object was to discover what changes to make in order to operate the Midvale ~~Steel~~ Steel Co.'s machine shop at maximum efficiency - i. e. to determine how best to alter the countershaft speeds, what qualities of tool steel and what tool shapes to employ, and, above all, finally to construct a slide rule with which and the help of records of time studies it would be possible to discover semi-automatically how quickly any given job could be performed on any machine. The first step was to make a scientific investigation of the individual effect upon cutting speed of each of the following variables:-

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The bulk of the material for this chapter has been "lifted" from the following sources as well as from this paper:-

TAYLOR	- "A PIECE RATE SYSTEM"	Trans.	A.S.M.E.	Vol XVI.
"	- "SHOP MANAGEMENT"	"	"	Vol.XXIV
GANTT	- "TRAINING WORKMEN"	"	"	Vol.XXIX
"	- "A GRAPHICAL DAILY BALANCE IN MANUFACTURE	"	"	Vol.XXIV
"	- "MODIFYING SYSTEMS OF MANAGEMENT"	"	"	Vol.XXV
BARTH	-			Vol.XXV

and a number of magazine articles by Taylor and his former associates.

(a) Quality of metal to be cut,

(b) Diameter of work,

(c) Depth of cut,

(d) Thickness of shaving,

(e) Elasticity of work and tool,

(f) Shape of cutting edge of tool, clearance and lip angles,

(g) Chemical composition and heat treatment of tool,

(h) Presence or absence of a copious stream of water, or other medium poured on tool,

(i) Duration of cut (without regrinding tool),

(j) Pressure of chip on tool,

(k) Possible changes of feed and speed,

(l) Pulling and feeding power of the lathe,

The method finally adopted by Taylor in the course of this preliminary investigation was to isolate one variable at a time, and thoroughly study its relation to the cutting speed by keeping the remaining variables, as far as possible, constant. His procedure, under each selected set of conditions was to determine very closely that cutting speed which would completely ruin a tool in 20 minutes. This criterion of complete ruination was adopted as the personal equation was found to enter so largely into a determination of the time at which any other phenomenon, such as the necessity for regrinding the tool, took place; and 20 minutes was found to be the shortest possible period for the purpose consistent with

reliable results.

By adopting these standards, Taylor succeeded in obtaining a set of formulae such as the following, connecting the cutting speed with the different variables:-

$$V = \frac{1.54}{t^{2/3}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where V = speed in ft/min. which ruined tool in 20 minutes,
and t = thickness of shaving (depth of cut) in inches;

$$V = \frac{12.22}{d^{7/32}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where d = depth of cut in inches;

$$P = C\ D^{14/15}\ F^{3/4} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where P = pressure on tool
D = depth of cut (inches)
F = feed (")
and C = a constant, depending on hardness of metal.
(This formula is only applicable to cast iron)

$$V = \frac{90}{T^{1/8}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where V = speed in ft/minute
and T = duration of cut;
et cetera.

The above and similar formulae were all deduced by plotting the experimental results upon a time base, and the various formulae were finally connected by Carl Barth in a series of groups such as the following for a 1/2" tool whose cutting edge has a radius of 3/32":-

$$V = \frac{C \times 0.87}{F^{0.665} \left(\frac{48}{5} D\right)^{.2373} + \frac{2.4}{18 + 48} D}$$

Where V = standard cutting speed (feet/min.),

F = thickness of feed,

D = depth of cut,

and C is a constant, depending upon the chemical composition and physical properties of the metal and tool.

As a description of this investigation is not essential, I shall merely state that it was marked by some of the most important discoveries that have effected recent industrial developement (by none so much as that of the so-called Taylor-White heat treatment for tool-steel, resulting in the production of a tool which would remove metal from 2 to 4 times as fast as any other tool then extant) and that it finally enabled Barth, with the assistance of mathematics dexterously applied, to evolve the longed for slide-rule.

The following were the landmarks in the series of experiments:-

1881 - Discovery that a round nosed tool could be run at a much higher speed than the old diamond pointed tool;

1881 - Discovery that coarse feeds with necessarily slow cutting speeds would do more work than fine feeds and the higher speeds which were possible at those feeds;

1883 - Discovery that a heavy stream of water poured on the steel chip at the point of fracture increased the amount of work done by 30 - 40%. (water was supersaturated with Na_2CO_3 to prevent rusting, and machines set in pans to collect water.)

1883 - Determination of the effect of speed on duration of cut. Formulation of laws relating cutting speed, depth of cut, feed, and life of tool.

Measurement of the power required to feed a tool with varying depth and thickness of cut, and discovery that a dull tool required as much pressure to feed it as to drive the cut.

Design of an automatic grinder.

1885-1889 - Experiments on the effect of allotting definite tasks to mechanics, resulting in a greatly increased output.

Proved that the thickness of chip removed by the tool has a greater effect on speed than any other element. This resulted in the successful installation of broad nosed tools with high speed and coarse feed.

1894 - Discovery of the tremendous gain attainable by the use of self hardening tools, varying from 90% for soft metals to 45% for hard.

1895 - Discovery that a heavy stream of water thrown on the shaving at nose of tool produced a gain in cutting speed of 33%, in the case of self hardening tools.

1898 - '00 - Taylor - White discovery that Chromium - Tungsten tools if heated to the melting point when being dressed, would do 2 - 4 times as much work as any other tool.

1899 - 1902 - Developement of slide rules.

1906 - Discovery that there is a 18% increase in cutting speed for cast iron if a heavy stream of water be thrown on the chip at point of fracture.

1906 - Discovery of the effect of a small percentage of Vanadium in the tool steel, (increase of red hardness, endurance and therefore of cutting speed).

Of a large number of other independent investigators who have entered this field during the last 20 years, the most extensive as well as the most authoritative experiments were performed

(1) At Berlin in 1901 under the auspices of the Verein Deutscher Ingenieure; and

(2) At the Manchester Municipal School of Technology, 1902.

The former consisted of 250 trials - the latter of about 1000. At Berlin the only elements given complete scientific

consideration were the cutting speed, area of cut (depth of cut x thickness of feed) and the quality of metal being cut; and from the results a curve was drawn for each quality of metal being cut. The tool steels were used as supplied by three German firms, and the trials were of widely varying durations, the only bases of comparison of results being "with one or two exceptions" that the tool should last at least an hour "without requiring regrinding". Neither tool angles nor quality of tool steel appears to have been considered, and the term "duration of cut" was more or less meaningless.

The Manchester experiments, though more extensive were not appreciably more scientific than those at Berlin, apart from that portion of them in which the vertical, traversing and surfacing pressures of the work on the tool were studied with the help of a most ingenious lathe dynamometer invented by Dr. Nicolson. This portion, however, was of little practical value in elucidating the mysteries of the art of cutting metals (beyond shedding a little light on the phenomenon of chattering), and is now more charitably credited with having been undertaken with an entirely different object. But whether or not Nicolson's principal purpose was then to design a lathe which should combine the advantages of minimum first cost with maximum rigidity and adaptability for rapid work, he was soon tempted by deductions from his results to enter into a controversy, somewhat at cross-purposes, with Taylor: - and

this launched him into still further investigations in order to prove that the formulae of his opponent were inordinately as well as hideously complex. Nicolson had himself derived a relation of the form

$$V = \frac{1}{a} + 15$$

Where V = cutting speed in ft/min.

and a = area of cut in sq. in.,

which he regarded as giving a cutting speed in close enough agreement with current practice to be accurate. It is strange that his opponents made so little capital of Nicolson's continual tendency to check each deduction at which he arrived, with the empirical rules of current practice - thus incurring the somewhat undignified suspicion. for a scientist, of regarding existent manufacturers as the ultimate and infallible arbiters of technical controversy, and their methods as the mathematical limit to industrial progress.

Nicolson then attempted to reconcile his results with those of Taylor by deducing a new relation of the form

$$V = \frac{K}{a + Bc^n}$$

Where V = cutting speed (ft/min.)

a = area of cut (sq. in.)

C = Carbon in forging, and

the constant K depends on the tool steel, and B and n upon the other chemical constituents of the bar, without reference to

thickness of shaving or depth of cut. - For this formula he anticipated a greater practical usefulness as involving eight fewer constants than those of Taylor. This formula gives cutting speeds within 5% of Taylor's for cuts above 1/8" in depth, and Nicolson disposes somewhat airily of lighter cuts by stigmatising them as relatively unimportant, and, in any event, not amenable to the discipline of any conceivable mathematical rules. Taylor seems to have succeeded in proving that they are so amenable, and Nicolson's compromise formula is apparently subject to the following further defects:-

(a) Taylor has proved abundantly # that a variation in the thickness of feed produces an effect on the cutting speed which is three times as great as a proportional variation in the depth of cut. Therefore the area of cut cannot be regarded as a single variable;

(b) Taylor had previously considered a similar formula, and discarded it as unsuitable for use on slide rules;

(c) As machinists on small lathes are paid about the same wage as those on the more spectacular machines, it is extremely important to curtail unnecessary expenditure of time on the former as well as on the latter. Furthermore, as it is on work requiring light cuts and feeds that the average machine of every country is engaged for the greater part of the time,

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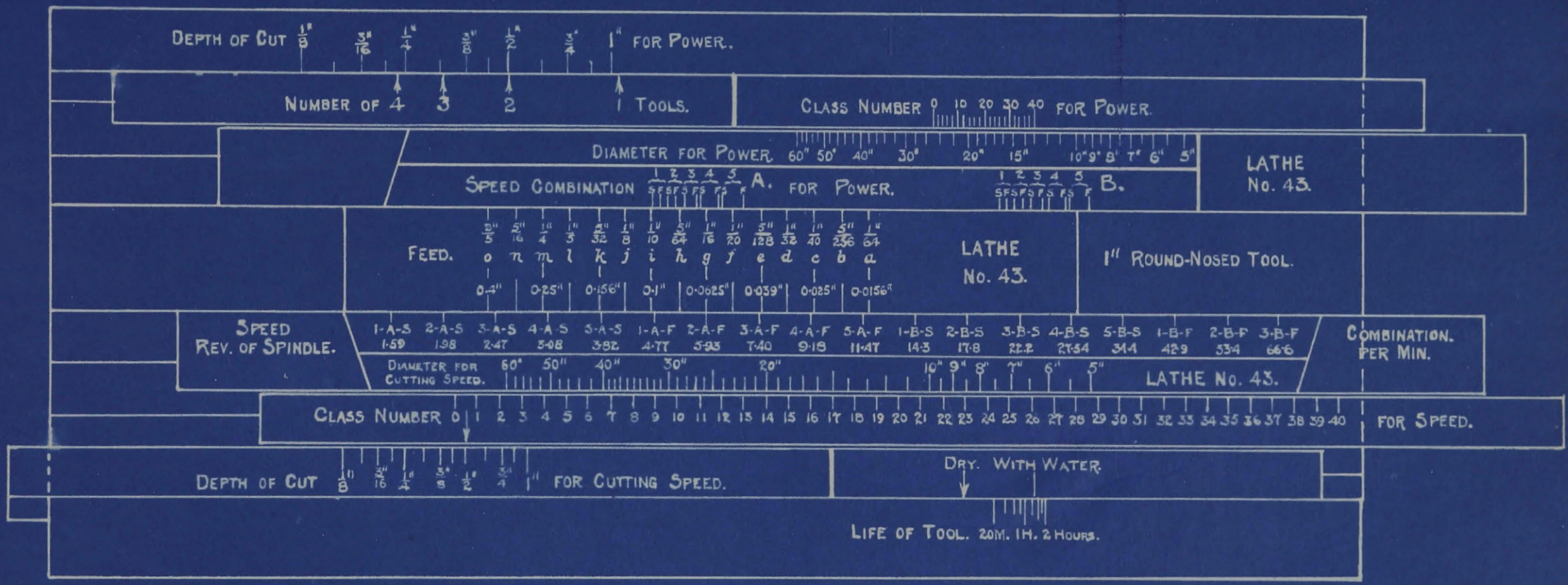
"THE ART OF CUTTING METALS" §§ 292 - 306.

it is more than desirable to take precautions to effect such curtailment.

The evidence adduced during the controversy, the immeasurably greater experience of Taylor than of his opponents, and the successes of his system of management, which last would be unthinkable but for the accuracy of his fundamental formulae, must involve a complete vindication of their truth and applicability to all cutting combinations.

The first mathematical solutions for the best cutting combinations on a given machine were obtained by overlying a number of curves on ordinary cross-section paper, with which a set of tables was laboriously worked out for each machine - covering most of the conditions of ordinary work. An improvement was instituted by Gantt, in the shape of laying out the curves on logarithmic paper, and using an elaborate cross slide embodying some of the formulae, thus enabling a much readier solution to be made. The next developement, bringing the ideal within measurable distance, was the construction by Barth of an extremely complicated slide-rule embodying all the variables except the rigidity of the work (Fig. 5). As is shown, there were two slides in the upper and three in the lower part of the rule, which together solved the problem of determining that speed combination which will at the same time most nearly utilise all the pulling power of the lathe, and the full cutting capabilities of the tool - when values are


DEPTH OF CUT 1/8 3/16 1/4 3/8 1/2 3/4 1" FOR POWER.
NUMBER OF 4 3 2 1 TOOLS.
CLASS NUMBER 0 10 20 30 40 FOR POWER.
DIAMETER FOR POWER 60" 50" 40" 30" 20" 15" 10" 9" 8" 7" 6" 5"
SPEED COMBINATION 1 2 3 4 5 S F S F S F S F F A. FOR POWER. 1 2 3 4 5 S F S F S F S F B.
LATHE No. 43.
FEED. 5/32 5/16 1/4 3/16 5/32 1/8 1/10 5/64 1/16 1/20 5/128 1/32 1/40 5/256 1/64
o n m l k j i h g f e d c b a
0·4" 0·25" 0·156" 0·1" 0·0625" 0·039" 0·025" 0·0156"
LATHE No. 43.
1" ROUND-NOSED TOOL.
SPEED REV. OF SPINDLE.
1-A-S 2-A-S 3-A-S 4-A-S 5-A-S 1-A-F 2-A-F 3-A-F 4-A-F 5-A-F 1-B-S 2-B-S 3-B-S 4-B-S 5-B-S 1-B-F 2-B-F 3-B-F
1·59 1·98 2·47 3·08 3·82 4·77 5·93 7·40 9·18 11·47 14·3 17·8 22·2 27·54 34·4 42·9 53·4 66·6
COMBINATION. PER MIN.
DIAMETER FOR CUTTING SPEED. 60" 50" 40" 30" 20" 10" 9" 8" 7" 6" 5"
LATHE No. 43.
CLASS NUMBER 0 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 28 29 30 31 32 33 34 35 36 37 38 39 40 FOR SPEED.
DEPTH OF CUT 1/8 3/16 1/4 3/8 1/2 3/4 1" FOR CUTTING SPEED.
DRY. WITH WATER.
LIFE OF TOOL. 20M. 1H. 2 HOURS.

V

are assigned to the other nine variables. This saved a large amount of labour, as to solve two simultaneous equations by any other means necessarily involves a number of tentative solutions - while this method is quite direct.

Since the appearance of the first Barth slide-rule, the instrument has been simplified almost beyond recognition. An exact fac-simile of the type now in use at the Angus shops is shown on Fig. 6, and the method of utilising it will be indicated under (4).

(2) It is not only practicable, but comparatively easy, through a systematic and scientific time study, to obtain exact information as to how much of any given work a first class man can do in a day.

In the Angus Shops of the Canadian Pacific Railway, all suitable standard work is being transferred as rapidly as is consistent with thoroughness from day to piece work. For the purpose of making time studies there are three extremely intelligent, and more or less experienced "demonstrators", as they are called on account of one of their other functions; and, after it has been decided to convert a certain operation to piece work, a demonstrator is told off to set a price upon it. The procedure is then as follows:-

He first obtains from a blue print room conveniently situated to the office in charge of piece work, a drawing of the finished

DIRECTIONS

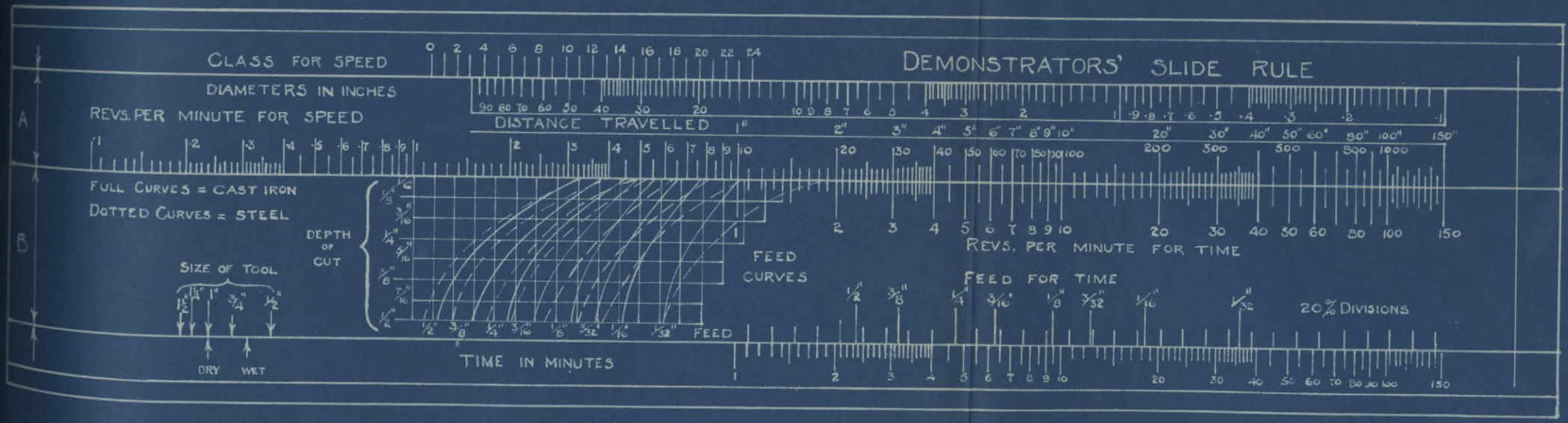
REVOLUTIONS PER MINUTE

Place the DIAMETER IN INCHES, of the piece to be turned (slide A), of the proper CLASS NUMBER at top of rule. On slide B, set SIZE OF TOOL (width across top) opposite arrows WET or DRY, as the case may be Select DEPTH OF CUT LINE (slide B); follow it to its intersection with CURVE of FEED the highest convenient for machine,- Directly above intersection point is the NUMBER of REVOLUTIONS at which piece should run.

TIME ALLOWED FOR CUT

Set slide A at zero position. Select on slide A, on scale marked "DISTANCE TRAVELLED," the length of the cut in inches. To this bring R.P.M. used, (Scale B). On TIME SCALE, read TIME ALLOWED for cut, opposite the FEED being used - The TIME SCALE may also be used for stroke machines by substituting for R.P.M. strokes per minute, and using feed per stroke.

MATERIAL CLASSES	
Hard cast iron	21 - 23
Medium " "	12 - 14
Soft " "	5 - 17
Hard steel	18 - 20
Medium "	6 - 8
Soft "	1 - 3

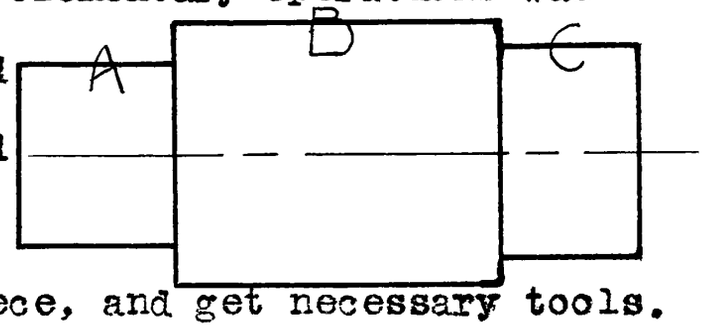


part, which he examines in detail. In most cases, standard operations have, for some time, been performed each on the same most suitable machine. If, however, the operation in question should be a new one, or if no regular machine has been assigned to it, the first function of the demonstrator will be to decide on which machine it shall always be performed, considering, of course, the proportion of standard work to all work already performed on that machine, and the frequency with which the new operation will have to be performed. Thus, if all the work already performed on the most suitable machine (having regard to its size, capacity, rigidity and other conditions affecting accuracy and speed of performance), is standard, it may be cheaper to put the new standard work on the second best machine than to dislocate the routine of the former. However the new operation may have to be performed so often or in such large quantities and some of the older ones so rarely that the loss involved in moving them will be smaller than the saving effected by performing the new one on the most suitable machine. In such a shop as Angus, new standards are constantly being adopted, but the old ones are not entirely superseded, as the parts made before the adoption of the new standards will probably be repaired or replaced several times before the engines embodying them are scrapped.

However, this is rather an indication of the procedure in deciding on what machine to perform new standard work, than of

the method of obtaining a time study. The allottment of work to machines falls, at present, rather within the province of the foreman, though already the demonstrators are far better acquainted than the foremen with the capabilities of the various machines.

The demonstrator then proceeds to construct a programme of elements in the performance of the job. For the simple operation of turning this medium steel pin from 4 3/4" stock, the following typical programme of elementary operations was constructed, considerably curtailed by the use of customary symbols and abbreviations:-



(1) Prepare machine for first piece, and get necessary tools.

(2) Lift to Chuck, True and Clamp.

(3) Set Left Hand Side Cutting Tool.

(4) Face end, and remove tool.

(5) Set Drill in Tailstock, and drill hole in centre of work.

(6) Reverse work in Chuck; True and Clamp.

(7) Set Left Hand Side Cutting Tool.

(8) Cut off end to length and remove tool.

(9) Drill hole in centre.

(10) Remove Chuck and Drill and set up work on lathe centres.

(11) Set Roughing Tool.

(12) Rough Turn B and C to 4" (2 cuts).

(13) Rough Turn shoulder C.

(14) Reverse work in centres.

(15) Rough Turn shoulder A (3 cuts).

(16) Substitute scraping tool for roughing tool.

(17) Finish Turn A and B.

(18) Substitute Left Hand side cutting tool for scraping tool.

(19) Square shoulder A B.

(20) Reverse work in centres.

(21) Square other shoulder and end.

(22) Substitute scraping tool for side cutting tool.

(23) Finish Turn C.

(24) Remove work and tool.

Where there are a number of such parts to be made at a time, it will probably be found simpler to centre all first - then to remove the chuck, and complete the operations; as, for stock of the given proportions, it will be quicker to remove each piece when centred and lift a new piece to the chuck than to remove the chuck after centering each piece and replace it before commencing the next. Attention must be paid to these considerations, and where there are two best methods of performing the job according as there are more pieces than one to be made or only one, there must also be two standard times.

Having constructed the programme, then, the demonstrator proceeds to observe the time taken by a first class machinist to perform the job - element by element. With his special knowledge of the capabilities of the particular machine, the

demonstrator decides in every case what combination of depth of cut, thickness of feed and cutting speed shall be employed, and subtracts from the total time spent on each element all time that, in his opinion, has been wasted. If, for any reason, he deems the figures obtained in his observation of the job unsatisfactory, he may repeat his readings any number of times according to the relative importance of further accuracy - i. e. the number of times which the job will probably have to be performed per year; the fact that the material supplied for the job will not always be of exactly the same grade or uniformity as that on which the study is being made; and the fact that a certain more or less arbitrarily determined percentage of the total minimum time required for the job must always be allowed for unavoidable delays and necessary rest.

Thus the method of recording the stop watch observations depends largely upon the character and importance of the work being performed. If the job consist simply of the same operation repeated over and over again, the time of one may be set down, or, if that be very small, of ten or more. Thus, at the Angus shops, it has been found practicable and very uniformly fair, to remunerate the semi-skilled labour on a number of standard turret lathe operations, on a basis of 5 ¢ per hundred movements.

Where the operation consists of a series of elements, the time for each element should be recorded opposite the name of that element on a simple standard form.

The study of an operation by small elements, though longer, is far more certain to be successful than that of a number of small elements combined. The greater the length of time involved in a single time study, the greater will be the risk of having the results invalidated by accident or other interruption. It therefore becomes profitable to subdivide some operations into a number of elements so small that it seems impossible to obtain the exact time required for the performance of each, by means of an ordinary stopwatch. In such a case, however, the difficulty may be easily surmounted by taking observations of the elements successively in sets. Thus, let us suppose that an operation is divisible into five small elements, requiring respectively a, b, c, d, and e seconds. Then, taking observations in sets of three, we are able to determine very approximately A, B, C, D, and E where

$$a + b + c = A \text{ ——————(1)}$$

$$b + c + d = B \text{ ——————(2)}$$

$$c + d + e = C \text{ ——————(3)}$$

$$d + e + a = D \text{ ——————(4)}$$

$$e + a + b = E \text{ ——————(5)}$$

Let $A + B + C + D + E = S = 3(a + b + c + d + e)$

then $a = A + D \pm 1/3\ S$

$b = B + E \pm 1/3\ S$

$c = C + A \pm 1/3\ S$

$d = D + B \pm 1/3\ S$

and $e = E + C \pm 1/3\ S$

thus giving the time for each element.

It is well to note before applying this method, that the equations similar to [(1)---(5)] are only possible of solution when the number of successive elements observed is prime to the total number of elements in the cycle # - i. e. the number of elements in a set must contain no factor which is common also to the total number of elements. Thus if there were eight elements, and two, four or six in each set, the equations would be incapable of solution; but if each set consisted of three, five or seven elements, the solution would be simple.

Having obtained these elementary times, it is easy to construct formulae for obtaining the elements. Taylor gives ## a formula for obtaining the time required for picking, loading on wheelbarrows, and wheeling any given kind of earth to any given distance, when the wheeler loads his own barrow. The formula is typical and is obtained as follows:-

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BARTH

"SHOP MANAGEMENT" - Trans. A. S. M. E. Vol. XXIV.

Let a = time to fill barrow with given material

b = " of preparing to wheel

c = " " wheeling full barrow 100 ft.

d = " " dumping load and turning

e = " " returning 100 ft with empty barrow

f = " " dropping barrow and starting to shovel

p = " " loosening 1 cu. yd. of earth with pick

P = Percentage of day required for rest and to allow for necessary delays.

L = load of barrow in cu. ft.

B = Time 1 cu. yd. picking, loading, wheeling, etc.

then

$$B = \left\{p + (a + b + d + f + \frac{\text{distance hauled}}{100}(c + e)\frac{27}{L}\right\}(1 + P)$$

The formula is then simplified by substituting the average values of the constants:-

giving

$$B = \left\{p + \left[a + .18 + .17 + .16 + \frac{\text{dis.}}{100}(.22 + .26)\right]\frac{27}{L}\right\} 1.27$$

$$\text{or } B = \left\{p + (a + .51 + .0048 \times \text{dis.})\frac{27}{L}\right\} 1.27$$

which is applicable to any kind of earth and any distance for men working at the recorded speeds. Thus, if the material were sand, and the haul 50 feet,

we would get by complete substitution for the constants,

B = 29.4 minutes per cubic yard.

Thus, the study of the constituent elements in one case of picking, shovelling and wheeling dirt enables one, with the determination of a few subsidiary constants for different kinds of earth, to determine the exact time required for each of an indefinite number of complete similar jobs. Such a determination as this is of tremendous importance as an assistance to enlightened bidding on tenders, and the Aberthaw Construction Co. of Boston is said to secure practically every contract on which they bid, thanks to a comparatively simple similar system for the determination of unit costs on reinforced concrete construction work.

The extent to which it will be profitable to subdivide any job before commencing the time study, is a problem whose solution implies the exertion of considerable judgment. Where the job is to be repetitive - i.e. performed in large quantities at a time - the subdivision into rudimentary elements should be far more exhaustive then in the case of ordinary standard operations, such as making duplicate repair parts for equipment when it is not desired to keep capital lying idle or to occupy a large space by making and storing spare parts in large quantities.

Consider, in this connection, the simple unskilled work of loading pig iron on cars, upon which Taylor inaugurated his time study work at Bethlehem. The operations involved in this work are

(1) Picking up pig from ground or pile;

(2) Walking with it on the level;

(3) Walking with it up an incline to car;

(4) Laying it on pile;

(5) Walking back empty handed.

Almost any of these elements is capable of further subdivision; for example, the first operation consists of (a) Stooping to reach pig (b) Grasping pig (c) picking pig up and (d) turning around.

Now, the total time in which a good man could pick up a pig would be about one second, while that required for walking to the car and returning (the distance was about 50 feet) would approach half a minute. No matter how far the operation of picking up a pig might be subdivided, the waste or loss of time which would become apparent through the assignation to each element of a reasonable minimum time, could not, by any flight of fancy, exceed one-fifth of a second if - as was postulated - the original observations were carefully made a large number of times on a first class man working at his maximum reasonable speed and picking up pigs from various heights as the pile diminished. Obviously, then, the maximum saving attainable by the most exhaustive subdivision would be only one fifteen hundredth of the total time, and therefore not worth striving for.

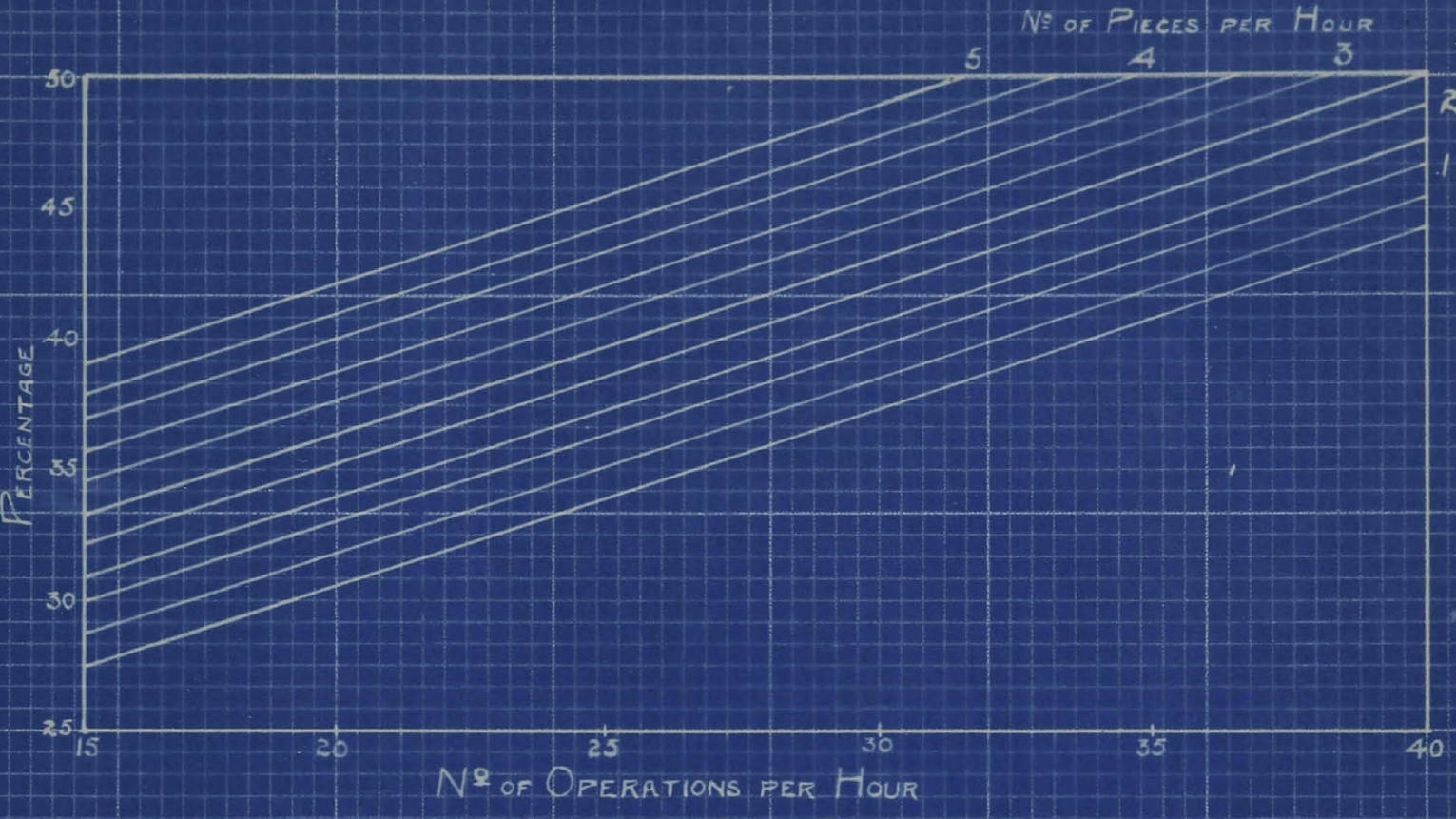
A perusal of the schedule of elements in turning the pin (pages 93, 94) shows that many of the elements are common to a large number of operations. Such elements are - preparing machine for work and getting necessary tools; drilling centres; changing tools; cleaning machine, etc. Others which will be practically constant for pieces of approximately the same weight and shape would be lifting work to chuck, truing and clamping; reversing work in chuck, or in lathe centres; and removing work. One of the most important functions of the time study department will be to collect data regarding the times required for these elementary operations on various machines. With well arranged immediately available records as to these, the work of the time student is greatly simplified, and his responsibility reduced to seeing that the actual machine work is done as rapidly as is consistent with only reasonable depreciation of the machines. As regards supervision of cutting speeds, his work is still further simplified if he is able to manipulate the latest form of a Barth Slide Rule (Plate VI) - which shows with two settings the best combination of cut, feed and speed for any machine in good condition. Such a demonstrator, if he be intimately acquainted with the capabilities and condition of each machine under his charge, can very often set a perfectly fair time allowance without the assistance of a time study at all. The minimum time in which a

first class man can perform any given operation under prevailing shop conditions is therefore very exactly determinable in any plant and on any kind of work.

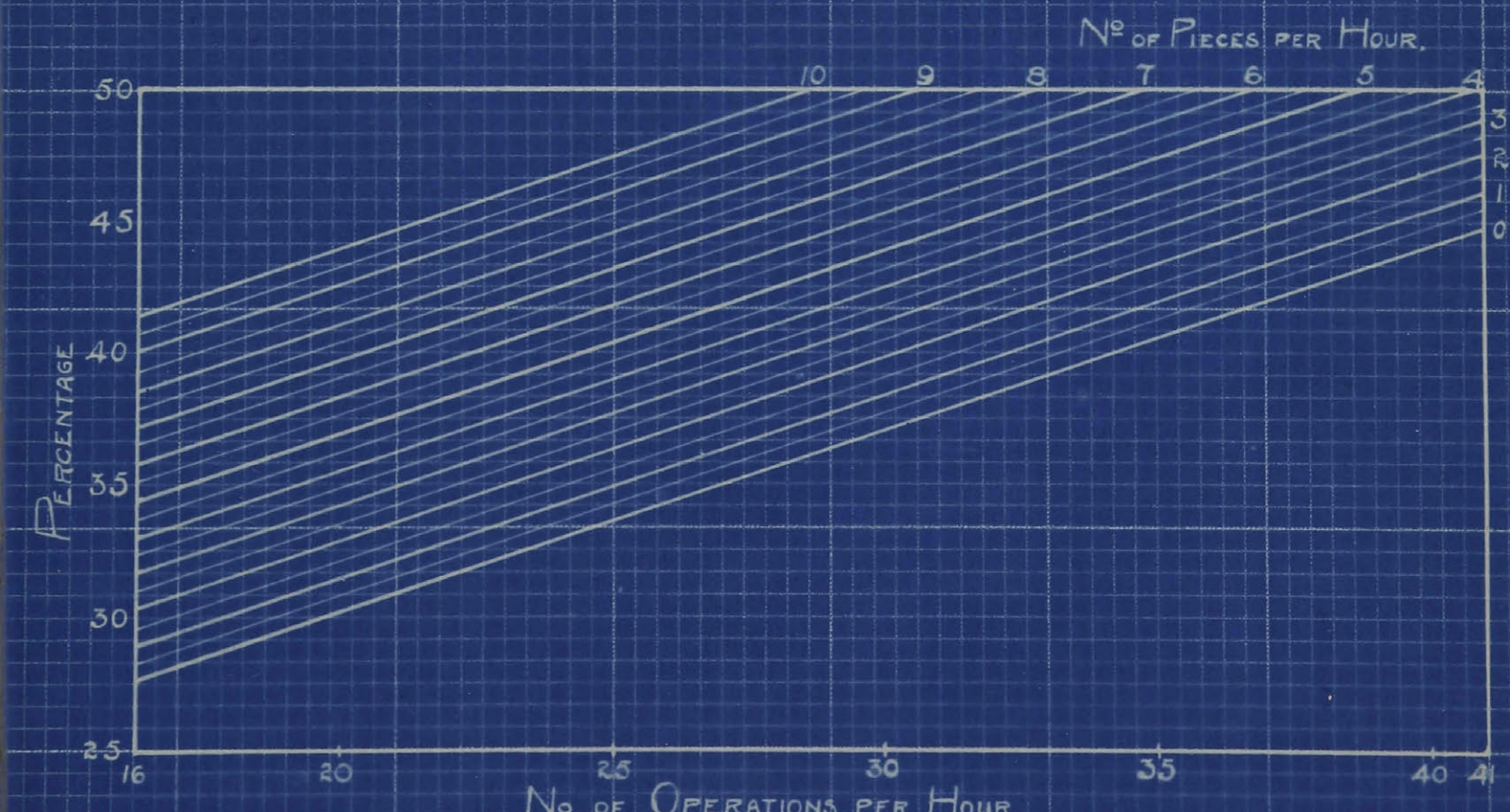
The time students or demonstrators generally set the time subject to approval of the head of the department, upon the work which he has been observing. The latter official must be both able and experienced on account of the moral effect produced on the men by an error in fixing a rate. Thus it is only in a plant sufficiently large to keep such a man continuously employed, or sufficiently small for the whole work to be included within the province of the superintendent that this plan will appeal to the owners. There is, however, a large margin of intervening plants in which it is still profitable to employ such a man to establish the system upon a firm basis.

The most difficult element upon which to decide is the percentage of a day which even the best workman should be allowed for rest and for unavoidable delays; and as to this practically all technical papers bearing upon the subject are silent. In the Angus Shops, recourse is always had to a series of curves (Plates VII and VIII) which purport to show what is the fair and proper allowance on various kinds of machine work according to the number of operations performed per hour on each particular standard job. They were drawn, according to accumulated experience, by Messrs. Hood and Spidy of the

TURN AND BORE

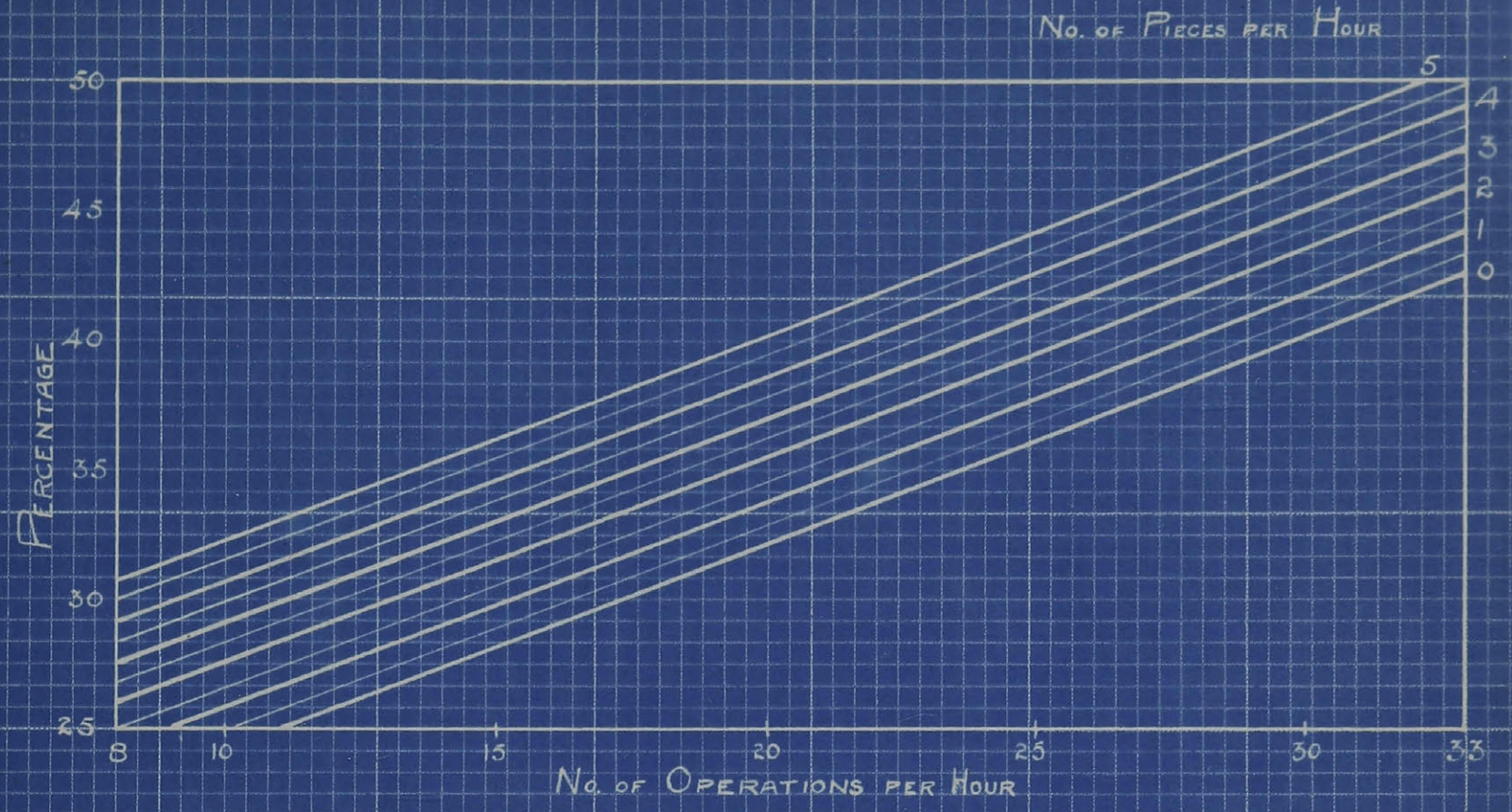


DRILL

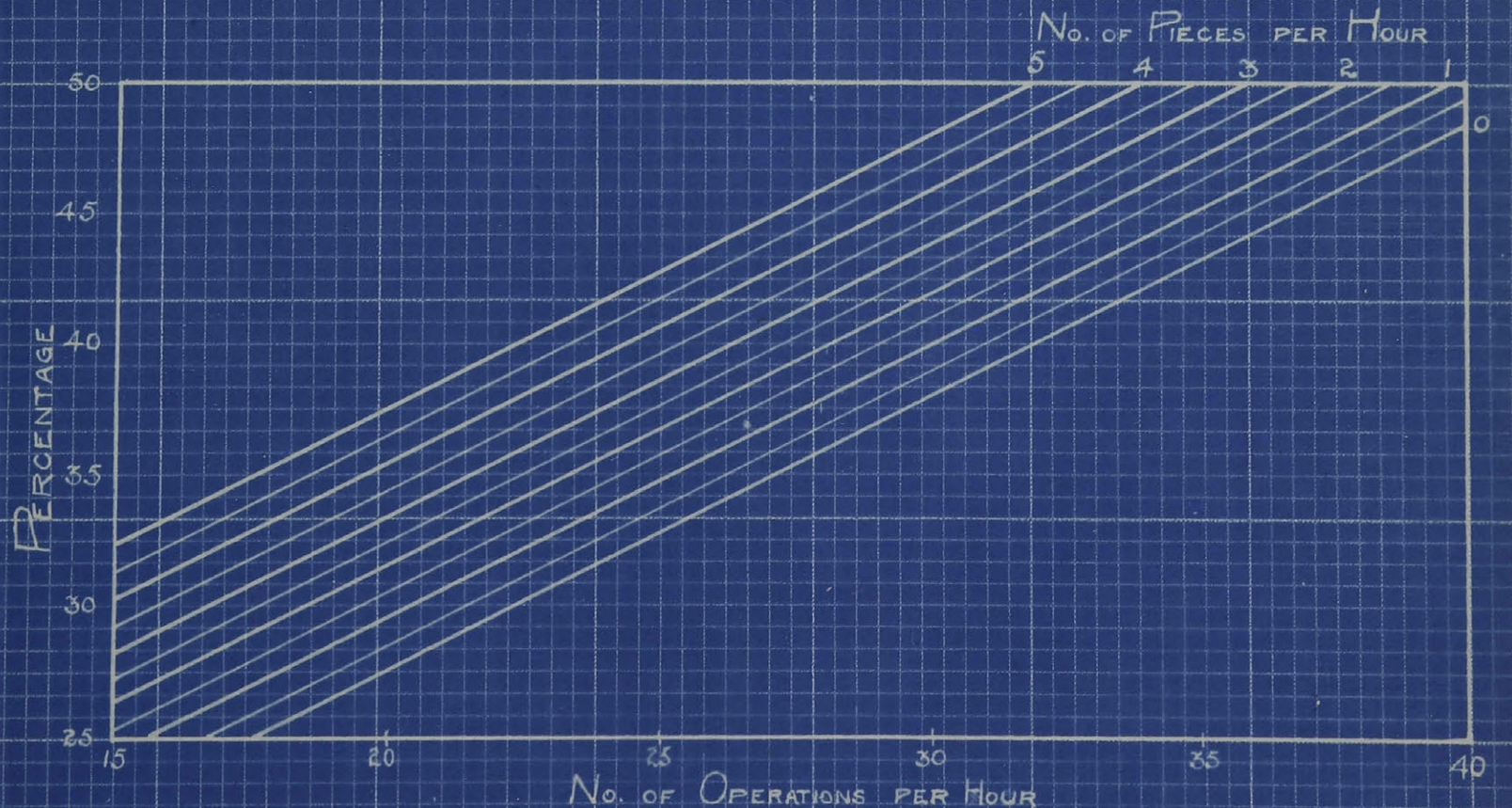


VII

PLANE


No. of Pieces per Hour
5
4
3
2
1
0
50
45
40
35
30
25
Percentage
8
10
15
20
25
30
33
No. of Operations per Hour

SLOT


No. of Pieces per Hour
5
4
3
2
1
0
50
45
40
35
30
25
Percentage
15
20
25
30
35
40
No. of Operations per Hour

C. P. R. Piece Work Department, and though considerable mystery surrounds the figures upon which the curves are based, the piece rates obtained with their help seem to give every satisfaction.

The only difficulties with which a time student is likely to be confronted, arise directly from the extent to which the attitude of the men towards his work is adverse. From past experience, the workers in most plants have considerable justification for a conviction that no change which the management are anxious to institute can be to the men's advantage; and few things are better calculated to irritate a workman than the consciousness of a minion of the management standing over him with a stop watch, and timing his every movement. If the men are not taken into the confidence of the management, the natural and logical deduction which they are almost certain to draw from the phenomenon will be that the latter are collecting information for the purpose of forcing them to work still harder without any corresponding increment of wages. When the men are in this frame of mind, it is obviously a matter of extreme difficulty to derive any useful information from a study of the times which they take to perform operations. Many "unavoidable" mishaps are liable to occur on the machine which is being observed. Perhaps the tool steel is inferior; or the work may be a succession of hard spots; or perhaps the belt is too loose for an application to

the work of the most economical combination of cut, feed and cutting speed. If the time student should be so unfortunate as to know less of the capabilities and properties of machines, tool-steel, belting, etc., than the workmen, even where he is sure that the work could be done more rapidly, he is unable to confute any of the above plausible excuses for slow work, and the records of his observations are so much waste paper.

Where, however, the time student is a skilled mechanic, not necessarily first class, but promoted to the position on account of his intelligence and reliability, the disability under which the management labours is greatly diminished. Certainly, such a man must be paid more than the clerk above, but as the records obtained by the clerk are admittedly worthless when the men are opposed to the innovation, the efficiency of his salary is zero, and is therefore incomparable with that of the intelligent mechanic. An additional advantage of employing a man of the latter type for time studying, is that he can be used also as a demonstrator, to show the men how best to earn a maximum daily wage as the piece rates on their work are set, and thus to inspire confidence in the new system. Such a man, when observing men's times on standard jobs, should be given a limited executive power, enabling him to insist on having the various operations constituting the job performed in whatever sequence he considers most suitable, and to enforce what he deems to be the best combinations of

depth of cut, feed and cutting speed on machine work.

It is only by the greatest tact, which amounts to taking the man whom he is studying into the confidence of the firm, that he can enforce his views regarding the time and method in which the performance of hand operations - such as lifting work to bed, truing and clamping work, setting and changing tools, calipering, removing work, cleaning machine etc. - should be performed. And although the time which such a man will decide upon as essential, under existing conditions, for the proper performance of the work will be immeasurably more exact and more uniformly fair than if fixed by the clerk, it will not be quite so accurate, nor nearly so liable to be accepted without question as if the men's sympathy and co-operation had been won in the first instance. On the other hand, the extent to which a tactless time student endowed with even this minimum of executive authority could irritate the workers, might easily be the last straw in precipitating a strike; and would, to a certain extent, excuse the dislike of the average manufacturer to this method of instituting the piece work system.

It is generally possible to persuade one or other of the first class workmen in each shop to work at his best speed for the purpose of observing his times and methods - partly by paying him an increased rate while the studies are being made, and thus rendering him sufficiently jealous of the position to avoid risk of losing it through incurring suspicion of not

working at his best speed; and partly by proving to him that the object of the time study is not merely to facilitate a further exploitation of the workers, but also to enable the best workmen to earn a much higher wage.

Where public opinion throughout the shop has been so strong and so unanimously opposed to piece work as to defeat this plan, some firms have gone to the extreme of making secret time studies, either by means of stop watches concealed in books or by hiring a skilled worker from outside, and observing his operations on a machine lodged in a separate room. This procedure has been known to end satisfactorily; but its primary effect can only be to intensify the feeling of the men against piece work or whatever else it may seem to portend.

In cases where the opposition to piece work is so bitter or distrust of the management so deep-rooted that no headway can be made in the machine shop, it is often diplomatic to commence by winning over the unskilled labour, where the organisation is generally rudimentary, and the market for which, to all intents and purposes, inexhaustible. It was here that Taylor commenced his classical reorganisation of the Bethlehem Steel Works, - on the extremely simple work of loading pig iron on cars.

(3) This daily assignment to each worker of a maximum reasonable daily task is really the ideal for the attainment of which Taylor originally began his life's work - and the laborious researches essential for the compilation of sufficient

data to be regarded as a satisfactory solution of problems (1) and (2) were just as incidental to the attainment of this supreme end as was the comparatively minor subsequent problem of inducing men to turn out the desired quantity and quality of work per day.

(3) and (4) It would unquestionably be the height of folly, and has already been the cause of strikes where attempts have been made by inexperienced innovators, to introduce (3), the crux of the system, without having first taken care to make the accomplishment of the daily tasks uniformly possible.

As explained under (2), it is impossible for any man, except on repetitive work involving only a short cycle of simple movements, to perform any job in the predetermined minimum time obtained by simple addition of the elemental times. There must always be an allowance for necessary rest and unavoidable delays, and this allowance must be, as far as possible, uniformly fair, and always fixed upon the same regular plan, which will take into consideration the quality and quantity of each class of labour available, and the shop conditions generally. Thus, in a great industrial centre such as Oldham, Sheffield, Philadelphia or Detroit, where the community contains a very fair sprinkling of highly skilled workers, the individual daily task might be made so large that even a first class man could not accomplish it until he had been keyed up almost to his maximum reasonable

efficiency. As will afterwards be explained, in such a plant it is only necessary to manipulate the payment system wisely to have the works, after confidence has been established, literally besieged by first class workmen eager for a chance to earn what they are really worth, so that the labour problem, under proper handling of the system, need present no difficulty.

On the other hand, in Vancouver and many industrial towns in the Southern States it would be a farce to set so high a task, as the highly skilled workers are in an almost insignificant minority. Consequently, any task set, if it is ever to be accomplished by the average worker, must be a compromise between what I have called the labour unit, and the prevailing average individual daily output.

Since consideration of the shop conditions is essential to the setting of a uniformly fair daily task to each worker, the standardisation of shop conditions and methods, appliances, tools and fixtures, has become a sine qua non of the Taylor system of shop management. The reason for this, briefly, is that the time required for the performance of each operation, as determined by time studies, presupposes ideal appliances in perfect working order. Consider the elementary operation of clamping work between centres on a lathe. The standard time allowed for its performance is based on the assumption that the machinist will run the clamping screw of the dog down to the work with his fingers, and apply a wrench only during the last

quarter turn to tighten it. Suppose that the thread of the screw has become damaged, or the screw bent, as they are apt to do under the prevailing extravagant neglect of appliances. The workman must then run the work all the way down with a wrench, and will consequently be in danger of failing, through no fault of his own, to complete his task in standard time. Therefore standard times would be unthinkable, if bereft of standard appliances.

THE STANDARDISATION OF APPLIANCES.

~~Thus,~~ In order to ensure that all such appliances shall be maintained in good order, it is essential that they be kept in a tool room in charge of a person competent to inspect and repair them, or to issue instructions for their repair should it be necessary to do this work in the shop. Under most systems only the finest and most expensive tools such as drills, taps, reamers, gauges, etc. are kept in the tool-room; cutting tools at the machines on which they are used; and blocks, holding down bolts, etc. wherever they happen to have been left. Thus, considerable time is lost every day by each machinist in seeking the tools and clamps which he requires; and still more through the damaged condition in which he often finds the latter; in grinding his cutting tools to whatever angles he happens for the moment to be affecting; in waiting his turn at the emery wheel; and in having to regrind his tools much more frequently than if all were ground before being set

up to the correct angles, as actually determined by Taylor and specified in his aforementioned paper.

Not one of these time wastes but is obviated under the Taylor system. All tools, appliances, jigs and fixtures are kept in the tool-room when not in actual use. When any are wanted, they are caused to be delivered to the man who requires them just before he starts on the job for which they are needed; and returned to the tool-room when finished with. Each man is supplied with a number of small brass checks bearing his clock number, and one of these is suspended on a hook in the tool-room corresponding with each tool or appliance in his possession. This not only enables the ready location of small equipment, and involves insurance against loss; but it also facilitates the maintenance of simple records for assigning the responsibility for unnecessary damage to tools, and thus discourages preventable rough usage of them. Tools are repaired or replaced as is considered advisable, and maintained very close to a general standard condition of excellence; and the work of tool grinding is taken out of the hands of machinists, and performed by a man, who does little or nothing else, on an automatic grinder. In this way the tools are ground in large lots to the same standard cutting angles for various kinds of work which Taylor discovered to be most efficient, and without injury by overheating - a common phenomenon when each machinist grinds his own tools. A shop working under the Taylor system therefore requires a larger tool

equipment than it would have under any other system; but this is more than compensated for by the large increase in efficiency and life of each tool. The tools themselves are of standard type and grade of steel for each purpose, or, where possible without appreciable loss, for all purposes. For such tools as drills, reamers, taps and dies one grade of tool steel is generally sufficient, regardless of the composition of metal upon which they are to operate. But for lathes, planers, slotters, milling machines, etc., there must generally be two or even three sets of tools if the hardness of metals which they are required to work varies considerably - one set for wrought iron and soft steel, another for medium steels, and a third for cast iron and hard steel; but there should not be more than three grades of tool steel.

Milling tool shapes are now being very well standardised by the makers. Lathe, planer and boring tools are the ones most affected by the Taylor standards - and those for slotters in a lesser degree.

Standard cutting tools necessarily represent a compromise in order to fulfil the best economical combination of the following desirable but conflicting conditions:-

(a) to leave the work with a true and smooth surface,

(b) to remove the metal in minimum time,

(c) to do a maximum of work with minimum cost of grinding, forging and of tool steel,

(d) to be adaptable to a large variety of work.

~~Some~~ standard tool shapes ~~are~~ shown on Plate X. The forging and dressing of such tools are expensive; but a single heat treatment suffices for thrice or more times as many grindings as any other standard shape, without redressing; and such tools can be ground more cheaply than their forerunners.

The principal desideratum in laying out or reorganising a tool-room is the provision of storage accommodations which (1) will occupy a minimum of space, (2) permit of rearrangement or extension as the tool-room grows and (3) are arranged for minimum interference with light. There must be just one definite place in the tool-room for each tool, and all tools shall be so classified that there shall be no difficulty, and a minimum of time loss in delivering any that are desired. The system of tool classification, which serves another and equally important purpose, to be described later, is as follows at the Angus Shops:-

Table I.

Classification of Tools.

Class

A Miscellaneous tools - not elsewhere classified;

B Bending tools - all tools for producing changes in shape by bending, folding, spinning, etc.;

C Clamps and Holding Devices of all kinds, including bolts and screws;

D Drilling and Boring tools - tools that remove metal from the interior, such as drills, boring bars, cutters, and all appliances relating to them;

E Edge tools - for working wood and plastic materials - clay, moulding sand, putty, etc.;

F Heating tools - all kinds of tools used for heating, lighting, melting and moulding; oil tempering, annealing, drying and cooking, etc.;

H Hammers - and all tools that work by striking or being struck, such as sledges, tups, chisels, sets, flatters, etc.;

L Transportation tools - all tools used in moving materials from one place to another, such as buckets, boxes, trucks, shovels, wheelbarrows, bogies, rigger's tools, slings, chains, etc.;

M Measuring tools - all instruments of precision, weights, gauges, measures, electrical instruments, etc.;

P Paring tools - all tools that remove metal from the surface, by cutting, except slotter and milling tools - (lathe boring tools under D);

R Milling tools - all tools for milling or sawing metal;

S Slicing tools - all parting tools and slotter tools;

T Templets - and all instruments for duplicating work, including jigs and fixtures;

V Abrading tools - all tools used for rubbing, scraping, filing, grinding, shearing, punching, breaking, etc.;

W Wrenches - and all tools used for causing rotation;

X Painting tools - all tools used for covering a surface with an adhesive foreign material, and any for removing same.

Each of these groups is then further subdivided, as follows:-

	SUB-CLASS		
Drilling and Boring Tools " D "	Boring Bar - A		
	Lathe Boring Tools - B		
	Cutters - C		
		Parting =	C
		Round =	R
		Square =	S
		Side =	U
		V shape =	V
	Drills D	Flat =	D
		Fluted =	E
		Twisted =	F
	Reamers F	Parallel =	L
		Taper =	M
	Rosebits R	Spiral =	N
	Taps T		
		Special =	Z

	Sub - Class	Shape of Nose	Bend
Paring Tools " P "	Parting = C	Sharp = S	Straight = A
	Round = R	Blunt = B	" Right = B
	Square = S	Broad = W	" Left = C
	Side = U	Bevelled = A	30° Right = D
	V shape = V		" Left = E
			45° Right = F
			" Left = G
			60° Right = H
			" Left = J
			90° Right = K
			" Left = L

and similarly for the other groups.

A blunt, left hand, round-nosed lathe tool would be specified PRBC; and the size of the tool, as represented by the width of bar stock from which it is forged, is shown by a number prefixed to the above letters. Thus a 1" parting tool with a cutting edge inclined at 30° to the right of the normal position would be stored under 1 PCSD, which symbol is also stamped upon the shank of the tool to prevent loss of time in restoring it to its allotted place on being returned to the tool-room.

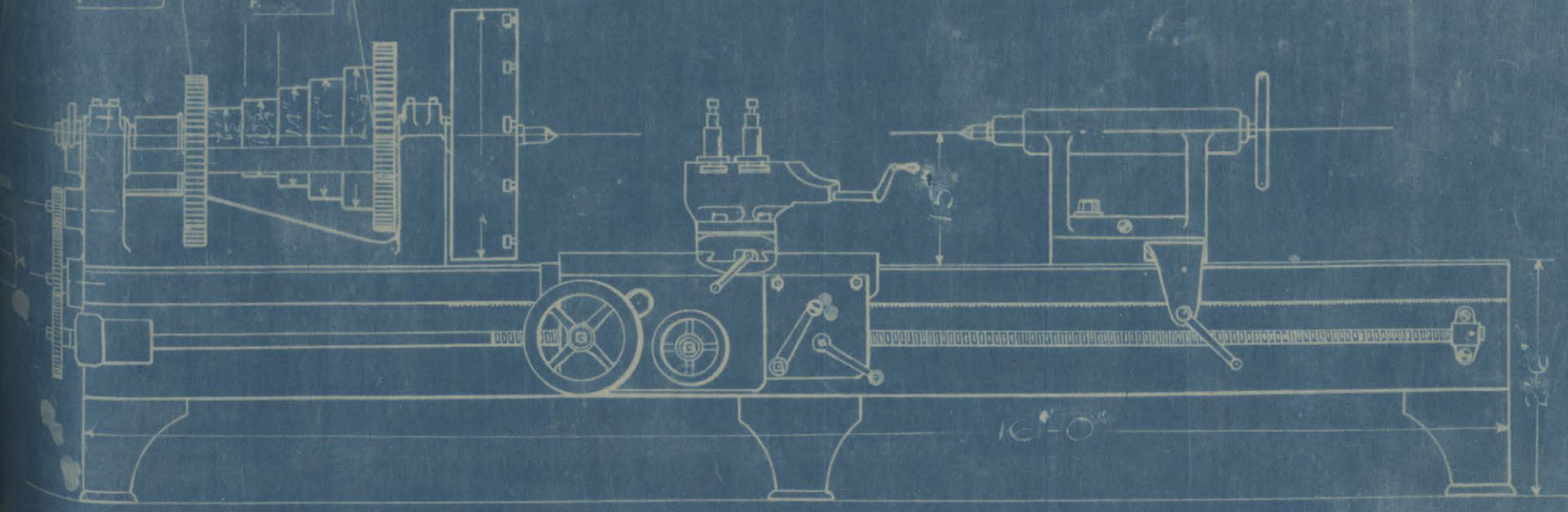
SPEED		CROSS FEED		FEEDS ⅛ IN.				
CONE STEP	SPINDLE R.P.M.							
1	35							
2	103							
3	150							
4	84							
5	86							
6	170							
7	120							
8	194							
9	298							
10	438							

BK. GR.

4" Belt.

T.
P.
PD.
F.

T.
P.
PD.
F.



MAX. DISTANCE - CENTERS TO BED 15"

" " BETWEEN CENTERS. 40"

LENGTH OF BED. 14'-6"

HEIGHT - BED FROM FLOOR 2'-6"

DIAMETER (MAX) BETWEEN CHUCK JAWS. 14"

PITCH OF GUIDE OR LEAD SCREW. 4"

MOTOR H.P. 1" BELT DRIVE

SPECIAL ATTACHMENT

DIMENSION OF FLOORSPACE 16' x 2'

DATE PURCHASED

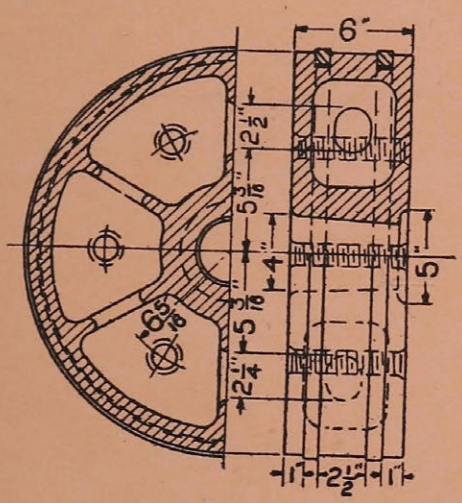
CONDITION GOOD TO DATE.

RATIO DIRECT TO BK. GEAR

IX

BERTRAM LATHE 15CR

INSTRUCTION CARD — LIST NO. 56 L 253

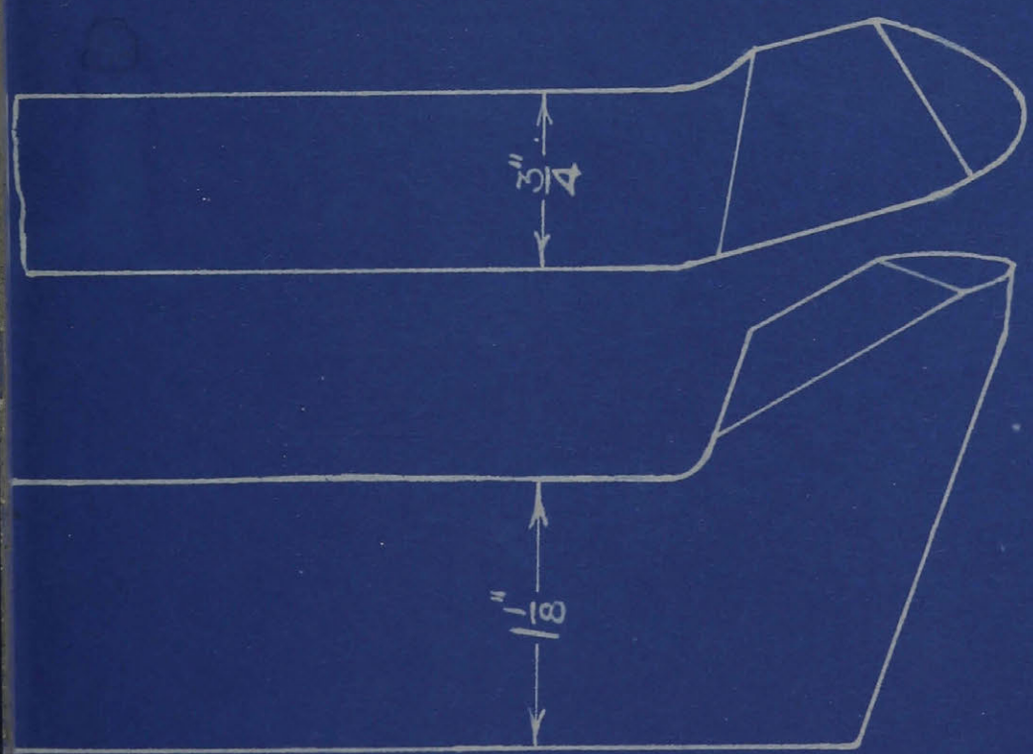


NOTE:- DIMENSIONS ON SKETCH MUST NOT BE USED IN MACHINING. USE STANDARD DRAWINGS.

DRAWING No.	56 L 3.
NAME	PISTON HEAD.
CLASS	ALL CLASSES OF THIS TYPE.
SCHEDULE No.	56 L 76, 108. ISSUE A
OPERATION	TURN FACE AND EDGE, TURN GROOVES AND RECESS.
OPERATION No.	1 b MATERIAL C. I.
MACHINE	NILES VERTICAL BORING MILL No. 38
TOOL STEEL	HIGH SPEED.
No. OF PIECES	1
TIME	1.4 MAN-HOURS PER PIECE
No. OF MEN	1 DATE 4-13-10
PAY EQUIVALENT FOR	
FIRST PIECE.	2.05 HRS.
EACH ADDITIONAL PIECE.	1.75 HRS.

SEE CARD 1 a FOR 1st. OPERATION.

DETAILED INSTRUCTIONS		Tool Used	Depth Of Cut In Inches	Feed In Inches	Spindle R.P.M.	Speed In Feet Per Min.	Minutes Allowed
PREPARE MACHINE ETC. FOR 2nd. OPERATION, 1st. PIECE ONLY.							18.0
1. SET UP PISTON AND SET TOOLS.							10.0
2. ROUGH TURN FACE.	1	1-4 PRSC	1-8	1-8	8	33	
ROUGH TURN EDGE.		"	3-8	1-16	8	44	18.0
3. CHANGE TOOL AND CALIPER.							2.0
4. FINISH TURN EDGE.	1	1-4 PRBC	1-32	1-8	8	44	7.0
5. CHANGE AND SET TOOLS.							5.0
6. ROUGH TURN GROOVES.		PSWAZ	13-16	1-32	4	22	8.0
7. CHANGE TOOL.							3.5
8. FINISH TURN GROOVES.		PSWAZ	1-32	1-32	4	22	8.0
9. CHANGE TOOLS.							1.0
10. RADIUS TOP AND BOTTOM EDGES.		1 1-4 PZ	1-4	1-16	8	44	4.0
11. REMOVE CLAMP AND CHANGE TOOL.							2.5
12. ROUGH OVER RECESS.	1	1-4 PRSC	5-16	1-16	8	10	4.0
13. TURN RECESS.		"	3-16	1-16	8	10	5.0
14. REMOVE.							6.0
				TOTAL MINUTES			84.0
B.D. ANGUS SHOPS, C. P. R.				TOTAL HOURS PER PIECE			1.4



"$\frac{3}{4}$PRBC"

THE STANDARDISATION OF MACHINES.

Having thus centralised the control and maintenance of cutting tools, it now becomes necessary to standardise the machines. The equipment of the Locomotive Department of the Angus Shops consists almost wholly of two groups of machines, one group purchased about 1904, and the other in the vicinity of 1909. Now, other things being equal, it is hardly likely that any mechanic working on a machine, A, of the first group will produce as much per day as if he were operating a similar machine, B, in the second, on account partly of the five years extra depreciation of the older machine, and partly of the five years extra knowledge and experience that went into the design and construction of the new. Therefore, if the two men who actually run the machines, A and B, each produce the same daily output, the former is manifestly deserving of a higher wage per piece, or per day, than the latter. But, unless this difference in remuneration were actually based upon a determination of the individual capabilities of the several machines, such discrimination would immediately be vilified by a not over satisfied working force as favouritism. Therefore the firm must have sufficient data about every machine in the shop to know the reasonable maximum amount of work which it is capable of doing per day when handled by a first class man.

In light of this knowledge, and other conditions such as belt tensions being equal, the actual daily output of each machine gives a ready measure of the efficiency of its operator, and thus affords a basis for the fair payment of wages - by the piece or otherwise.

The theoretically ideal method of obtaining this information, is to make a number of time studies on each machine, of the performance by a first class man of each operation that is usually done upon it. In the average machine shop, however, where each machine is required to turn out a number of parts, all of which are subject to change, such an investigation would be not only interminable and expensive, but unnecessarily exhaustive, and all desirable information can be compiled from a study of a few of the more typical operations. Such information could all be tabulated on a form only slightly more elaborate than that shown on Plate IX representative of the type adopted at the Angus Shops - where a number of these, one for each standardised machine in the shops, are bound together in a "Machine Capacity Book".

It will be noticed that these provide space for information as to maximum size of work which the machine can handle, height which work will have to be lifted in setting up, spindle speeds, and possible combinations of feed and speed, but the only information bearing upon the pulling and feeding power is imbedded in the adjective "Good", "Fair",

"Bad", or "Very bad" under "Condition of Machine". It is the intention of the authorities at the Angus Shops to extend the usefulness of the machine capacity book by embodying in each form more definite information upon the pulling and feeding power of the corresponding machine.

The drawings on these forms are quite empirical; but serve to show the type of machine, and are especially useful to a railroad company operating a large number of widely separated shops, as a basis for comparing their several efficiencies of producing the same article. At present the only place where the Angus machines are thoroughly standardised is in the heads of the Demonstrators.

Amongst other shop conditions which must be thoroughly standardised as a prelude to speeding up the shop to its maximum capacity, one of the most important is the belting, which is frequently far too loose to stand the cuts of which the tools and machines are really capable. Very few Machinists or even foremen know how best to tighten a belt. The amount to be taken out is guessed at, and much machine time is lost both in waiting until the belt is laced and later in having to run at something less than the best economical speed through the belt not having been tightened to the right tension. However, the use of proper belt clamps and a spring balance in tightening, and consignment of care and maintenance of belting to a special staff, - which will do most of its work outside shop hours, but will do it properly -

goes far towards eliminating belt troubles, and enables each mechanic to operate his machine at maximum efficiency - subject only to the limitations of his own intelligence.

THE STANDARDISATION OF METHODS-

This involves the creation of a new department, to relieve the workmen of the necessity of planning the actual methods of carrying out their work. While effecting this change, the Taylor system takes advantage of the opportunity to eliminate at the same time the weakest link in the industrial chain - i. e. the foreman - by distributing his multifarious functions to various members of the new department.

The limitations of the ordinary foremanship system may be surmised from the following typical case described in "Industrial Engineering and the Engineering Digest" March 1911, of a machine shop equipped with lathes, planers, drills, etc., run by about 30 men under the supervision of a single foreman.

"Among these men are half a dozen, Morgan, Brooks, Smith, Johnson, Sweet and Flannery. The foreman is at Johnson's lathe, supervising the production of a rather difficult and important piece of work, which has to be made very accurately, and on which the foreman must see that no mistakes are made. While he is so engaged, Brooks approaches him, and informs him that he has finished the job he was on, and that he wants another. The foreman, being much engaged with Johnson, tells Brooks that he

will see to him in a minute or two, and continues what he is doing. Brooks stands around or goes over and talks to Sweet until the foreman finishes with Johnson. The foreman then examines the orders which have been assigned to him by the office for the production of work, and gives a job to Brooks. It is a rather complicated job, and requires some explanation. While explaining the work, and discussing the best method of doing it with Brooks, Smith comes up and demands a job. With a hurried "Well, you see how it is to be done", the foreman leaves Brooks, to get a job for Smith. Brooks is not altogether sure that he does see, but, rather than say so and further detain his boss, proceeds on his own responsibility, makes a mistake and spoils the piece. It is not evident to him, however, and he continues to work; and the foreman, being concerned with Smith and worried over the fine job in Johnson's lathe, does not get to Brooks for a long time. Consequently Brooks' work is not inspected and the error is not discovered until a lot of time and money have been wasted, which would have been saved had the foreman not been so busy.

"Meanwhile the foreman has found a job for Smith. It is the machining of half a dozen large castings, and the office has indicated that it expects these to be done on piece work. It is a new job in the shop, and the foreman and Smith haggle a while over what is a fair rate. Neither one knows just how long it should take to finish one casting and a considerable discussion ensues, but finally a compromise is reached,

although each thinks he has been "stung". The foreman then tells Smith that Flannery had brought the first casting in the day before and put it at the big planer where it was to be machined; and goes back to Johnson. Smith fails to find the casting, and once more goes to the boss. He assures himself that the casting is not at the planer, and, not seeing Flannery around, the two spend a lot of time in hunting, until they find the casting at one of the milling machines where Flannery had put it by mistake."

This example, though unusual, serves to indicate the limitations of the ordinary foremanship system; and similar extravagance of expensive labour may be seen on a busy day in hundreds of plants. Such a slovenly system can only result in unnecessarily high costs of production, not only on account of the unproductive nature of wages paid to idle machinists, but still more through the distribution of the overhead expenses over an unnecessarily small volume of product. At last, however, the foreman is being found out - not through any other fault of his own than that of failing to possess a superhuman combination of desirable qualities.

Taylor specifies possession of the following qualities as essential to perfect foremanship:- "Brains, Education, Special or Technical Knowledge, Manual Dexterity or Strength, Tact, Energy, Grit, Honesty, Common Sense and Good Health", and one might almost be justified in adding "Ubiquity". The

duties of gang boss could only be thoroughly fulfilled by an almost similar combination of man and qualities, and, were such men obtainable, any company would find it extremely profitable to employ them in much higher positions than that of foreman.

As plenty of men possess three, four or even five of these qualities, it is a simple matter and a profitable, because efficient one, to extend the sphere of the foreman, and at the same time to subdivide his duties and allot them in suitable parcels to a number of trained specialists. This involves the substitution in the shop of functional management for the military type of organisation.

Functional management consists in so dividing the work of management that each man from the Assistant Superintendent down shall have as few functions as possible to perform; and the Taylor ideal is, where practicable, to confine the work of each official to the performance of a single executive function. Where the shop is sufficiently large, Taylor recommends that the foremen be replaced by a corps of eight kinds of functional foremen who are called (1) Gang Bosses, (2) Speed Bosses, (3) Inspectors, (4) Repair Bosses, (5) Route Clerks, (6) Instruction Card Men or Demonstrators, (7) Time and Cost Clerks, (8) Shop Disciplinarians.

Their respective functions are as follows:-

THE GANG BOSS, being supplied with full information as to what work is to be performed upon the machines under his supervision,

and the order in which it is to be machined, sees that each man's next job is delivered beside his machine before completion of the last. He further sees that all tools, jigs, templets, fixtures and drawings required for the next job, and sling chains for hoisting work to the machine, etc., are ready at hand before they will be wanted.

He must also see that loss of machine time while the work is being set is reduced to a minimum, either by helping the machinist or showing him how to hoist and set the work with the utmost despatch.

THE SPEED BOSS must see that the work is machined with maximum rapidity consistent with accurate workmanship and only reasonable depreciation of machines, according to instructions supplied with each job. He must see that these instructions are being rigidly followed in every detail, as to cutting tool, speed and feed combination, depth of cut, and sequence of operations. He must also be prepared to demonstrate that any job can be done in the time laid down on the instruction card, if the man who is actually doing the work should fail repeatedly, and raise a question as to the possibility of its performance.

THE INSPECTOR:- a very important official under all systems involving a piece rate. This man must carefully examine all work to discover how nearly it has been made to specifications, and no entry is made on a workman's pay roll for any job until

that job has received the approval of the Inspector. This man, therefore, must be impartial, and possessed of sufficient judgment to discriminate between jobs that are distinctly inferior, and those that are imperfect but quite good enough for their purpose.

Both workman and speed boss must see that all work is finished according to his wishes.

THE REPAIR BOSS:- This official is only indirectly concerned with production, but maximum production is unattainable without fulfilment by somebody of his functions. He must see that the men keep their machines clean and free from rust, and that all standards established for the care and maintenance of equipment (care of belts and shifters, orderly piling of work, etc.) are rigidly maintained.

THE ROUTE CLERK is the first official to influence the career of work in the shop; but, while he must be intimately acquainted with the topography of the shop, all the work connected with his particular function is performed in the "planning" office. Having ascertained that all materials required for a job are available, and knowing the date on which the finished product is to be delivered, he examines the drawings and bill of materials and then makes out a list of the machine operations which will have to be performed upon the various parts such as planing, boring, and drilling. He then

decides in what sequence the various operations on each part will be performed, and, finally, on what machine or group of similar machines this will be done.

He must therefore have had sufficient experience of machine work to know from the drawing whether a certain surface had better be milled or planed, or whether a boring mill or lathe is more suitable for a given boring operation.

Having decided upon a route by which the work will pass as nearly as possible in a straight line through the shop, he will write instructions for the various gang bosses showing the exact order in which work is to be done by each group of machines in the shop. In so doing he will make extensive use of data regarding times required for the various operations and will pay continuous attention to the date at which each part will be required in the erecting shop, in order that the machines may be finished in time for delivery on the stipulated date.

THE INSTRUCTION CARD MAN or DEMONSTRATOR is more particularly occupied in devising methods for performing all new operations, that are at once quick, accurate and economical. He must therefore not only be a highly skilled mechanic, but must be able to handle accurately some form of Barth slide rule, and must further have at his disposal profuse data regarding such elementary hand operations as lifting work of various weights

and shapes to the machine, setting tools, starting machines, changing feed or speed, changing tools, cleaning machines, etc. With these, and his knowledge of the capabilities of each machine in the shop, it is a simple matter to lay out a programme of operations for each job in that sequence which best lends itself to the most rapid completion of the task. Opposite each operation, in special columns, on the standard instruction card, he writes all necessary information as to the detail methods upon whose use the time allotted for each elementary operation is based. Plate X shows the form of card adopted at the Angus Shops for conveying information, simple complete and free from ambiguity, as to the best known means of performing the operation of turning the face, edge, grooves and recess of a locomotive piston head on Boring Mill No. 38, from the planning department to the shop. This, as will be seen gives fairly complete information as to what is done in each operation, what tool is used (symbols ending in Z refer to special tools, which are readily identified by the other letters), Depth of cut, Feed (in inches per revolution), Spindle R. P. M., Cutting speed, and Time allowed. The total time in which the first piece can be completed is 1.7 hours, and subsequent ones 1.4 hours. Turning to the front, we see printed the words "Pay Equivalent for

First Piece	2.05 hrs.
Each Additional Piece	1.75 hrs."

implying an allowance of a little over 20% for rest, unavoidable delays, and incentive. The object of stating the piece price in time equivalent is that each worker in shops throughout the C. P. R. system is paid a fixed hourly rate, whether his piece work earnings fall short of this or not (vide Contract System, Ch. IV. p.63), and the same grade of labour is more heavily remunerated in Winnipeg than at Angus; and better again in Vancouver than at Winnipeg. Therefore the statement of an actual piece price on the back of the card would limit its usefulness to one shop only. This, however, is a digression, as the C. P. R. does not operate its shops wholly under the Taylor system. In plants which are so operated, one of these cards is delivered to every machine with the tools required for each job that is performed upon it, and is returned to the tool-room or planning department on completion of the job.

THE TIME AND COST CLERK receives direct from the men by means of a job order, or other form, all the information that he needs for the men's pay rolls, and for his cost accounts.

A suitable form for the conveyance of this information from the shop is shown on Plate XIV, and briefly described in Chapter VIII.

THE SHOP DISCIPLINARIAN deals with workmen or bosses in all cases of insubordination, impudence, repeated failure on work, lateness or unexcused absence; and applies in each case what he

considers to be the proper remedy. He keeps as complete a record as possible of incidents that shed light on each man's reliability and deficiencies; and he should invariably be consulted when wages are being readjusted or promotions made. An important function requiring tact and good temper is that of peacemaker between his fellow foremen and their men.

In the case of a first offender, the disciplinarian should speak to him in a friendly manner. As some men mistake this policy for timidity the misdemeanours may continue, and they should be met with increased severity of words until "the desired result is attained, or the possibilities of the English language exhausted".

To discharge a man is effective so far as that particular individual is concerned, and may result happily as a deterrent to other prospective malingerers, but several expedients should be interposed between the extremes of verbal remonstration and dismissal. The more common intermediate measures are

(1) Lowering the man's wages,

(2) Laying him off for a period,

(3) Fining him,

(4) Giving him bad marks for various offences, and, when these reach a certain total, apply (1), (2) or (3).

The first and second remedies are too drastic for most offences, and the latter may punish the employer even more than the offender. The fourth will have the deleterious effect of almost encouraging

carelessness until the critical number of marks is nearly reached. Therefore Taylor prefers the fining system if properly administered. Its success is dependent upon (1) the impartiality and judgment with which it is applied, and (2) the fate of the money so received by the employer. If this money, or any part of it, is retained by the employer, the men are easily persuaded to regard the motive for the infliction of the fine as partly one of cupidity, and the consequent dissatisfaction more than counterbalances the moral effect of the fine. If all fines be immediately returned to the whole employés in some form or other, the men quickly recognise it as purely a system of discipline, and, as such, it is soon strengthened by the approval of the more competent workmen.

For this purpose Taylor recommends the creation of some form of mutual benefit association to which all the men, as well as the employer, contribute - and regards an accident insurance association as less liable to abuse than any other form. When practicable, this association should be formed and managed wholly by the employés, and all fines can be handed to their treasurer weekly. This, however, is a little aside from the actual functions of the disciplinarian.

One of the advantages of having a special official for disciplinary purposes is almost self evident. The only functional foremen with whom the workman is likely to quarrel

seriously are the gang boss and speed boss - whose special function it is to show him how to produce a maximum amount of work. The enforcement of discipline by one of these would quite probably engender hard feelings between the workman and himself, and the result could only be a reduction in overall efficiency of the pair.

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As the special knowledge which each of the above eight men must possess or acquire forms only a fraction of those without which no ordinary foreman can properly fulfil all his duties, a good functional foreman is much more easy to find and more easily trained than an efficient specimen of the type he supersedes. Taylor states that an intelligent workman can be converted into a good functional foreman in from 6 to 18 months; so that even a new company can be equipped with competent shop-officials in a comparatively short time - a human impossibility under the old régime.

As an instance of the manner in which the qualities requisite for efficient foremanship are subdivided into not uncommon groups, the possession of any one of which will qualify a man for one of the functional offices, - the gang boss requires executive ability, foresight and a certain amount of manual dexterity; the speed boss need only be a careful and expert mechanic; the disciplinarian, besides being a keen judge of human nature, must be firm and eloquent, yet tactful and

good natured; the repair boss should be conscientious and neat; the demonstrator should be ingenious, and thoroughly versed in his trade, but need not necessarily have executive ability, and so on.

The number of each kind of foremen required depends upon the magnitude of the plant, and on the character and variety of the work - not at all upon the number of any other type. Where there are many functional foremen of any one type, it is often desirable that they should have a foreman over them; and the principal functions of the speed foreman, head gang boss, chief inspector, etc., will be

(1) To teach subordinates the nature of their duties, and to encourage them to insist upon the instruction cards being followed;

(2) To prevent conflicts of authority with other kinds of functional foremen.

The members of the Planning Department (Route Clerks, Demonstrators, and Time and Cost Clerks) should be housed together in an office near the centre of the shop. The ideal is to have the shop managed by the planning department; but its office should be close to those of the manager, superintendent and his assistant, and, if possible, to the drafting room also.

In addition to the foregoing functions, Taylor considers that the following also should devolve upon the planning department:-

(1) The analysis of all orders received by the company. This indicates what designing and drafting will be necessary; and supplies all data required by the stock clerk and purchasing agent. When the drawings are received from the drafting room, and information as to date of delivery from the general office, the individual operations can be analysed, and the routes planned.

(2) The fixing of piece rates from time study data and extensive use of a slide rule.

(3) The maintenance of a balance of raw materials, stores and finished parts, and of work ahead for each class of machines and workmen.

This last is not only of extreme importance in stimulating the production from each shop of the exact, instead of the approximate output required, but is applicable under all systems of shop management. Gantt recommends the use of a form for each production order similar to that shown on Plate XI, which is made up daily, and therefore reflects the almost instantaneous efficiency of each department.

The form selected relates to the passage of a group of locomotive frames through a machine shop, and the progress of work is compared at each step with the programme originally made out by the route clerk. For this purpose each column is crossed by two heavy horizontal lines opposite the dates

PART		FRAMES											
SKETCH OR PATT. No.													
OPERATION		REC'D		PLANED		SLOTTED		DRILLED		ASSEM'D			
TO BE BEGUN		1.20.3		1.20.3		1.22.3		1.27.3		2.2.3			
TO BE FINISHED		1.30.3		2.3.3		2.5.3		2.6.3		2.12.3			
NUMBER WANTED		15		15		15		15		15			
NUMBER FINISHED		DAILY	TOTAL	DAILY	TOTAL	DAILY	TOTAL	DAILY	TOTAL	DAILY	TOTAL		
1903 JAN.	20	2	2	2	2								
	21	2	4										
	22			2	4								
	23	1	5										
	24	2	7	1	5	3	3						
	25	4	11	2	7	1	4						
	27												
	28	1	12	2	9	3	7	2	2				
	29	2	14	1	10	1	8	1	3				
	30	1	15	1	11	2	10	1	4				
	31			3	14	1	11	1	5				
FEB.	2					1	12	1	6	2	2		
	3			1	15	1	13	3	9	1	3		
	4							2	11	2	5		
	5							2	13	1	6		
	6					2	15			2	8		
	7							2	15	1	9		
	9									2	11		
	10									1	12		
	11									1	13		
	12									1	14		
	13									1	15		
	14												
	15												

XI

ISSUED		MAN'S No.
RETURNED		ORDER No.
MACHINE SHOP	HOURS WORKED	MACHINE No.

No. of Pieces Finished	SYMBOL	OPERATION No.

HOURS	RATE	WAGES	CONTRACTOR'S No.

I HAVE INSPECTED THE ABOVE WORK AND ENTRIES AND BELIEVE THEM TO BE CORRECT

SIGNED BY THE FOREMAN OR HIS REPRESENTATIVE _____

ENTERED IN		
PAY SHEET	COST SHEET	RECORD SHEET

XIV

at which the work should be begun and completed; and the position of the entries show to what extent the shop is maintaining the schedule. The balance thus becomes an extremely helpful instrument in locating inefficiency or deficiency of labour or equipment.

When accompanied by cards of the type shown on Plate XIV, but little clerical labour is necessary for the daily compilation of the balance, and the results amply justify the employment, if necessary, of such extra labour. The plan has been proved conspicuously successful at Angus; and its employment is stated # to have increased the output from the foundry of the American Locomotive Co. at Schenectady by 600%, in a single year.

With the help of this balance and that dealing with the stock of finished parts a daily or weekly report should be made to the manager and sales department to enable them to avoid embarrassing the harmony of production with a congestion or scarcity of work.

(4) Analysis of all enquiries for new work, and promises as to date of delivery.

This is a simple matter thanks to the abundance of time data and exact knowledge of the amount of work ahead for

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"A GRAPHICAL DAILY BALANCE IN MANUFACTURE"

Trans. A. S. M. E. Vol. XXIV - Discussion.

the various machines and departments.

(5) The construction and application of a mnemonic symbol system for the identification of orders, parts and operations; and for the filing of information relating thereto. The clerical work and chances of ambiguity in records are thereby greatly reduced.

At the Angus Shops, the basis of the mnemonic system is the classification and subclassification of drawings as follows:-

Classification of Drawings

C Cars,

D Power Plants,

E Electrical,

F Frogs, Switches and Track Work,

H Buildings, Water Tanks etc.,

K Furnaces and Forges,

L Locomotives and Tenders,

R Cranes, Hoists and Traversers,

T Machines,

U Office Furniture.

Divisions of "L".

11	Ash Pan	31	Draw Gear (Engine)
12	Axle	32	" " Tender
	Crank Pin	33	Eccentric Strap
13	Boiler	34	Engine Truck
15	Boiler Details		Leading and Trailing
16	Boiler Attachments	35	Erecting
17	Box, Driving	37	Exhaust and Steam Pipe
18	Box - Engine Truck	38	Expansion Bracket
	" Tender "	39	Firebox Fittings
19	Brackets, Stands	40	Fastenings
	Ornaments	41	Frame
20	Brake - Engine	42	Frame Detail
21	" Tender	43	Fuel Oil Burners
22	" Equipment	44	Front End - Rear End
23	Cab	45	Gauges, Templets, Dies,
24	Cocks and Valves		Jigs, etc.
26	Crosshead	46	Guide Bar and Attachments
27	Cylinder	47	Grate
28	" Attachments	48	Hand Rail and Foot Step
29	" , Compd. "		(Engine and Tender)
30	" , By-Pass	49	Injector and Feed Water
	Relief Valve		Attachments

50 Lagging
51 Link Motion
52 Lubrication
53 Miscellaneous
54 Preliminary Design
55 Piston
57 Packing
58 Pipe and Fittings
59 Reverse Lever
60 Rocker
61 Running Board and Wheel Covers
62 Rods (Connecting etc.)
63 Steam Gauge, Safety Valve Steam Heat, Reducing Valves, Special Fittings, etc.
64 Steam Chest and Attachments
65 Superheater
66 Signal Equipment, Lamps, etc.
67 Smoke Box
68 Springs
69 Spring Gear
70 Tools (Engine and Tender)
71 Tank and Coal Bunker
72 Tender Frame
73 Tender Truck
74 Throttle and Dry Pipe
75 Tool Box and Cab Seat
76 Wheels
77 Wash Out
78 Whistle

Group Subdivisions

<u>44</u>

Arrangement
Details
Buffer Beam
" " Angles
Foot Plate
Pilot
Pilot Details
Pilot Knee

<u>51</u>

Arrangement
Details
Link
Link Lifter
Transmission Bar
" " Hanger
" " " Bracket

Pilot Stay

Engine Plows

Bumper Knee

Flangers

Smoke Box Stay etc.

To each article is assigned a list number, by extending the number of the drawing for that type. Thus all valve motion link drawing numbers begin 51L3, and each link has a list number such as 51L336, which readily serves to identify the information already compiled regarding any job which has to be repeated.

(6) The planning department should thereby acquire considerable importance as an information bureau. The responsibility for indexing all information should be centred in one man.

(7) Maintenance of the system and plant. A time table should be drafted showing when and where each report is due. As a mechanical aid to the man who has to see that reports are compiled when due, Taylor recommends the use of some form of "Tickler", such as a portfolio with a pocket for each day in the year. Notices for inspection etc. are then placed in the tickler in advance, and the deterioration of equipment can then be attacked and remedied before it becomes

so serious as to necessitate a suspension of production.

By the adoption of standards, the use of a tickler, and of instruction cards for overhauling machinery, Taylor reduced the repair force at the Midvale Steel Works by two thirds.

(8) Organisation of the messenger system, providing for regular collections and distribution of routine reports, records and messages that are in no especial hurry.

(9) The selection of new employés. This duty generally devolves upon the Shop Disciplinarian.

(10) Performance of whatever clerical labour is necessary in connection with the mutual accident insurance association.

(11) Provision for rushing special work through the shop.

(12) Improvement of existing methods and equipment.

Unquestionably the cost of production is lowered by segregating the brain work and the function of planning into a separate organisation. The most common criticism levelled against the Taylor system is the extravagant tendency to increase beyond all reason the proportion of non-producers to producers. Taylor, however, states that comparison of a number of successful plants with a similar number of mediocre ones of about the same size will immediately betray the fallacy of the assumption that this is necessarily an evil; and further declares

that almost all shops are under-officered. In his opinion, a company doing an extensive engineering and miscellaneous machine construction business should employ one non-producer to every six or seven producers (the term non-producer here including general officers, clerks, watchmen, messengers and salesmen as well as superintendent, foremen and gang bosses). No one now questions the economy of the drafting office, and before long the planning department will be considered equally indispensable.

(5) THE DIFFERENTIAL PIECE RATE:-

As has already been stated it were futile to set each man in a plant a maximum reasonable daily task without taking means to secure its accomplishment. I have already discussed the measures prescribed for making the completion of each task possible, and the corps of instructors created for the purpose of helping and encouraging every workman to fulfil his task. But it is not yet apparent what means are to be taken to secure the co-operation of the employés - for it will certainly not be won by provision of the above facilities alone, and without it maximum production is unattainable.

While the ordinary piece work system, if fair and reasonably liberal, goes far towards stimulating a large increase of production, it is not automatic in securing the daily completion of a maximum reasonable task. Men will not do an extraordinary

day's work for an ordinary day's pay, and any attempt to induce them to do so is foredoomed to failure. The fear of being discharged is totally inadequate for producing maximum output, as men find that they can take many liberties, before the management will apply the extreme penalty. Under Taylor, the automatic element is introduced by the setting on each standard job of two piece rates - one so large that, by successfully completing his task each day, a workman is permanently assured an unusually high wage, relatively to the average earnings of his fellow tradesmen in surrounding plants - and the second, on which basis he is paid in the event of failure, so low that, even if he just fails to complete his task, his daily earnings will be no higher than the average of his trade.

Thus each man is continuously stimulated to maximum production by the sudden automatic increase in his piece rate the moment that standard output is reached. Employment of such a system, therefore, must rapidly single out the first class men in the plant; and, while it will discourage the less efficient ones, the fact that good workmen are permitted to earn an unusually high wage in this particular plant soon becomes common knowledge in the trade, and the owner becomes inundated with applications for employment from first class tradesmen anxious to better their position.

Where work is done on large and expensive machines, and the quantity of output depends upon severe manual labour as

well as on the skill of the machinist (while a large proportion of the cost of production is overhead expense) it is often advantageous to establish three or four differential rates as maximum output is approached. In addition Taylor advocates graduation of the incentive to maximum effort according to the class of work on which the effort is being expended. For work demanding neither exceptional intelligence, close application, skill nor extra hard work, he recommends a wage 30% greater than the average. Where great physical strength is required without skill or brains, the incentive is 50 - 60%; for delicate machine work, requiring unusual skill, brains and close application, but not severe bodily exertion - 70 - 80%, and, for a combination of all four, 80 - 100%. more than the average. For the above percentages, plenty of good men can be found who are willing to do their best, especially when they become convinced that the high wage is not only a transient bait to lure the unwary workman into demonstrating his capabilities, and betraying himself with his class to further exploitation.

The stimulus to exertion should be a daily one, involving rapid, but complete inspection, and immediate returns to apprise every workman each day of the results of yesterday's work. Much of the moral effect is lost even by a short postponement.

OTHER FEATURES OF THE SYSTEM.

Of these, perhaps the most important is the fact that it contemplates so apportioning the work, that each job is performe by the cheapest grade of labour capable of accomplishing it. Almost any repetitive work, requiring however great skill and dexterity, which is being done continuously, should be given to a trained labourer, and not to a mechanic. The average labourer can be taught to perform the most delicate work if it is repeated often enough, and his lower mental calibre enables him better than an intelligent mechanic to bear the monotony of repetition. Such a workman should be paid more than a labourer, but not necessarily as much as a mechanic. This ideal perhaps attains a more congenial aspect when restated as "each workman should be given the highest class of labour for which his brains and physique fit him". In this form it is at once seen to offer to every man in the plant a prospect of rising above his class, and so constitutes an additional incentive to maximum effort.

At Bethlehem, Taylor applied this principle to such an extent that, when he left, 95% of the men performing roughing machine work, and 25% of those on finer work were trained labourers.

During the expert investigation of machines and work, a number of hitherto unsuspected defects in the design of both

generally declare themselves, and point the way to improvements whose introduction will effect a tangible and immediate increase in efficiency of production. It is therefore advantageous to locate the drafting office in close proximity to the planning department.

In any works where the Taylor system has been adopted in its entirety, it is a simple matter to determine very approximately the time and cost of manufacturing each standard product. The selling organisation is thus enabled, not only to contract with perfect confidence for the delivery on the stated day of each article sold, but, further, to concentrate on selling those products upon which there is the greatest margin of profit. The consequent enhanced reputation of the firm for reliability in the fulfilment of contracts, and the increased demand for the most profitable lines must militate very perceptibly towards raising the annual turnover of the company to a maximum.

When the introduction of the system is complete, and all the workers are habitually completing their tasks, we have all the conditions which piece work was expected, but failed to fulfil. Even then, however, it is advisable to retain the differential element, or production will surely decline.

In illustrating this point, Taylor relates the history of the operation of turning a standard forging at Midvale before,

during and after the era in that plant of the Taylor system. In the first period the standard daily output, under piece work, was 5 per day at 50 cents each. In the second, a period of ten years, 10 pieces were produced per day with unfailing regularity, - the prices being 35 and 25 cents for standard and less than standard output respectively. The following table shows the comparative costs of production per lathe per day in the first two periods.

	Piece Work	Differential Rate
Man's wages	$2.50	$3.50
Machine cost	3.37	3.37
Total cost/day	5.87	6.87
Pieces produced	5	10
Cost/piece	$1.17 1/2	$0.69

At the end of the second period, the Taylor system was superseded by piece work, and the output at once fell to 6 - 8 pieces per day, where it remained. The value of the differential rate as an automatic stimulant to maximum efficiency must therefore not be lightly regarded.

Precautions to be Adopted in Introducing the System:-

Although Taylor himself has never had to contend with a strike in attempting to introduce his system, many others less conversant than himself with its peculiarities have been

considerably less fortunate. The cause to which most of these failures are directly attributable is impatience or cupidity - generally the former. To the uninitiated, the only vital features of the Taylor system are the differential piece rate and functional foremanship; and any plagiarism of the system so superficial as to omit the standardisation of machines and appliances is practically predestined to ignominious and disruptive failure.

Uniformity of standards throughout the shop is essential; and it is better that they should be uniformly second class than mainly first, part second and part third, owing to the natural tendency of a number of men on the same kind of work to adopt the pace of the slowest. The selection of the most suitable standard in each case need not be a very protracted process, and its installation should be commenced at once, but should not be unduly hurried. The economies attainable through the adoption of uniform standards are almost incredible, and Taylor states that the standardisation at the Midvale Steel Works more than paid the expenses of the whole reorganisation.

While the chosen standards are being introduced, the men most suitable for employment as functional foremen should be selected, and their training commenced. Taylor recommends that the full number be picked at once, as two out of every three either prove unsuitable or leave to take up a more lucrative position. In any event, more bosses will be required during

the transition period while the workmen are adjusting themselves to the new conditions than after the introduction is complete.

As the process of training the future foremen is now the most important element of the incipient reorganisation, it should be actively superintended for a considerable time by the expert in charge of the regeneration. Copious time studies are made, at first by the expert, and afterwards by prospective demonstrators under his supervision, of the performance by future speed bosses of standard machine operations, according to instructions. One of the first lessons which the speed bosses must be taught is the advantage of rigidly following instruction cards - at first made out by the expert, and, as soon as practicable, by the future demonstrators.

This period, with its interminable time studies is so laborious that there is always a temptation to curtail it, and to proceed to some more tangible change in the management. As the system is impossible without the existence of ample time study information, properly classified tabulated and indexed, the policy of unduly hastening the time study work can only result in the collection of a mass of data that is either insufficient, unreliable or not easily available, and such policy is therefore suicidal.

Having got the training of functional foremen well under weigh, the expert may now relegate its supervision to an assistant, and turn his attention to the following tasks:-

(1) The standardisation of machines, by analysing their speed and feed combinations and pulling power,- for the purpose of making slide rules;

(2) The design of suitable time cards whereby all desired information will ultimately be conveyed from the shop to the planning room;

(3) Investigation of methods of recording issues and receipts of stores, to establish a complete running balance of materials;

(4) Devising and having printed a suitable and sufficient set of blanks for shop returns and reports, instruction cards, expense sheets, cost sheets, stock cards, maintenance of standards and of plant, etc.;

(5) Rearrangement of equipment where considerations of routing the work render it expedient; and

(6) Starting such functions of the planning department as do not affect the men.

As soon as the selected shop standards have become generally established, the men chosen as inspectors, if there are none already, appear in the shop, and relieve the foremen of one of their most distracting duties. When, and only when, the men have been given to understand just what degree of accuracy will in future be demanded of them, the speed bosses and gang bosses also appear in one or two departments; and each job on which work is done in those departments is accompanied by an instruction card. As far as the workmen themselves are

concerned, this is the only sudden step in the whole process of rehabilitating the plant.

Than the average workman, perhaps no one stands to gain more or lose less by an alteration in the present method of regulating society - especially by an advance towards industrial co-operation - yet no one could possibly be more suspicious of change. Therefore the number of radical steps in the reorganisation to be made at any one time should always be a minimum. Each worker should have become aware that changes are going on, through his being relieved of responsibility for his belt, and of the necessity of grinding his tools, before any step is taken which will have a marked personal effect upon a number of workers.

This sudden simultaneous appearance of speed boss, gang boss and instruction card is such a radical step, that, were either the instruction card or time studies defective, or the training of either of the two new bosses imperfect, the system would at once become discredited. The functions of the gang and speed boss consist, at first, in seeing that an extremely limited number of men follow the instruction cards as to cutting speed and feed etc., thus proving to them that the machine operations, at any rate, can be performed in the apparently insufficient allotted times. The standard time allowed for each whole operation is already printed on the cards, and the men are soon given to understand that they

must eventually be prepared to do the job in that time if they hope to retain their positions.

When the men have come to realise that the gang and speed bosses are a help rather than a hindrance to them, the Differential Piece Rate System may be started with one man, preferably in the least efficient department of the plant, so that the moral effect produced in the other shops by success of the system in this one, may be favourable to its extension. The most promising man in the department. and not necessarily the one who is best paid, should be selected for this purpose. He has already cultivated the habit of following instructions, and knows that the machine operations can be performed as stated, without trouble to himself. He must now be subjected to the concentrated attention of both gang and speed bosses who will at once help him to simplify his movements, and stimulate him to perform the manual operations in standard time, by envy of their ability to do so.

After a few days, when this man has begun to earn the high piece rate regularly, the battle is practically won; and attention to him may be relaxed in favour of one of his fellow workmen. It may well be imagined that the other workers in the shop are far from disinterested spectators of these proceedings; and once these are convinced that the increase in speed is permanently possible, and that the remuneration of success is also real, public opinion in the shop soon becomes

favourable to the innovation.

A typical description of the problems encountered during this phase of the introduction is that of Taylor's classical conversion of the yard labour at Bethlehem. As soon as a careful study had been made of the elementary operations involved in loading pig iron on cars, a single first class workman was selected, and started on differential piece work. Hitherto the men had been paid $1.10 per day, and the pioneer was now offered an increase to $1.85 if he would perform each day an amount of work from 3 1/2 to 4 times as great as the previous daily average. The man regarded the task as a fair one, and earned the high rate from the start.

As usual, the sentiment throughout the plant was strongly opposed to piece work, and the town of Bethlehem generally was by this time on the side of the men - mainly through a conviction that if piece work succeeded, the larger individual output would enable the firm to reduce their staff, thus involving a set back to local trade and prosperity. For these considerations enormous concerted pressure was brought to bear upon the first few piece workers with the object of discouraging or intimidating them from continuing to do their best. Several were lured away by the offer of still more lucrative positions; but others took their places, and earned the high rate regularly, so that opposition suddenly crumbled away after ten weeks. The only difficulty then was to make time studies fast enough to suit the men.

Throughout the conversion only one man was put on each new standard job, and no other was permitted to attempt it until the first had shown by his success in earning the high rate that the task was a fair one. Throughout the period of conversion, the day and piece workers were under separate management, and were never allowed to work together.

Two important elements in the conversion were

(1) The distribution every morning to each worker of a slip stating the amount of work done and amount earned the day before- thus enabling him to measure performance against earnings while the details were fresh in his mind; and

(2) Measuring each man's work by itself wherever practicable. Only on very few occasions were more than two men allowed to work in a gang, as gang work almost invariably creates a drop in individual efficiency.

The following figures summarise the justifiability of the conversion, as regards the yard labour of loading and unloading cars on their arrival at or departure from the works:-

	DIFFERENTIAL PIECE WORK	DAY WORK
Tons handled in 1901 (2240#)	924,040.13	
Total cost	$ 30,797.78	
Former cost of same tonnage		$67,215.47
Saving	$ 36,417.69	
Cost/ton	$ .033	.072
Earnings /day /man	$ 1.88	1.15
Tons handled / day / man	57	16

Thus the effect of the conversion was to increase wages by 63 1/2% and to decrease labour cost by more than a half; and instead of mutually antagonising employers and employés, it revolutionised their previous attitude. All that now concerned the workers was to present a satisfactory and convincing answer to the simple question "Are you a first class worker?" As regards the yard labour, each newcomer was given to understand that if he could not earn $1.85 per day, he would have to make room for some one who could. If they succeeded, their industry was well rewarded by a sudden increase by 60% of their wages; and they were well content to remain - while if they failed, they left without hard feelings against the management - and there was always a sufficiency of first class men willing to leave other jobs, and try their hand at Bethlehem piece work. Consequently, the men at Bethlehem became so prosperous as to have no need to strike in order to better the wages of their class, and finally they left their unions voluntarily rather than be implicated in a strike which could not possibly ameliorate their own conditions.

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Summary.

In a plant operating under the Taylor system, we have seen that high wages are successfully combined with low labour cost; that the production of a plant approaches the maximum; that every official is forced to help his subordinates; and

that each man is given an opportunity to rise to the highest position for which his intelligence and physique fit him, - thus affording ample scope for ambition, and providing all the elements of real industrial co-operation.

As it so vastly increases the profits of the manufacturer and the earnings of the superior workers, while making possible a reduction in the price to the consumer, there should apparently be a strong public opinion in favour of its adoption into every large plant in all manufacturing countries. And yet, of all the American plants into which the system has been introduced, only two, the Link Belt Mfg. Co. and the Tabor Mfg. Co. of Philadelphia, have adhered to it. The system, therefore, is not inherently self-perpetuating; and it may fail for any of the following causes#:-

(1) By a change of management, replacing men trained under it by men not so trained - this was the principle cause of its downfall at the Bethlehem Steel Works;

(2) The cupidity of the management - cutting rates or increasing the tasks. At Midvale, the principle of the system was falsified by a cut in the piece rates;

(3) The cupidity of the workers. This is a highly improbable cause, unless the piece rates or tasks have first been tampered

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GANTT - "WORK, WAGES and PROFITS".

with by the management;

(4) A general industrial depression may ruin a firm operating a plant under scientific management, but such a plant would unquestionably hold out much longer than if it were not so highly organised.

Of these, the first is by far the most likely cause of failure, as a system which forces every servant of a company, from the manager down, to work continuously at maximum human efficiency is always likely to be destructively meddled with when death or other cause necessitates a change of management.

The Taylor system is probably the best for any one of a large number of plants, but its introduction is often only effected after overcoming the most bitter and protracted opposition from a number of men who were considered indispensable under the old regime. As these men usually have obtained their positions by the possession of an unusual force of character, inconsistent with submission especially to what they are prone to regard as a bumptious outsider, their opposition generally ends in the severance of their connection with the firm. Thus each introduction of the Taylor system casts adrift a number of admittedly capable men who cannot or will not work under it.

That this jettisoning operation cannot be performed in a large proportion of a country's factories, let alone throughout a community, is obvious. Therefore there would seem to be scope for the modification of the Taylor system in the direction

of greater flexibility - creating s similar system which will have some regard to the limitations of the average worker (while keeping the ideal in mind), and which will pay greater attention to the personal equation, the problem of solving which Taylor circumvents by eliminating those persons who have equations.

The outstanding features of such a system will be indicated as concisely as possible in the next chapter.

VI

SUBSEQUENT DEVELOPMENTS OF THE TAYLOR SYSTEM.

The recent trend of evolution of the Taylor system, especially since the retirement of its progenitor, has been all in the directions of greater flexibility, and of applicability to an increasing number of plants. No system of shop management can be a permanent success which does not render the proper operation of a shop independent of any particular man, and apparently the Taylor system proper is extremely susceptible to sudden collapse when bereft of the genius of its introduction. The two Philadelphia plants, which are conducted under the Taylor system, are still managed by the gentlemen - Messrs. Dodge and Hathaway - who re-organized them, so that the system cannot yet be said to have perpetuated itself even here.

The expert upon whom Taylor's mantle would seem to have fallen is Mr. H.L.Gantt, whose system is essentially that of Taylor, but with the addition of certain devices which make for flexibility and permanence. The Gantt system, like that of Taylor, is based upon analysis of operations, time studies, slide rules, and the assignment to each productive worker of a definite daily task. The principal distinction, as regards

flexibility, hinges upon the payment to each worker of a fair daily wage in the event of failure to complete his task; and the addition of a bonus if he succeed. The system, therefore, becomes piece work as soon as the workers have been induced to earn their bonuses, and constitutes the best known method of converting a plant without labour troubles from day to equitable piece work.

There is no issue upon which the workers can raise any valid objection. They are offered a certain bonus over and above their daily ~~route~~ rate if they accomplish a fixed reasonable task,- and they are at liberty to refuse the offer or accept it. An instruction card accompanies each piece of work, but the bulk of the workers may please themselves whether they follow it or not. Anyone anxious to try for the bonus has at his disposal the expert advice of functional foremen, who are stimulated to give all the assistance in their power by the offer of a bonus for each workman under their charge who shall complete his task, and a substantially greater bonus per man when all succeed. This offer immediately changes the foremen from drivers into teachers, and when successful it liberates the management to concentrate upon effecting some other improvement. Moreover, it helps to generate the spirit of co-operation in the shop, as ordinarily a foreman

is extremely cautious about imparting useful information to a subordinate, who may thus learn all that he knows and then be selected to replace him.

The functional foremen may not at first insist that the ambitious workman, who likely prides himself upon his intelligence and mastery of his trade, shall rigidly follow the instruction cards. A little patience and a few object lessons, such as failure to earn the bonus in any other way, soon convinces him as to the advantage of doing so. Having learned that the times allotted for machine operations are uniformly fair, the men are easily stimulated by the chance of gaining a bonus to curtail the time of manual operations also. The battle is then over, and the continued success of one man in earning the bonus, as in differential piece work, soon inculcates throughout the shop a sentiment favourable to task work. The Gantt system, however, allows the inefficient worker a fair daily wage while he is learning to become efficient.

Adoption of this system in any plant infallibly isolates the weaklings of the organization, and paves the way for their reform or dismissal; but it is neither so forceful nor so drastic as to engender any irreparable breach between the firm and those of its important officials whose services are really

invaluable. So far as I am aware, the introduction of a modification of this system, embodying many of its essential features, into the Angus Shops caused no such quarrel. Certainly the foremen were initially unanimous in resenting the new methods as an unwarrantable encroachment upon their traditional prerogatives,- academically ideal, perhaps, but practically ridiculous and, consequently, foredoomed to ignominious failure.

For some time the bulletins of the Schedule Department (see page 10a) were not taken seriously even by the clerks who compiled and issued them. Even now the foremen are not overfond of it on account of its relentless faculty of publishing daily to the whole shop a record of the previous day's failures in each department; but they have learned that the department can be extremely useful to them, and its value is being shown, if in no other way, by the frequency with which the foremen and gang bosses apply to it for information. Undoubtedly the adoption of the whole Gantt system would have accelerated the growth of this negative appreciation, but the entente is now certainly real.

A feature of the Gantt system which must strongly militate towards permanence is the extension of the offer of a

bonus to a number of persons having little apparent connection with the work, for whose satisfactory performance it is offered. A typical example, taken from "Work, Wages and Profits", will suffice to illustrate this point.

It relates to the work of inspecting, which included mending slight defects and trimming ends of the pieces of cloth produced in a textile mill which Gantt was reorganizing. A definite task of so many pieces per day had been set for this operation, high grade work, and high quality output being exigible for payment of the bonus to inspectors. The girls doing this work were supplied with cloth and helped in handling it by three men, of whom each was offered 2 cents for each inspector who received a bonus. It soon developed that the girls were considerably hampered in negotiating their tasks by variations in the finish of the cloth with which they were supplied, mainly through the simultaneous speeding up of production in the weaving room. It was then decided to offer the foreman weaver a bonus for each inspector who earned one, and the immediate result was an improvement in the quality of cloth turned out from the weaving room. Moreover, the foreman weaver soon acquired the habit of paying frequent visits to the inspecting room, where the girls were only too glad to point out defects whose correction would simplify their own

work, and enable the foremen weaver as well as themselves to earn more. The result was an appreciable continuous improvement in the quality of the output.

We have thus a remarkably close approximation to efficient as well as practical co-operation, where it is not only profitable for each worker to assist his fellows, but which gives him a tangible interest in improving the quality of the finished product. Under ordinary day work it is a rare and beautiful sight to see one workman asking another to hurry, that he himself might go on with his work. They seldom complain to the foreman that they are being interfered with, unless actually caught while waiting for the interference to cease. Under this system, however, the failure of one person to do his duty involves a distinct loss to a large number of others, who may be relied upon to make the way of the transgressor sufficiently hard to prevent a recurrence of the failure. It is the duty as well as the privilege of each workman to report any condition which prevents him from earning his bonus, and repeated losses soon educate him to do this. Each case is investigated, and each possible delinquent is glad to help in disclosing and removing obstacles to efficient operation, in order to clear himself of blame for the failure. Thus censure can almost always be applied to the person who

merits it, and the morale of the productive force is inevitably enhanced.

The system, therefore, has most of the advantages of differential piece-work, and the extension of the bonus principle makes it to the strong financial interest of every worker to support its perpetuation. At the Bethlehem Steel Works, where the Gantt system was introduced into the machine shop, the monthly output was doubled in six months, and the wages bill considerably reduced. Eventually, however, the company committed the fatal error of discontinuing the bonus to the foreman, and the return to drive methods produced labour troubles which culminated in a serious strike. Thus the system is not essentially indestructible, but the temptation to tamper with it is much less insistent than in the case of the Taylor system.

One of the peculiar advantages of this and the Taylor systems is that certain features of them may very profitably be introduced into any plant without necessarily involving an introduction of the whole system. As regards the inauguration of certain of its elements into the Angus shops by Mr. Gantt, I have already discussed the Piece Work Department, and its essential functions. Of other innovations, the most important

is the Schedule Department.

While it is desirable to reduce to a minimum the time lost by each engine undergoing repairs in the shop, the repairs must be so well executed as to make the intefvening intervals on the road a maximum. As each locomotive has to be rebuilt in a certain not over-elastic order, the delay of any one part from the boiler shop, machine shop, blacksmith's shop, foundry or stores may nullify the effect of general efficiency, and delay the engine for an unnecessarily protracted period. Therefore, one of the first measures to be taken in attempting to increase the efficiency of the shop would to be arrange that each part is delivered to the engine just when it is wanted.

To this end, the following procedure has been adopted.- Each engine is inspected before being despatched to the shop, and a list of necessary repairs is forwarded to the chief schedule clerk. As soon as the engine enters the shop, except where firebox repairs are necessary, it is "put on schedule"; that is, the earliest day on which the locomotive can be turned out, without the work being unduly rushed to the detriment of other engines, is at once fixed. At present there are three schedules for ordinary repairs (No.1, No.2 and No. 3) according to the quantity of work to be done; and

the times allowed for the first two are, respectively, 18 and 14 days. No. 3 repairs are special, such as split frames, cracked cylinders or other slight specific injuries, and each necessarily has an individual schedule.

The date of completion being settled, the schedule department then works back from this, knowing how long before an engine is completely rebuilt each part will be wanted. Thus, in the case of a No. 2 Repair engine, the Guide Bars and Valve Motion will be required on the 9th day after arrival of engine in the shop, Springs and Spring Gear on the 10th., Main Rods and Brake Gear on the 11th., and so on. From a knowledge of the time required for the performance of each operation, the schedule clerks are then able to draw up a programme of operations, and to arrange about what foreman shall be responsible for the delivery of each part at the right time.

Each schedule clerk has charge of one Shop, so that someone in the Department always knows where each piece is, when it went there, and when it will reach the erecting shop. Each day a report, similar to that on Plate XII, is issued for the information of the superintendent and foremen. In addition to showing what work should be done for each engine during the day of issue, it states what operations scheduled for previous

days have not yet been delivered to the erecting shop. Opposite each of the latter operations is a cross for each day that has passed since the work was due, with a brief explanation of the delay - "Waiting on Castings", "East Machine Shop Late", etc.

The fact that each failure to adhere to the operation sheet will certainly be recorded in the late report of the morrow has a tremendpus moral effect in securing adhesion to the schedule. The man at fault naturally dislikes publicity; and the greater his fault, the greater is the publicity. It further precludes the visitation of censure for delays upon the wrong man.

The entire scheme is dependent for success upon the accuracy with which the times of redelivering locomotives to the road are predetermined. As I have said, it has proved of great assistance to the foremen, and has served to even up the efficiencies of the several departments to that of the most efficient, besides practically eliminating interdepartmental friction,- hitherto a prolific cause of inefficiency. The combined cost of the Piece Work and Schedule departments is something under $1000 per month, and the ~~estimated~~ saving in time of locomotives on the road alone is estimated at worth $65,000. per year. The diminution in cost of production, assuming

CANADIAN PACIFIC RAILWAY COMPANY
ANGUS SHOPS SCHEDULE OFFICE

February 23rd,1911.

Messrs.Osborne, Meedie and Kendall.

Please note material late in delivery to Erecting Shop 2/23/11.

Eng. No.	Material		Remarks	Promised
440	Wedges	XX	East Machine shop late	2/23
	4 Ecc.Straps	X	Castings received late	2/23
1100	Wheels	X	Widths received 2/23 a.m.	2/23
569	Rev.lever feet	XXX	Not received from Steel works	?
	Bell Stand etc.	X	Waiting for Bell from Brass shop	2/23
	Dry Pipe and Elbow	XX	Dry Pipe not received	?
1490	Runboard Brackets	XX	Not received from Steel works	?
	Sheaves and Straps	X	West Machine shop late	2/23
1659	1 Spring	X	Robbed for 1670	2/23

-:-:-:-:-:-:-:-:-:-:-:-:-:-:-:-:-:-:-

Material due 2/23/11

Repairs

1490 Wheels
Motion and Valves
Pillars and Fillers

440 Wheels
Motion and Valves
Pillars and Fillers
Cab Support Plates

1659 Pistons
Engine Truck
Side Rods
Brake Gear

569 Brake gear
Firedoor
Number Plate
Glass Plates
Pinlifter
Pilot and Diag.Stays
Cab Handrails
Lampboard

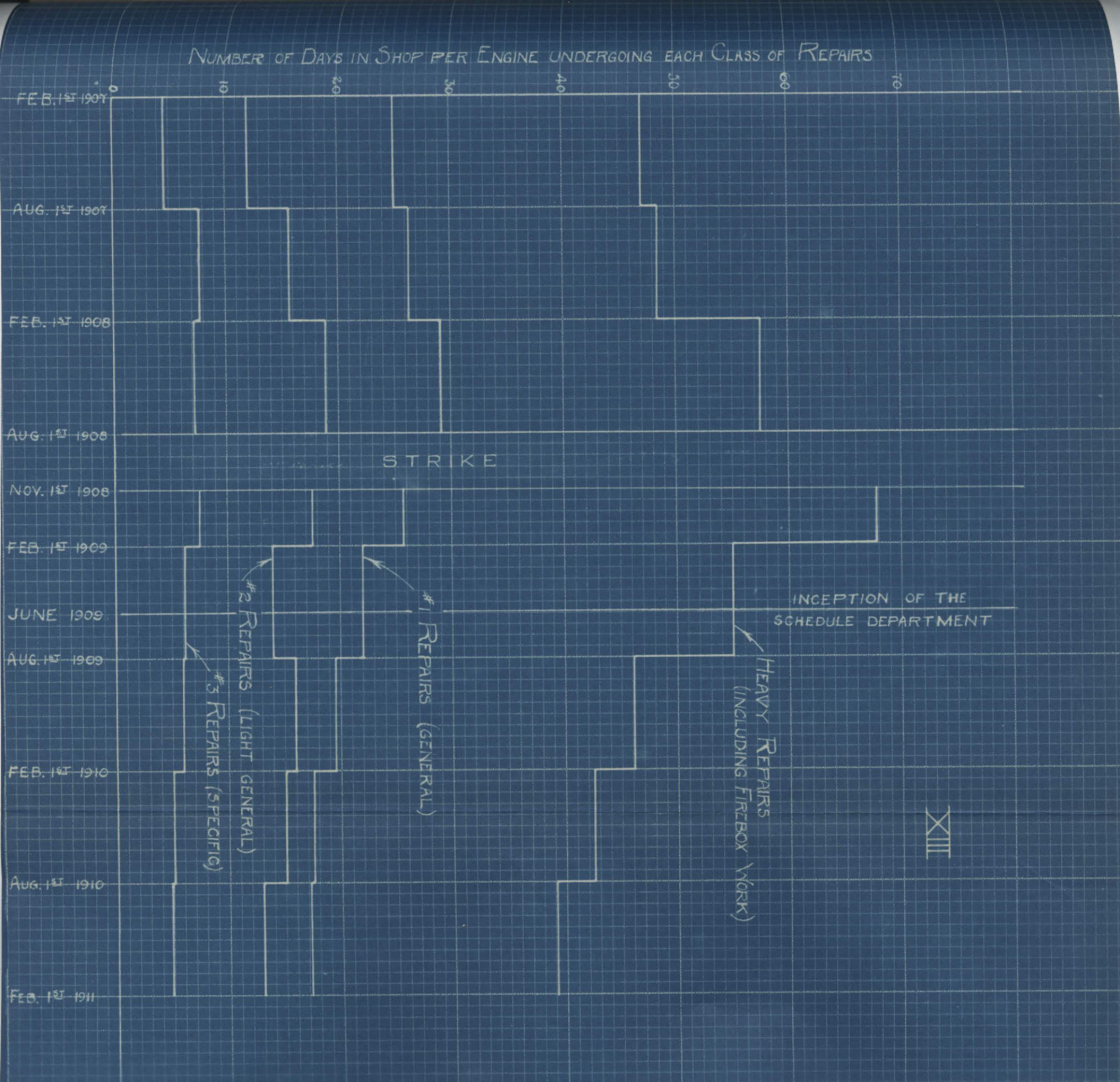
1100 Springs and Gear
Ash deflector

XII

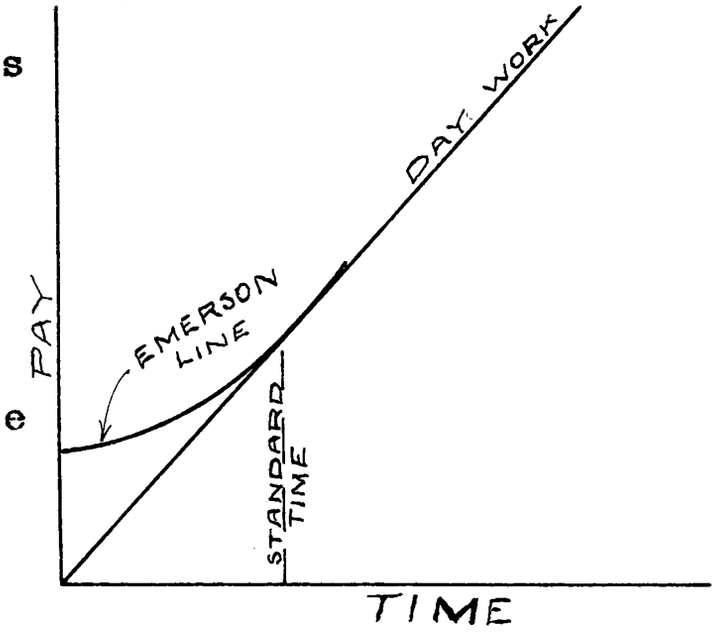
overhead expense distributed on a scientific basis, must be considerable, as will be seen from Plate XIV which shows the progressive reduction in time spent by the average engine undergoing each class of repairs during a number of periods from June 1909, when the Schedule Department commenced operations, to January 1911.

Thus the Taylor system in its most modern form is applicable, wholly or in part, to practically any plant. When in full operation it combines the advantages of low labour cost and high wages, though neither reaches the high extreme obtainable with an extraordinarily able staff under the early form of differential piece work. But the Gantt system, being so much more adaptable, represents for the average plant of any country the best available method of attaining maximum efficiency. While not essentially incapable of improvement, it would seem now to be approaching its final form. However that may be, it has been, and is now being introduced with conspicuous success into a large number of plants of almost all sizes and trades in the United States.

A number of other systems, most notably the Emerson system, based upon that of Taylor have been recently proposed and put into effect. The Emerson system is based entirely upon the Taylor standard appliances and methods, and its only


NUMBER OF DAYS IN SHOP PER ENGINE UNDERGOING EACH CLASS OF REPAIRS
0
10
20
30
40
50
60
70
FEB. 1ST 1907
AUG. 1ST 1907
FEB. 1ST 1908
AUG. 1ST 1908
STRIKE
NOV. 1ST 1908
FEB. 1ST 1909
JUNE 1909
AUG. 1ST 1909
FEB. 1ST 1910
AUG. 1ST 1910
FEB. 1ST 1911
#2 REPAIRS (LIGHT GENERAL)
#3 REPAIRS (SPECIFIC)
#1 REPAIRS (GENERAL)
INCEPTION OF THE SCHEDULE DEPARTMENT
HEAVY REPAIRS (INCLUDING FIREBOX WORK)
XIII

distinguishing feature is a payment system which is a mean between those of Taylor and Halsey. This, however, was designed to meet the special conditions which prevailed in the shops of the Atchison, Topeka and Santa Fé Railroad, when Emerson commenced to reorganise them (about 1904). The men refused flatly to countenance anything which savoured of piece work or the daily task, so they were paid a daily rate for each job unless they completed it within a time corresponding to the Halsey base. At this point the amount paid for the job became a point on a parabola, as shown in the figure, so constructed that for a small saving on the basic time the reward over the time rate would be small, but, for a large improvement, much more than proportionately great. Thus, if the basic times were 10 hours, the parabolic line merges into the time line at the 10 hour ordinate.



This system is said to have proved remarkably successful in the Santa Fé shops, and is claimed to have saved the road $5,000,000. ince its inception. While above reproach in the Santa Fé shops, however, it would have the disadvantage that it does not automatically stimulate maximum reasonable production

appreciably more than an output a little under maximum. Moreover, it becomes difficult under such a system for the individual workman to calculate his earnings day by day - provision of facility for doing this is a great psychological asset of the Taylor and Gantt systems - and there may consequently be considerable disappointment on pay day.

The bulk of the material for this chapter has been drawn from the following sources:-

H. L. Gantt - "Work, Wages and Profits".

" " - "A Bonus System of Rewarding Labour". Trans. A. S. M. E. Vol.XXIII

" " - "Training Workmen" " ------- Vol. XXX.

H. Emerson - Iron Trade Review July 23, 1908.

VII

THE ATTITUDE OF ORGANIZED LABOUR TO INDUSTRIAL EFFICIENCY.

Even among people who continually have to do with members of trade unions in the conduct of their business, there is a great diversity of opinion as to the present mission of organized labour. Gantt in propounding the dictum* that "the unions today admittedly constitute the most serious menace to industrial stability" crystallises prevailing American opinion, while Shadwell confesses** to a conviction "that on the whole they are a source of industrial strength to England at the present time, and constitute a decided advantage to her over her competitors". The fact is that, although the attitude of organized labour to industrial efficiency is practically the same the world over, the power of a particular union to dictate terms to employers varies considerably with the trade and locality. Although several American unions are now more powerful than the strongest in England, the latter probably more nearly represents the ultimate type into which all other unions will eventually merge. Therefore, in order to limit a chapter whose scope is practically unbounded, I propose to confine myself to sketching in brief the origin and development of trade unionism in England; to an exposition of its present ideals, and to a necessarily superficial discussion of the theory and practice of labour

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** INDUSTRIAL EFFICIENCY Vol. II p.330.

legislation as a factor in industrial efficiency.

I. THE ORIGIN AND DEVELOPMENT OF TRADE UNIONISM.

About the year 1760 industrial England became convulsed by a revolution involving a complete dislocation of the prevailing regulations and customs, which, with occasional minor changes and amplifications, had ruled and defined the relations between master, journeymen and apprentices from the reign of Edward I. As the obsolescent small shop developed first into a large one and finally into a factory, its owner, who had previously performed the multifarious functions of manager, foreman, skilled journeyman and personal supervisor of apprentices, if enterprising and shrewd, soon found himself, by the pressure of widening interests and responsibilities, compelled to relinquish these duties one by one. Eventually, as the owner became more completely immersed in the management of his commercial interests, even the supervision and control of shop methods and processes was relegated to a superintendent. The sudden cessation of daily contact between the owner and his employees; of the tactful handling, timely praise and good example with which he had erstwhile stimulated them to maximum endeavour, not only gave a very real meaning to the terms Capital and Labour, but served to accentuate the line which separates them. The substitution of driving for the older method of management brought its own punishment in alienating from the employer the sympathy of his men; and the subsequent transference of ownership from a definite, visible and possibly sympathetic

owner to a mysterious and intangible body of stockholders, concerned only to secure a maximum return on their investment, has in no wise tended to bridge the gap. The palpable distinction between employer and employee has thus become a prolific source of mutual distrust, resulting only too frequently in strikes and lock-outs, disastrous not only to the two conflicting parties, but to the community as a whole.

This sketch typifies the development not only of those plants which had greatness thrust upon them during the industrial revolution, but of practically all which came into existence before 1870, and of many still more recent ones.

In the infancy of the factory system, employers were naturally not averse to profiting by the regulations regarding freedom of contract which had existed in some form or other since the year 1425, and which were now strengthened by the sanction of the classical economists and their disciples - an influential group of men, solicitous rather for the wealth of the nation than for its health or happiness. Moreover, the combination of workmen for the purpose of forcing up wages or otherwise altering the terms of their service had long been considered contrary to public policy, and was expressly forbidden by more than thirty acts passed between the years 1425 and 1800. A statute of the latter year summarised and reaffirmed these acts, and made the promotion of such combinations an offence punishable by three months' imprisonment in a common gaol.

The employers of labour had, by now, in many industries, a monopoly of the means of production, and tradesmen were becoming so dependent upon them for the right to live as to be compelled to accept their conditions of employment or starve. The enactment of so unfair a law naturally promoted secret combinations, and provoked acts of violence. It was repealed in 1824, but the act of repeal was amended beyond all recognition in the following year, before the workers had had an opportunity to arrive at even a semblance of unanimity. The state of unrest was then prolonged until 1855, when workmen at allied trades were permitted by Act of Parliament to incorporate themselves into Mutual Benefit* or Friendly Societies. It was still illegal, until the passage of later acts in 1871 and 1875 for the members to employ these associations as a lever for raising wages.

The vogue of political economy which occupied intellectual and pseudo-intellectual England for many years after the publication of "The Wealth of Nations", exercised an almost incalculable influence upon every phase of the development of trades unions. The freedom of contract theory passed almost unquestioned until the appearance, in 1843, of Carlyle's "Past and Present" - and the general acceptance of such a doctrine by the class which then ruled the country must inevitably have kept in abeyance any plan whose adoption would disturb by one iota the existing conditions. The classical conception of wages, as fractions of a nebulous fixed fund, was not refuted until much later in the century, when General Walker advanced the opinion

that wages are paid out of the product of labour. Until then it was widely believed, in all good faith, that any increment in wages which one group of workmen might wring from their employer must necessarily and automatically involve a corresponding loss to some other group. Naturally no one who believed this would deliberately connive at the granting to certain favored groups of workmen of the power so to despoil some less fortunate group.

Simultaneously, however, the teachings of Ricardo, Marx and other real pioneers of modern socialism were giving a belated stimulus to the inevitable reaction against the over-ripe teachings of the "laisser faire" school, and served to crystallise the prevalent discontent. The subsequent policy of all Friendly Societies, and of the Trade Unions which succeeded them, has ever been influenced by the Marxian dogma that "labour produces all wealth", and the majority of them, in certain stages of their development, by the logical deduction that the worker will never receive his fair share of the product of his labour until he obtains it all.

The development of English trade unions since their limited legalisation in 1871 has been progressive in the extreme. Practice of their privilege of striking, whenever circumstances seemed propitious has frequently won for them better pay, shorter hours, and better conditions generally. Until the election succeeding the recent Osborne judgment, many combinations of workers were even actively represented in that parliament which had so effectively vetoed the existence of

their organization and afterwards hindered its growth.

From the present status of the more important organizations, it would appear that the union, though inaugurated for purposes of industrial warfare, tends towards practical co-operation and industrial stability. Thus, at a Trade Union Congress in 1905, "acquiescence in a resolution in favour of the eight hour day was expressly refused on behalf of the Lancashire cotton workers on the ground that they could not afford to shorten hours until they were reduced in other countries".* This, however, is a stage which has only been reached at the cost of much strife and tribulation, and few unions promise to become so broad minded in their own interests except by way of bitter experience. In this indutry, however, as in many others, the workers are now reaping a fair reward for past sacrifices, and the end is considered to have justified the means.

Although the power of striking has been and still is apart from the vote, the only weapon of the unions by which they have succeeded in wresting any appreciable concession from the employers, the treatment is so drastic for all parties that its use is frequently delayed until the conditions become a scandal. Thus a protracted general strike by the Lancashire textile workers would not only suspend the wages to labour, and dividends to the employers, but would of necessity involve a diversion of trade, which might never return. In 1909 practically all of the best steam coal used in the Southern Pacific Ocean came from Newcastle, N.S.W. The demand for it far ex-

*SHADWELL - INDUSTRIAL EFFICIENCY. VOL.II p.107.

ceeded the supply, and the miners, considering the moment auspicious for the assertion of their authority, suddenly struck work. No complaint was made to the employers until a week after the commencement of the strike, when a list of trifling grievances and unreasonable demands was forwarded to them. The men were convinced that coal had to be mined, and could see only one possible conclusion to the strike - unqualified victory for themselves. The strike endured for eighteen weeks, the Southern Pacific ship owners decided to depend no longer upon so unreliable a source of fuel; new mines were opened up in other parts of Australia for the needs of the railways - so that when the miners finally surrendered, only a fraction of them was able to secure re-employment.

To obviate the necessity of striking, and the possibility it would involve of so disastrous a conclusion, several of the strongest English unions have contrived during the past decade to set up tribunals for the settlement of industrial disputes before these have reached an acute stage. Thus almost all incipient quarrels in the Lancashire textile trade are settled out of hand by two secretaries - one of the union, and the other of the employers' association.

If their decision be unacceptable to one side, the case is referred to a district joint committee, and, failing that, to a central joint committee. Should the mill-owner concerned be so ill advised as not to fulfil the terms of the award, he is subjected to the combined pressure of his own workers, who are threatening to strike, and of his fellow employers,

who fear a general strike. If each employer were to deposit a bond with the association, the machinery for preventing disorganization of the industry by a strike, would be almost perfect. The decisions of the central joint committee are almost certain to be both sound and impartial, and the workers will seldom risk a strike - even where success would bring them a handsome gain - in the face of an adverse public opinion. Few issues ever reach this final tribunal, however, the majority of the difficulties being rectified by a conference of the two secretaries, and many with still greater dispatch and directness by mutual agreement between the union secretary and the mill-owner concerned.

We therefore see that there is considerable justification for the following statements, and, consequently, for the faith of the English workman in his union:-

"Why do men in one trade get 30 s. or 40 s. a week, whilst in another, apparently in all respects similar, they get only 15 s. or 20 s. ? It is the Trade Union that makes the difference..... If a man keeps asking for more wages, he gets the sack, and there is an end of it. A man who belongs to a Union has no need to ask for a rise of wages. His Union does that business for him, and a Union Secretary, paid by the men to manage their affairs, is not afraid of an employer, because his living does not depend upon any master except his fellow workmen."

"Men in a Union act together; and their Union often makes them stronger than any one master, and sometimes almost as strong

as all the masters put together. An employer may sack one man for a mere whim. It is nothing to him. But he will often give up half his profits sooner than drive a big Union into a strike."

"Men who want good wages and think they will get them without the help of a Trade Union are fools."

"What is true about wages is true about hours. A strong union gets men good wages for short hours; long hours and low pay fall to the men who do not unite..... No trade gets short hours unless it has a strong union."

"Remember one thing! It is the Trade Union in a trade which keeps up wages and keeps down hours; which makes the master respect his men and treat them like fellow-creatures. Unions are paid for by the members. Any man who does not belong to the Union when there is one in his trade, is sponging on his mates. He benefits by the better wages and shorter hours which the Union has obtained, but he refuses to pay his share towards the cost of getting them."

The foregoing extracts are selected from an unusually terse tract distributed in 1900 by the Fabian Society - the sanest and soundest of all Socialistic organizations - and illustrate what must be the attitude of every thinking English unionist to his union, and to non-unionists generally. Without making a single misstatement (in the light of history), it affords a complete explanation of the phenomenon that workmen seem ever willing to make present sacrifices to the union, in the form of cash contributions and sympathetic strikes, on the fre-

quently illusory chance of future gain. They have become convinced, and with reason, that it is futile to look elsewhere than to their unions for the means of ameliorating their lot, and most futile of all to seek real co-operation with their employers.

It will doubtless be observed that the above extract is silent as to the quantity and quality of work that employers contrive to exact from non-unionist workers, and to what extent the organization of labour has succeeded in restricting these - and this brings us to one of the most prolific causes of England's relative industrial decadence in the past generation. The English and most other trade unionists are widely suspected of fostering a "conspiracy, whereby a given quantity of work can be distributed to as large a number of hands as possible", and "everyone who has ever employed a plumber knows what making work means".*

However, the causes underlying this phenomenon must, in fairness, be traced much further back than the inauguration of the first trade union. As has been shown, the workmen's sympathy with their employers had, in most plants, already been alienated, and their individual ambition almost stifled by a payment system which herded men into classes, without regard to personal diligence or honesty. The employers attached a reasonably great importance to the attainment of the minimum labour cost ideal, but made no pretence of testing the quality of the labour which they were purchasing.

*DIBBLEE - ECONOMIC JOURNAL - VOL.XII.

8.

Those admirable as well as industrially invaluable attributes - diligence and honesty, becoming apparently of no profit to their possessors, were naturally suffered to fall into a deplorable desuetude. The men ceased to take pride in their work, and rapidly lost whatever compunction had once restrained them from idling - an insidious evil, which increases in going, and which ultimately unfits its victims for the performance of a good day's work. The commonest form in which this ~~system~~ symptom of atrophy betrays itself is a preternatural disposition to spare no effort to avoid the necessity of working at maximum efficiency. Combine with this tendency the fear of unemployment or of reduction in wages, which inevitably accompanies the conviction - still permeating all classes of labour, whether organized or not - that there is only a certain amount of work to be done (i.e. that the demand for any commodity is independent of its cost of production) and you have the principal causes of deliberately restricted output. Another factor perhaps unduly emphasised by Taylor is the desire of workmen in plants conducted under ordinary systems of management, to prevent the manager from discovering how much work a man actually can perform in a day, lest he use the knowledge to compel his men to work at maximum power factor without any increase of pay. This fear is far from groundless, as the history of almost any plant operating under the ordinary piece work system will prove.

A still further cause, not accorded sufficient attention is the influence of surroundings and tradition. Shadwell

Foster Fraser, and many other observers have been struck by the almost incredible development which succeeds the emigration of English skilled workers to America. To Shadwell, several admitted that had they been asked to work half as hard in England, they would most emphatically have struck work without a moment's consideration. They were unable to account for the transformation; and change of environment, with liberation from the influence of restrictive tradition would appear to constitute the only feasible explanation.

Where unions are relatively strong, and their product protected by a tariff or other partial monopoly, they are able to restrict output - and often do so - far more deliberately and effectively than would be possible without organization.

THEIR IDEALS

Whatever the cause may be, there is beyond doubt ingrained in every workman, in greater or less degree, an innate tendency to restrict his productivity; and his natural inclination must not be disregarded by analysis of the attitude of organized labour towards industrial efficiency if the results are to be of value. Restriction of output, therefore, must be considered as one of the ideals of organized labour.

As might be expected, workers who cherish this ideal are also opposed to piece work. The injustice which has frequently characterised the administration of piece work alone constitutes an excellent justification of this opposition; and yet, the two strongest unions in England - the textile workers and the Amalgamated Society of Engineers - have been com-

pelled by the pressure of economic forces to countenance it, or to forswear the restriction of output, which is equivalent. However, the circumstances of these two unions are peculiar, as the members of both depend for existence largely upon their ability to manufacture a product which will compete successfully in protected countries against the corresponding articles of local production. The workers had thus to choose between ceasing to restrict output, and starvation. In the ordinary plant, with a sufficient home market at its door, there is no such necessity, and practically all unions so situated (including the Machinists' Union of the United States) prohibit their members from working on any other plan than day work.

The other ideals, which are of less direct import than the foregoing in connection with industrial efficiency, are the recognition and enforcement of a minimum wage; the prohibition of overtime; the imposition of limitations on the proportion of apprentices to journeymen in any plant; and prohibition of the employment of women, boys or of non-unionists on work that falls within the province of the union. Most unions undoubtedly long for shorter working hours, but are not unanimous as to the exact number of hours that constitute an ideal working day. As many trades demand greater intensity of application, or more sustained physical effort than others, there is no reason, apart from the advantage of uniformity, why the ideal should be the same for all trades. However, the eight hour day is the one about which most is heard.

The extent to which any given union cherishes these various ideals depends largely upon such circumstances as locality, existing systems of management, and whether the union possesses a complete or only partial monopoly in its trade. On the Pacific coast, for instance, each union insists successfully upon payment by the day of a minimum wage, which tends to become standard throughout the trade, but carpenters have contrived to secure a higher minimum wage than the mechanics; and overtime is not only countenanced, but welcomed - for a consideration.

The method by which organized labour gains its ends is, of course, by striking, or threatening to strike - for the latter is generally sufficient - or by influencing legislation.

III. THE QUESTION OF GOVERNMENTAL REGULATION OF INDUSTRY.

It is the custom of the most influential section of the Canadian press to anathematise all industrial legislation as necessarily unsound, and as constituting an unwarrantable interference with the sacred rights of the individual. Whenever any such legislation is proposed, such as Mr.Studholme's recent Eight Hours Bill in Ontario, we are treated to, and presumably influenced by, a faithful reproduction of every argument standardised in England upwards of eighty years ago, to justify the maintenance of a condition of industrial anarchy that was not only damnable, but suicidal to the working population. At this time, manufacturing profits in Lancashire were being reckoned in hundreds per cent; and, simultaneously, through complete absence of restriction on the employment of child and female labour, the

proletariat existed, not lived, in a condition whose horrors far exceeded those of the colonial and foreign slaves, whose condition aroused the respectable captains of industry to righteous indignation.

The textile mills of the north were operated night and day without intermission, and children, who were housed in pent-up buildings adjoining the factories, worked twelve hours per day - so that their beds were said never to become cold. "Epidemic fevers were rife in consequence. Medical inspectors reported the rapid spread of malformation of the bones, curvature of the spine, heart diseases, rupture, stunted growth, asthma, and premature old age among children and young persons."* Conditions in the mines were, if anything, more appalling. Quoting again from the same article, which comprises an authoritative summary of facts brought to light by various commissions, ".....children of both sexes worked together, half naked, often for sixteen hours a day. In the foetid passages, children of seven, six and even four years of age were found at work. Women were employed underground, many of them even while pregnant at the most exhausting labour..... In some places women stood all day knee deep in water, and subject to an intense heat ..... Women and young children of six years old drew coal along the passages of the mines, crawling on all fours with a girdle passing around their waists harnessed by a chain between their legs to the cart....."

Had the policy of non-interference been persisted in, there cannot be the slightest doubt that England would long ago

* WILLIAM CLARKE - THE INDUSTRIAL BASIS OF SOCIALISM .

have become industrially moribund; and the fact that permanent industrial progress cannot be built upon the physical exhaustion of women and children make restrictive legislation expedient in almost every state. Industrial efficiency is a national asset which it should be one of the first duties of any government to guard.

Hitherto, the principal directions in which restrictive measures have been enacted are those of increasing the minimum age at which children may be employed, and limiting the working hours especially of women, young persons and children - these being the ideals to which organized labour has succeeded in attracting the greatest amount of public sympathy.

The ground upon which objections to the shortening of hours are based, is fairly reasonable. In any given plant the overhead charge per day is practically independent of the number of hours during which the plant is operated. Let us assume that the overhead charge is half the factory cost in a plant which works eight hours per day, and which competes with another concern groaning under an equivalent overhead burden ($x per day), but working ten hours per day.

Then if the number of articles produced per hour in each be y, the manufacturing cost per piece in each is $\$\frac{x}{8y}$, and the overhead cost is, in the former $\$\frac{x}{8y}$, and in the latter $\$\frac{x}{10y}$

∴ the total factory costs per article are respectively

$\frac{2x}{8y}$ and $\frac{x}{8y} + \frac{x}{10y}$ i.e., $\frac{x}{4y}$ and $\frac{9x}{40y}$

Thus, in the plant with the shorter working day it costs one ninth or over 11% more than its competitor to produce each

article of product.

Although every one admits the desirability of curtailing the working day, many people are gulled by this argument, which involves the unwarrantable assumption that a workman works just as rapidly and efficiently throughout a ten hour day as he would if the hours were not so long.

At an investigation in 1901 into the hours of labour by the United States Industrial Commission, several employers of labour testified* that a reduction in the working hours of their plants from ten to nine was directly productive, under piece work, of a slightly larger daily output, so that the reduction was profitable. In Australia where piece work is exceptional, statistics are quoted to prove that the workmen do more in an eight hour day than in other countries where the hours are longer. The report of the above commission showed that the bituminous coal miner of Pennsylvania does as much work in an eight hour shift as he used to do in one of twelve hours. The reason is of course that the intensity is more than proportionately greater in an eight hour working day than in one of longer duration - evidently fatigue does not vary as the simple product of speed, or intensity, and the number of working hours.

The reasons assigned to this increase, apart from the greater intensity of application and industry, are the creation of a better spirit in the men, who go more promptly to work and continue until the close of the day; an increase in the atten-

* BULLETIN, U.S.BUREAU OF LABOUR - JULY 1907.

tion paid to machinery, resulting in fewer breakages, and a better product; and that the increased cost of labour per hour gives a new stimulus to the invention and application of labour saving machinery, thus enabling the employer to economise in labour, and to improve its quality by better selection. A particular advantage of short hours, affecting the industrial efficiency of the nation as a whole, is that it affords the working classes an opportunity of becoming better educated, and of indulging in healthful outdoor exercise, thus obviating the tendency of industrial populations to mental mediocrity and physical deterioration.

Since it is apparently so profitable to reduce the length of the working day, it might ~~be~~ well be asked why individual employers do not, of their own accord, make the reduction. Apart from the short-sightedness and inertia which characterise the average employer of labour - as all other classes - it is a fact that in those trades where the workers are poorly organized, or where home-work prevails, sweating still "pays well enough to be contagious",* and the tendency of most employers is in the opposite direction. Furthermore, there is obviously a practical limit beyond which a further reduction in the hours of labour must involve a decrease in the daily output per man, under whatever system of management, and the average employer naturally has a conservative motion as to the location of this limit. A plant working long hours with cheap and inefficient labour may make much larger profits than a competing plant work-

* SHADWELL - INDUSTRIAL EFFICIENCY - VOL.II p.6.

ing under ideal conditions, but the former is doomed.

Thus the extent to which industrial legislation has been carried in the various states of the American Union varies according to expediency and the degree to which each legislature is the creature of capitalistic influence. Consequently the progress of state regulation in Massachusetts and Rhode Island has had to be deferred until competing plants in North Carolina, Alabama, etc., are placed under some greater restriction than that provided by their present travesty of an industrial code. This condition accentuates one of the most serious defects in the American Constitution, but the public are certain eventually to demand interference with a practice which is alrèady proving deleterious to an important section of the community.

Restrictions as to the employment of women, young persons and children need no present enlargement, being based upon the impossibility of industrial prosperity without a strong and healthy working force. Other legislation inspired mainly by organized labour in various countries includes regulations as to the proportion of apprentices to journeymen in any trade; overcrowding and ventilation; fencing of machinery; old age pensions; insurance against unemployment; arbitration and conciliation (to prevent strikes); and (in Australia and New Zealand) wages.

Of these the most revolutionary are the last two, and a return to the regulation of wages will practically complete the cycle which commenced in 1760.

The principal object of the trade unions in agitating for legislation to prevent strikes was mainly to ensure for themselves a continuity of employment and the remuneration thereof. But a still stronger reason for the passage of such statutes is that it is a function and duty of the State to make it impossible for any group of people to act in a way which must entail suffering to the community at large. "This is the foundation of all law, and the only logical alternative is anarchy."*

The theory of arbitration varies considerably in diverse countries. In England, where the employers' association fails to agree with that of the workmen, the President of the Board of Trade often succeeds by his good offices in persuading both sides to appoint independent arbitrators by whose decision they agree to abide. In Canada the continuity of operation of public utilities and mines is protected by the excellent Lemieux Act, whose principal defect is that it does not necessarily extend to other enterprises. About this law is nothing compulsory except the holding of an investigation, whose verdict will serve to guide public opinion - invariably the ultimate arbiter of industrial disputes. In Australia and New Zealand, either side may appeal to a court whose rulings are made applicable to similar industries within a limited range, and are therefore tantamount to state regulation of wages and conditions of labour. Beyond doubt, any legislation which would succeed in permanently obviating strikes without "so interfering with the process of production and exchange as to disarrange the functions of the

* SHADWELL - IBID.

business organism"*, would be an incalculable gain to the community which enacted it; but no existent arbitration law has enjoyed more than partial success, and all are, more or less, in a state of experimental transition.

* BULLETIN U.S.BUREAU OF LABOUR - MAY 1908.

The attitude of organized labour is therefore inextricably commingled with the history and environment, and its policy tends irrestibly towards the progressive destruction of untrammelled individualistic control of the means and methods of production. Every decade brings us perceptibly closer to the era of complete state regulation of industry; and, in that day, only those plants that are fit, insofar as their operation is beneficial to the whole community - can hope to survive. Even apart from the lucrative nature of instituting scientific management in his plant, it therefore behoves every employer of labour to forestall factory legislation, by setting his house in order before being compelled to do so by a combination of competition and state solicitude for the industrial proletariat. Inevitably the passage of time and the systematisation of competing plants will render subsistence increasingly difficult for those employers who are content to introduce no improvement until driven to it by law - and every postponement will probably involve a further reduction in the ability of his plant to bear the strain of transition.

THE ATTITUDE OF LABOUR TO SCIENTIFIC MANAGEMENT:

As truly scientific management implies unrestricted productivity, piece work and the employment of unskilled labour upon such skilled or semi-skilled work as it is capable of performing, the unions are practically one in hating and fearing it. In 1909 a committee appointed by the Engineering and Shipbuilding Trades' Federation of Great Britain was unanimous in condemning it, mainly upon the ground that "the system was

an adaptation of the most pernicious and degrading condition of employment in modern industrial history, the task system and created jealousy and ill feeling!

Of all human inconsistencies, perhaps the most curious is the usual result of the compound psychological process of setting up an ideal and devising a means for its attainment. The enthronement of the ideal is, as a rule, effected sub-consciously, and demands but little thought. Contrivance of the means, on the other hand, necessitates much subjective concentration. The relative values of the two when complete are then apt to be measured in terms of the conscious effort required for their consummation, and in proportion as the amount of ingenuity requisite in excogitating the means, so the ideal merges into relative insignificance.

Than Marx, Liebknecht and Bebel, no one could have been more sincerely solicitous for the welfare of the German labouring classes; and all were convinced that the proletariat could win its way to happiness only by way of a revolution. To this end, they at first encouraged the formation of trade unions, as a movement which appeared certain to end in industrial warfare.

About the year 1872, however, they became alarmed at the success of unionism in reconciling the workers with existing conditions, and so in promising to attain for them the right ideal by the wrong means - so they suddenly changed front, and thenceforward actively opposed the movement.

So with many union leaders. Being convinced that there

is no hope for labour save in its complete organization into unions, they are naturally predisposed to discredit any innovation which might result in the disintegration of existent organizations,- even though it promised to do more for the workers than the union ever could.

Fortunately few good workmen are gullible by so trifling and irrelevent an argument as that with which the above committee denounced scientific management; and the unions have been singularly unsuccessfull in proscribing the Taylor system. Practically all workmen are not only willing but anxious to work harder if, by so doing they are assured a large permanent increase in wages, so that the unanimity of each union is undermined by individual ambition.

The question as to whether or not the union will countenance and support the new system then becomes simply a matter of terms.

After Mr.Gilbreth had completed his investigation* into the art of laying bricks, his natural course of action was to put his theory into practice. At the time he was erecting a building in Boston ** where the bricklayers' union, as in other cities, had a recognized maximum daily performance. Gilbreth then interviewed the union leaders and offered to pay his men $6.50 instead of $4.50 per day to waive their maximum and follow his instructions - incidentally promising not to overwork them. Finally the union agreed. The walls of the building in question were twelve inches thick, with two

* See Chap.1
** "The Century" March,1911.

kinds of brick and drawn joints, and the previous record for that class of work had been 120 bricks per hour per man.

On this particular job, Gilbreth's gang, working under demonstrators of the new method, succeeded in averaging 350 bricks per hour per man. The gain to all parties concerned is obvious.

When introducing the Taylor system into a shop where many or all of the workers are members of a strong union*,

(1) One must be sure beyond the smallest doubt that every task is just and can surely be accomplished;

(2) Particular care must be taken to make the instructions exact and explicit;

(3) Concentrate upon a single workman, and make no attempt to institute changes upon a large scale until complete success has been attained in his case. It would not require the diabolical ingenuity with which the average union leader is credited, to construe an order to double output into a demand that the men shall work twice as hard and the commonest mistake in dealing with union workers, is to issue an order affecting a number of workmen simultaneously, and over-emphasing the increase of output required, rather than the necessity of following instructions. The point must be reached step by step, and man by man; for only thus can the workers be persuaded that the increased output is due to improved methods and appliances quite as much as to any increment in their own

* Taylor - Shop Management Trans.A.S.M.E.Vol.XXIV.

productivity.

Considerable judgment must be exercised in selecting for the first object lesson, work of such a character that definite instructions can be given for its performance. However, much it would like to do so, no union dare interfere with production to the extent of dictating what depth of cut a certain lathe shall be allowed to take, or on which cone step its belt shall be run. Failure to complete the task will then constitute direct disobedience of a simple reasonable order, and means can be taken to discourage repetition of the failure.

(4) In case the workman should raise a question as to the possibility of completing the task, the management must be prepared to demonstrate that it is not unreasonable.

Then, after one man, has been convinced by four functional foreman and an inflated pay roll, that he will prosper better under the new system than heretofore, the operation can be repeated upon the next man, and so on until public opinion throughout the department has become friendly to the new system.

Scientific management then is bitterly opposed by the unions in theory, but welcomed in practice (on closer acquaintance) by those of their individual members who expect to thrive under it - generally the most influential men in any union. Where the union rules are so inflexible as to prevent its members from working under any other system than that of day work, many of the members will sever their connection with it, as they no longer require its protection. It is therefore not improbable that, with the widening application of the

principles of scientific management, the unions will find themselves compelled in self-defence to revise their attitude towards it, and to relax their rules accordingly.

VIII.

COST AND OTHER ACCOUNTING.

This chapter must of necessity be extremely general, and can hardly comprise more than a bare exposition of the fundamental principles of accounting which must apply to all shops, and an indication of the methods by which enlightened accounting may be enlisted among the forces inimical to inefficiency.

Ever since man has purchased the labour of his fellows, cost accounting has doubtless existed in some more or less rude form. Until the end of the eighteenth century, however, an employer needed have no concern, in fixing his selling prices, for any elements other than material cost and labour expense on each job. With the industrial revolution, however, and the phenomenal development of the factory system, a new element - i.e. overhead expense - immediately obtruded itself into the sphere of cost accounting. At this date, as we have seen, the small shop ceased to be the type, and rapidly became an anachronism; and the necessity of purchasing boilers, and of embodying the numerous new inventions in the equipment soon raised the investment charges on new factories to a price that would previously have been regarded as prohibitive. The result of this is, of course, that a charge has to be made on the earnings of the plant every year, in order to cover interest on

first cost of real estate, buildings, and equipment;depreciation and maintenance of all three; insurance, taxes, light, heat and ventilation, and, moreover, the cost of non-productive labour, whose employment has developed with the growth of overhead charges.

Now, the importance of knowing very closely the total cost of manufacturing each standard product has already been hinted at. It is of paramount importance in the framing of estimates - which. by being low and reliable, obtain more contracts than could be secured without the knowledge of costs, and thus tend to increase the productivity of the plant. By indicating what lines are being manufactured at a loss it enables the management to eliminate or regenerate these and to concentrate upon the manufacture and sale of the more profitable ones; and it futher helps to show upon what lines it may be possible to increase business by a judicious reduction in prices. In the average engineering plant, the overhead charges are from 40 to 120 % of the direct labour cost. Therefore a fair distribution of the overhead charges over the whole volume of product is essential to an accurate determination of the manufacturing cost of even one line.

This postulate being established, it must be admitted

that probably no plant exists in which the ultimate assignment to each piece of product of its exact proper share in the overhead burden is either economically or humanly possible. There are some in which it is not even attempted- plants, for the most part, that have been developed by the industry, inventive genius or enterprise of their owners, and such plants are a menace to all well regulated competitors as well as to themselves.

Of all manufactures, one would expect the producers of machine tools to know their costs- yet the report of a board of enquiry appointed by the National Machine Tool Builders Association showed that many of its members had been, in ignorance, frequently selling at a loss - a proceeding which bade fair to demoralise the trade.*

This explains the remarkable variations frequently found in bids on the same work by a number of firms apparently equally favoured as to equipment and location. In the same article Evans cites a number of tenders on a large naval repair job, with detailed specifications, varying from $425,000 to $517,000; and others on a contract for a large number of small cast iron cylinders, from 6¢ to 21¢ per pound.

The result of the Tool Builders' report was the appoint-

*H.A. Evans - "The Importance of Accurate Costs" Am. Machinist Nov. 10 - 1910

appointment of a special committee to devise a uniform cost accounting system adaptable to all plants manufacturing machine tools.

But few trades are so well organized or so enlightened as the tool builders; and, in many of them, the competition most to be feared by a well conducted establishment is that of a firm which does not know its costs. It is small satisfaction to the former that the latter will soon become bankrupt, as there are always others just as ignorant willing to replace it.

Therefore it would seem that efficient production and accurate cost-keeping are inseparable. "It is curious that nearly all managers believe that they have very satisfactory cost systems, and the worst are usually described as sim ple and effective." Certain it is that many firms with defective systems are making money; but so are many others with antiquated equipment or poor organisation, although neither is capable of meeting and surviving determined competition.

The accurate determination of costs presupposes the solution of but one serious problem. The material cost of any job, generally, is simply a matter of weight. The labour cost is easily determinable, even under day work,

by any of the ordinary job order systems, whether the time of starting and finishing is stamped on the order in an office or simply filled in by the individual workmen, under some more or less complete supervision. At the Angus shops each man is provided with a form when punching clock number at 7 A.M. On completion of each job during the day, he fills in on this form the store order number of the job, the number of pieces made, and the time of starting and finishing. While this method has not the automatic precision of that under which the job orders are stamped in an office, the error is not comparable with these consequent upon their system of distributing the overhead charges - the real problem of all cost accounting.

The ideal system of accounting effects "the distribution of the indirect costs in such a way that each production order receives charges which closely approximates to the proportional benefits it receives from the various elements of indirect costs." X There has been, and still is, considerable diversity of opinion as to the best means of attaining this ideal; but, prior to examining them, it might be well first to analyse the burden itself.

X. H. A. Evans - The Distribution of Indirect Costs. Am. Machinist, Dec. 22nd, 1910.

Briefly its principal elements are:- #

(1) Interest on first cost of land and buildings - also insurance taxes, maintenance and depreciation thereof;- from the share of these borne by each building in the plant, divided by the total floor area in that building, is derived a figure termed the "floor rate", by which all machines and men in the shop may be charged rent on the basis of the amount of floor space allotted them.

(2) Cost of power (determined by floor rate of power house, interest on first cost and installation of equipment, power house, supervision, labour, fuel and supplies):

(3) Light,heat and ventilation oh a similar basis, and chargeable to each building or shop in proportion to the cubical contents, floor area, or number of employés, etc.

(4) Equipment:- Interest on first cost, including installation, of each machine, and insurance, maintenance and depreciation thereof. By adding to this the rent of the floor space occupied by the machine and its operator, and the cost of power used by the machine, a "machine rate" is derivable, by which all work done on any machine may be charged its share of all the foregoing portion of the overhead expense as a species of machine rent. Where a tool is used on one machine only, its first cost, interest and maintenance may be fairly added to the

(Principally) O.E.Perrigo - The Iron Trade Review Oct.3,1907 - Oct. 1,1908

machine expense, and only the special tools - taps, dies, reamers,etc. considered as part of the general expense. Under the Taylor system, the cost of tool room and tools would have to be treated as part of the general expense, and distributed over the total product. Special tools, jigs, gauges and fixtures can be charged direct to production orders.

(5) Shop Transportation, including interest, depreciation and maintenance of transport equipment, cost of power for elevators and cranes, and cost of labour on elevators, cranes and shop cars. This is an item of general expense in each department, and should be distributed over the whole product. Similarly for the cost of yard labour, of transporting castings or forgings from one department to another - which cost should be equally divided between the two departments concerned.

(6) Non-productive labour includes cost of supervision, planning department (if any) and all labour not directly chargeable to production orders. This is an item of general expense of any one department.

(7) General Office:- comprises interest on first cost of real estate and building; insurance and maintenance of building and furniture; salaries of officials and staff; light, heat, supplies, travelling, legal, telegraph, telephone, postage, express and other charges. In some plants the drafting office

might also be included, but generally the drafting expenses can be charged directly to production orders.

(8) The Sales Department is assessed with expenses similar to those of the General office, and also with the cost of advertising, commissions and allowances for collections, preliminary drawings and estimates. Many of these charges can be directly applied to the product sold.

(9) Storehouse:- this bears the usual expenses of a department or a separate building, besides the cost of insurance, depreciation and waste of stock, and the cost of labour employed to receive, store, reissue and account for it. These charges may be distributed over the material issued by the store, for production orders, and thus become an element in the cost of material.

(10) Other Items of General Expense - the operation and maintenance of general transportation facilities, railway tracks, yard cranes, yard labour, stables,etc.

We have already seen that several of the indirect costs are adapted for application to a certain group of products, while others must be shared by the whole output. The following bases for this distribution, either departmental or total, have been suggested, and are in actual operation (a) the man-hours expended on the job, (b) the direct labour cost of the

job, (c) the machine rate and man rate, by which the overhead burden on each department is applied directly to the machines and men in that department in the form of rent for the space which they occupy.

(a) The total shop costs for a period are divided by the number of man-hours of direct labour employed during that period. The result is an hourly rate of overhead expense per man-hour, and can be directly added to the labour cost as soon as the times of starting and finishing the job are known.

This method has the disadvantages that it fails to discriminate between different grades of labour, and takes no account of the machine on which work is done. Thus, to take an extreme case, a piston ring made by a raw apprentice on a small, simple lathe may be made to bear the same indirect cost as a locomotive driving wheel tyre, which is turned, bored and faced on a large multiple boring mill. Such a method would therefore be altogether inapplicable to a shop in which the operations performed and the grades of labour employed varied over a wide range. In a purely manufacturing concern, however, and especially if the output per man is approximately constant throughout each shop, this system is quite as good as any other and simpler than most.

(b) Under this system the overhead charge on each department for a certain period is divided by the total direct labour cost for that period, giving so many cents of overhead expense for every dollar expended on direct labour. Then, by multiplying this rate by the total dollars spent on direct labour on any job, and adding the labour and material cost, we get the total cost of filling the corresponding production order. This method, though making no pretence at uniformity, is the one most generally used. Like (a) it is admirably adapted to a strictly manufacturing concern employing a uniform grade of labour - but so is almost any other conceivable rational system - and its disadvantages soon become apparent in such a plant as the Angus shops, where a rather slovenly modification of it is in operation.

In many plants employing this system, what parts of the indirect costs are assignable to the various departments are so assigned, and the remainder is then subdivided and distributed among the departments according to some recognized principle - such as proportionately to floor space. It is then not nearly so difficult to apportion fairly the indirect costs of each department to its product, as if an attempt had been made to do so without this preliminary subdivision of the total charges. Yet this latter is the procedure adopted in the

Angus Shops. The accounting department, having discovered by simple subtraction that the indirect costs equal about 40% of the total direct labour cost, parcels out 40¢ of the overhead charges to all jobs on which a dollar's worth of direct labour has been employed. Thus the work done by a painter, who is generally on a locomotive while working, and therefore occupying no floor space beyond a fraction of the small storage shop allotted his gang, bears the same share of the overhead expense as that of a mechanic receiving the same wage, albeit his work be done on a large, expensive semi-automatic machine. Furthermore the painter uses no power, only a small share of the erecting shop light, heat and ventilation, and makes little use of the shop transportation facilities. This is only a typical case which proves that method (b), as usually applied, does not represent the conditions, and that it therefore fails to be an accounting system at all.

Incidentally, many of the expenses attached to a plant are in no wise dependent upon the expenditure on direct labour. The fixed charges continue throughout the working hours whether labour is employed or not, and this method of apportioning the burden takes no account of two men employed on the same kind of work, one working twice as fast and paid

twice as much as the second. It makes no provision for displaying automatically the difference in efficiency of the two men's wages. It therefore does not necessarily assist the manager in isolating and taking measures to eliminate extravagrance and inefficiency.

(c) This plan at once attracts as being apparently the only scientific means of transforming indirect into pseudo-direct costs. And yet it has made but little headway in practice through the difficulty of applying it to the average shop. In a strictly manufacturing plant, a simpler system is amply accurate; in such a plant as the Angus Shops, the probable inaccuracies in several elements of the machine rate would be sufficiently great to counteract its beneficent effects.

Of these elements in which scientific exactitude is unattainable, none lends itself better to purposes of illustration than the cost of power. In a plant where all power is electric, extended observations might afford a knowledge of the amount of power required for each machine, but even then this quantity, and consequently the machine rate, will vary according to the work which is being done. In many large shops, however, there are electricity, steam, compressed air and water for power, and the power expense

cannot be even approximately distributed in proportion to the power actually used by any machine.

As lighting circuits are generally taken from power mains, and the boilers that supply the steam for heating supply it also for steam hammers, steam engines and other purposes, it is impossible to distribute light and heating costs any more accurately than the cost of power.

Moreover, if the cost figures obtained are being used, as they should be, to stimulate the foremen to reduce the costs of work performed in their departments, the latter will rapidly acquire a habit of leaving large expensive machines idle rather than have operations performed on them which could be done on a smaller machine, although the latter may already be overcrowded. This defect would be particularly insistent in a jobbing or repair shop, and will ever constitute a difficult problem.

Conclusions:- It would therefore seem that no one method is equally desirable for all types and sizes of plant, but that the best system for any one plant which does other than strictly manufacturing work, would be a compromise between (b) and (c).

Each shop or department should have a separate expense

account, divided into a sufficient number of sub-accounts to enable the manager to know for what purpose each expenditure was made. This affords a check on extravagance, and displays the benefits derived from each expenditure. The common method of having only one expense account for the whole shop is unsatisfactory and makes an analysis of expenditures impossible; therefore each shop should carry its proper share of fixed charges, apportioned on a basis of proportionate investment.

The Power House expense where possible should be at least distributed among the various shops. The quantity of electric power supplied to each shop could be determined from individual meter readings. The amount of other power must be estimated from a consideration of the number of machines, proportion of the time that these are working, power required by men working outside the shop and the quantity of work being done in each shop. Thus the paint shop employs many man, but little power; while the steam hammer work employs a great deal of power in proportion to labour. An enlightened estimate would allow for this and would result therefore in a much more equitable distribution than if power were charged to general expense, and parcelled out in proportion to direct labour cost.

The principal disadvantage of the second system might be

largely eliminated by charging all machine work for the use of each machine in proportion to the time required for the performance of each operation, i.e. time × machine rate. The amount thus debited the work is deducted from the general expense for the department, and the remainder distributed proportionately to direct labour cost.

Incidentally, the charge for idle machines, and excess of machine cost of small work done on large machines over its cost on small ones should be kept as a species of inefficiency account in each department. This, being an item equivalent to general expense, and not assignable in the latter case to the work done on the large machines any more than to the other work which crowded it out of the small ones, should be distributed over the total product of the shop on the same basis as other indirect expense. If the small work is being repeatedly done on an unnecessarily expensive machine, the work is shown to be too costly, and a charge of equipment may be economical as well as desirable. This is a question, however, which must be decided upon its merits for each special case.

Records of repairs and spoiled work should be kept, and their cost spread over a number of months. as with cost of insurance. The cost of repairs on each machine can this be transformed into an element of the machine rate, which is not

necessarily invariable over a long period for any one machine, especially when the machine is still running satisfactorily after the close of the time upon which its rate for depreciation was based.

The cost system of any plant therefore represents a compromise between science and rule of thumb, the exact blend being decided by the manager or engineer, rather than an accountant, who is prone to worship figures for their own sake, and to arrange them with scrupulous precision on a plan entirely unsuited to the business. The manager is not interested in costs solely as costs, but largely also as a means to the end of obtaining more efficient production. The expert accountant, being unacquainted with manufacturing methods and conditions, is necessarily incapable of devising a system which will effect this purpose, and may take measures, at the cost of interfering with production, to obtain records which serve no useful purpose in increasing efficiency when they are secured.

It is equally futile to attempt to transplant a successful cost system from another factory by simply purloining or otherwise securing a set of the blank forms employed there.

The efficiency of production should be continually watched as closely as possible, and, to facilitate frequent comparison with corresponding periods in previous years it is strongly

advisable to make up the general expense accounts and distribute the indirect expense, at most, monthly.

The costs should be so recorded that the manager can readily determine all excessive expenditures, whether direct or elements of the expense burden. To economise on printing stationery and clerical labour, it is desirable in planning a system of accounting to devise cards or blanks which will serve as many purposes as possible, though plans for economy should not have priority over the necessity for reasonable accuracy.

The design of such blanks is greatly simplified where some system of mnemonic symbols for the identification of parts and operations is in use. Thus, cards such as that shown on Plate XIV will contain all the information necessary for compiling each man's pay roll (from all cards bearing his number); the cost of production (from all cards bearing the Order Number); and the progress of the order (from all those which have the same operation Number)¢. This last is particularly important under any system which comprehends the use of a graphical daily balance.

Each card then has all the prestige of an original entry, and the final records are far less subject to error than if the figures had to be copied more than once, or from a greater number of cards.

The procedure of the Canadian Pacific Railway Roundhouses in ordering locomotive parts from the various shops is an extreme case of the employment of a number of forms where one would be ample. The requisition from the roundhouse comes first to the storekeeper, who copies it on a similar form, of different colour, which he forwards to the office of the Assistant Superintendent of Motive Power, who is also Superintendent of the Angus Shops. After the order has been approved by this official it is recopied in his office, and the storekeeper's form retained for reference, while the new form is sent to the superintendent of the Locomotive Department, and, through him, to the foreman in whose shop the order will be filled, in the form of a production order.

Naturally all this takes time, and, about two weeks after the receipt of the first order, a requisition for material is sent by the foreman to the stores. It being a laudable ambition of the storekeeper to have as little capital, in the form of material, laying idle as is absolutely essential, the material is not immediately available, and still more time is wasted while the purchasing agent is obtaining it. Meanwhile, perhaps, a locomotive has lain crippled for several days ina roundhouse. Of course, a palliative for this prolific source of ineffiency lies in the adoption of a single form, to be partly filled in by the roundhouse foreman, and providing accommodation for whatever

additional information must be added at the various halting places, and by the delegation to the storekeeper of executive power to utilise his intellect and order material for the time when it will undoubtedly be wanted.

As regards accounting for stores, the most modern practice is for the storekeeper, after issuing material, to forward the requisition to a stock clerk. The latter then enters the depletion of stock upon a special stock record (reproduced Plate XV)for that particular grade, shape and size of material. As will be seen, each type of stock has a particular symbol or number, and the card, thus identified embodies further information as to low limit of stock (at which point a new supply must be ordered) standard order, and certain physical data for the determination of material cost. Such a stock record makes the ordering of standard material automatic, and obviates the necessary for periodic inventories of the stock.

The forms on which requisitions for material are made need generally provide for no further information than shop requiring material, job order number, stock number, quantity of stock required, date and foreman's signature.

By maintaining a Material Specification (Plate XVI) Card for each standard order, a form of production order similar to that shown on Plate XVII may be profitably employed. This is

XV

Stock Record

STORE Nº (FOR PURCHASED STOCK)

LIST Nº (FOR MFD. MATERIAL)

DESCRIPTION

RE-ORDER WHEN STOCK IS REDUCED TO STANDARD ORDER

FEET PER POUND WEIGHT PER LINEAL SQUARE FOOT POUNDS

AVAILABLE		RECEIPTS				DELIVERIES				IN STOCK	
DATE	QUANTITY	DATE	ORDER NUMBER	QUANTITY ORDERED	QUANTITY RECEIVED	DATE	ORDER NUMBER	QUANTITY RESERVED	QUANTITY DELIVERED	DATE	QUANTITY

MATERIAL SPECIFICATION

DESCRIPTION _____ DRAWING No. _____ LIST No. _____

DATE _____

DEPT. No.	OPERATION & PART	DETAIL OR PATTERN No.	DRAWING No.	DRAWING DATE	DELIVER TO	DRAW FROM	PIECE PART No.	REQ'D FOR No. PC'S	REQ'D FOR QUANTITY	DESCRIPTION

XVI

SUBJECT No.

DATE PROMISED

DATE FINISHED

FOREMAN'S ORDER

S.O. No. _____

FILE No. _____

DATE _____

OPERATION & PART	DETAIL OR PATTERN No.	DRAWING No.	DEL-IVER TO	DRAW FROM	NO. OF P'C'S	QUANTITY	DESCRIPTION

XVII

filled from the material specification sheets, and gives each foreman all information necessary for performing his part of the operations involved in the order. These orders are typewritten in triplicate, one copy being retained in the general office for costing, another going to the foreman concerned, and the third to the storekeeper, so that he may have the necessary material on hand when requisitioned. It is, however, of questionable profit to reproduce any set of blanks, as the form which these take in any one plant is so completely a function of the local conditions.

IX.

MISCELLANEOUS.

APPRENTICES:-

Among the features without which no system of management can be self-perpetuating, perhaps the most important is the provision for a supply of skilled labour sufficiently large to replace immediately and without disturbing production, all workmen whose services have been dispensed with, whether voluntarily or involuntarily. The attainment of this end necessarily involves the regeneration, in some form, of the old apprenticeship system.

The decline of the old system was the inevitable result of over development of industry. Until the last half of the 18th century, most shops were conducted by a master-workman, two or three journeymen and one or two apprentices each. These latter were the especial care of the master-workman, who was doubly stimulated to give them the full benefit of his instruction and accumulated experience. As is the case with modern factory owners on a large scale, he had to insure himself against inability to secure a sufficient staff of skilled journeymen; and it was to his less tangible but very real interest to make certain that those of his apprentices who afterwards left him instead of serving as his journeymen should do him credit wherever they worked.

One of the first of the phenomena which marked the industrial revolution was the economically enforced surrender by the master-workman of the task of instructing and supervising his apprentices. At first generally, the duty was relegated to the

owner's deputy - the superintendent - who also soon became too busy to fulfil it. And so the condition - still obtaining in many plants - was drifted into, of placing the apprentices under the various foremen; which means, finally, that each apprentice works as helper to a journeyman, to whom he must look for all his technical training. The journeyman, however, has no inducement, either financial or moral, to convert his apprentice into an efficient tradesman who will then become his own competitor. The apprentice thus occupies an unsatisfactory as well as anomalous position. The foreman employs him as an errand boy, and the journeyman delegates to him such work as chipping, filing or sandpapering patterns long after he has ceased to derive tangible benefit therefrom. Morever, if the boy be inefficient at one class of work, the foreman may leave him there to master it; but when he has mastered it, the foreman will leave him at it and exploit his acquired dexterity, rather than afford him an opportunity to gain new experience. This is but natural. The foreman, apart from anxiety to reduce unnecessary costs, will rather keep two boys at work which they perform satisfactorily than interchange them, and complicate his already multifarious functions with the duty of instructing and supervising the operations of two more inefficient workers.

That the old system has run its course is apparently incontrovertible. Only in the original form and primitive surroundings could it ever have proved successful. Many employers

noticing the deterioration in quality of labour, which is the inevitable result of employing the charred remains of the old system, have for several years been groping for salvation, and now almost every large plant, has a system of its own. At the Angus Shops, all apprentices are placed under the charge of a special Supervisor, who arranges for their instruction in mathematics and mechanical drawing. Otherwise, the apprentices spend all their time as helpers to the journeymen in various shops. The course lasts five years, and the remuneration rises from 9 cents per hour in the first year to 19 in the last.

The American General Electric Company at Lynn,Mass.has established # an apprenticeship system on more advanced lines, which, however, would be impossible in a plant of the average proportions. This Company offers to boys of sixteen years, possessing a grammar school education an opportunity to learn a trade, and makes such attractive conditions that it can afford to discriminate between the applicants for permission to take the course. The duration of the indenture is four years, but terminable at any time by the company for good cause - although the company recognizes its moral obligation to reform or develop the apprentice whenever humanly possible. The wages of the boys range from $4.50 per week in the first six months to $9.25 in the fourth year; and a bonus of $100. is paid at the end of the course. The trade instruction is supplemented during six hours per week with lectures of a very practical nature on mathematics, physics and technology, and instruction in

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mechanical drawing.

Here a special department occupying 10,000 sq.ft. of floor space and equipped with 105 representative machines, is devoted exclusively to the preliminary practical training of the apprentices. Some of the machines are modern, and others but one degree removed from the scrap heap; and it is on the latter that the youngest apprentices commence work. This plan prevents injury, through ignorance, to the new machines and gives the boys an opportunity of learning what troubles to expect from machines, and how to set about repairing them.

The whole department is under the control of an overseer with two assistants, but most of the instruction is done by the apprentices themselves. Before a boy is moved from a job which he has thoroughly learned, he is required to initiate his successor, and thus a faculty of imparting knowledge is early developed. After about two years in the training room the boys are transferred to the factory, where they spend the remainder of their term. They are allowed also to spend several weeks in the stores, tool room, shipping department and on shop clerical work, in order to acquire an understanding of the harmonious whole The system appears to give every satisfaction to the General Electric Company, and represents a distinct advance upon the ordinary plan.

Under the Taylor system,however, it is claimed that a still greater advance takes place; and the Taylor method is applicable wherever the essential features of his system are in operation. The plan adopted here is to bring the young apprentice into touch

with actual manufacturing conditions from the very first. The boy, being constantly surrounded by men working at their highest speed, is more likely to catch the spirit of the Taylor system and to acquire the qualities of industry, manual dexterity and ambition in a higher degree than if he had first spent two years in the less intensely industrial atmosphere of the training room.

Mr.Hathaway, General Manager of the Tabor Manufacturing Company, strongly supports the Taylor method, having found as far as the machine shop is concerned, that it takes only two years, on an average, to convert a raw but intelligent apprentice into a skilled mechanic, capable of operating any machine in his shop. He starts the boys on a drill press or turret lathe and states that a period of three to eight weeks suffices to make them efficient here - efficiency being measured by the Taylor standard, which is no respector of persons or operations. The youth is then promoted to a milling machine or planer, and later to engine lathes and boring mills. Hathaway states that this system produces a more competent and more efficient tradesman in two years than any other system does in four.

I have said that <u>almost</u> every large plant has an apprenticeship system of its own - for some there are that train apprentices in only one or two departments while others have no regular system at all. Such plants are dependent for a supply of skilled labour on their ability to attract graduate apprentices from other works. Thus some concerns expend a great deal of money in

providing buildings, equipment and instructors to train boys who will afterwards work for competing firms.

There is nothing immoral in offering a tradesman better pay or better conditions than he could obtain in the plant where he served his time, but the loss of such men on a large scale to rival concerns is a distinct disadvantage to the firm that trained them. Therefore measures should be instituted by every management to encourage all suitable graduates to remain with the firm.

In the discussion on the aforementioned paper # the case was cited of a plant near Philadelphia employing 4000 men, where the conditions were so unattractive that 15% of the working staff left every month. This is almost equivalent to changing the whole staff twice per annum, and there was therefore no return for the time and money expended in instructing new recruits, as these would migrate on becoming qualified for employment in more congenial surroundings. Yet this migration was completely eradicated by a change in the organization.

Conclusions:-

The apprenticeship system must be designed according to the proportions of the plant. The plan of devoting a separate manufacturing department, while better than the survival of the old system, is far too expensive for at least ninety percent of the plants in any country. The Taylor system of shop management is adapted to all plants employing more than 120 men ## so that his method of training apprentices has a much wider

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M.W.Alexander . Trans. A.S.M.E. Vol.XXVIII.
##J.M. Dodge. Trans. A.S.M.E. Vol.XXVII Discussion

sphere of usefulness; but the latter is not applicable until the essential features of the system have been adopted also.

Therefore the management of the average plant has an option for present purposes between

(1) Employing the remnant of the old system.

(2) the method employed at Angus (which is generally chosen)

(3) making conditions in the plant so congenial as to attract graduate apprentices from elsewhere (liable to be expensive, unless accompanied by some form of the Taylor system) and

(4) co-operating with other firms and trade schools to make the graduates of the latter efficient and intelligent tradesmen.

When conditions in competing plants become more nearly equal, the 4th will probably become the prevailing method. It has already proved extremely successful in several places, especially in some of the textile towns in Northern England, but its time is not yet.

The Committee System:

This has been very succesul in eliminating inter-departmental friction, and in correcting glaring differences of efficiency between the operations of the various shops in some plants. It simply involves the formation of a committee consisting of the principal foremen and the heads of the drafting office and sales department, with the superintendent as chairman, which meets periodically for the diseussion of questions of interest, such as #

(1) Plans to standardize product, and new methods of design:

PROFIT MAKING MANAGEMENT, p.30 - C.U.Carpenter.

(2) Actual progress made on new ideas already introduced into the factory - to counteract the tendency of new ideas to become starved in infancy:

(3) Reports upon economies already ordered into effect, and plans for further ones:

(4) Progress upon stock and contract work, in order to fix responsibility for delays:

Such committees are only advisory in character, but every man should have full rights to the floor, and should, moreover be considered as responsible for sins of omission in failing to tell all he knows upon the subject under discussion, as for sins of commission in the shop. They are therefore of tremendous value in acquainting the superintendent with all deleterious conditions existing in the shop, and indicating unsuspected possibilities for the further reduction of inefficiency. Carpenter recommends an extension downwards of the committee system, involving the creation of subsidiary committees (1) of general foremen, and (2) of gang bosses, at whose meetings the superintendent or another member of the general factory committee should preside. These auxiliary committees need not meet quite so frequently as the first, but they are important as a means of enlightening the minor executive as to the general policy of the management, and so gaining their support for innovations which could not otherwise succeed. By providing the foremen and gang bosses with an opportunity to prove their worth, such a system in the average plant would undoubtedly stimulate esprit de corps besides curtailing inefficiency.

ENCOURAGEMENT FOR SUGGESTIONS:-

Until comparatively recently, few firms gave real as well as apparent encouragement for suggestions made by the workmen, that might be of value in reducing costs. In Germany, to this day, such provisions are practically unknown #, and in many English and American plants, the workmen with ideas are not encouraged to impart them to anyone but their own foreman, who is only human and not ever disposed to assist a possible rival to promotion. The foremen are liable to be predisposed by jealousy against acceptance of ideas from their men; and, should they be so far convinced as to recommend to the superintendent that the idea be adopted, it is seldom that the originator is given full or much more than grudging credit.

The practical method of obtaining suggestions for imppovement from the men consists, not only in the offer of a prize, or a share in the saving effected, but in making the heads of the company more accessible, so that the suggestion may pass in a more favorable channel than through the foremen. This is a simple matter to arrange in any one plant - in a small plant the superintendent may attend to the matter himself - in a large one it may even be possible to employ a special official who will also investigate the economies effected by the various suggestions when put into practice.

THE EFFICIENT PURCHASE OF MATERIALS:-

The purchase of material for an industrial plant is generally supervised by a special agent, or corps of agents,

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The purchasing agent should be thoroughly acquainted with his market, and also with the economies of freight transportation. The principal points to be considered are,

(1) The necessity of ordering materials early enough to ensure their delivery when wanted - often contracts have failed, resulting in expensive and protracted litigation, through the failure of a purchasing agent to take this precaution;

(2) That the cost of material, as well as the cost of delivering it to the plant is generally much less if it be ordered in comparatively large quantities than in small, so that, in a sense, it usually pays to purchase a larger quantity of each material than is actually wanted at once; and

(3) That all material in the storehouse represents a certain amount of unproductive capital, and should therefore be maintained as small as possible.

Thus the economy of purchasing material in large quantities must always be balanced against the loss of interest on cost of the surplus which is not immediately used. Then, considering the rate at which each kind of stock is issued to the shop, and the time which must elapse between issue of the order for and delivery of a fresh supply, it is possible to compromise upon a best economical standard order for that article. These considerations also facilitate a determination of the most suitable low limit, at which a fresh supply is ordered, for each standard kind of stock. The sum of this and the amount of the standard order gives a ready measure of the space required for

each type of stock, and thus simplifies a redesign of the store if such should ever prove to be advisable.

The purchasing agent, to revert, should pay attention to, and be empowered to forestall or take advantage of fluctuations in the raw material market; and he should continually keep in touch with the plant, to ensure that the materials purchased by him are of the right grade.

THE GENERAL OFFICE:

Most managers pride themselves on keeping in touch with every detail of their respective plants, and many think to do so by having their tables continually littered with letters and reports waiting to be signed or overlooked.

In order to cope with this obvious example of mismanagement, and free the manager for the consideration of broad lines of policy, of suggested innovations and for studying the character and the suitability for promotion of his more important subordinates - the proper functions of a man qualified for the position of manager - Taylor advocates # what he terms the "Exception Principle". Under this system, all documents are perused by an assistant, who saves the manager from being troubled by letters which may be considered standard. These and other letters and reports he summarises, noting exceptions to previous standards, and then, with the manager, goes through the whole in a fraction of the time which the manager alone would require under the prevailing system.

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As a fact, the exception principle is gradually coming into general application, but its scope is not necessarily limited to the manager's office. The general employment of it practically forces each important executive officer to train, if not his successor, at least some one who could very ably fill his place during short absences.

"PATERNALISM":-

The establishment of better conditions of work, such as improvement in lighting or ventilating a plant, fencing in moving machinery, the removal of obstructions to free movement, and the provision of comfortable dining rooms is often so stigmatised by unprogressive manufacturers and their journalist friends, but such innovations are generally excellent business. It truly seems that the average manufacturer will never discover theeconomy of practical solicitude for the health and comfort of his workmen, whom the additional consideration and the removal of restrictions must make more contented, and ergo more productive- met at any rate until they are forced by public opinion and legislation to institute such improvements, and the compulsory element then halves the moral effect.

The workmen should therefore be encouraged to discuss their troubles, whether experienced in or out of the works, with those above them. Under the Taylor system the disciplinarian is naturally fitted for this post of confessor; and, if he be tactful and honest with the men, there need never be any fear of labor troubles.

It is when this so-called paternalism extends to the

provision of lecture halls and free lectures, music,etc., free night schools, kindergartens for the workmen's children, athletic grounds, gymnasia and model dwellings (possibly for advertising purposes) that the reproach of paternalism becomes applicable. Anything which savours of charity is seldom greatly appreciated by the men. The same end might be indirectly attained at the same nett cost to the company if a mutual benefit society were formed by the men at the instigation of the management. An increase of wages throughout the plant, would enable the staff to contribute the increment without loss, to the new society, and still feel that they have earned the library, athletic equipment,etc., which the society as a whole decided to purchase. Improvements of this nature should come in all isolated plants, but should not be allowed to engross executive attention to the detriment of duties more directly concerned with production, unless their inauguration should prove vital to economical operation of the plant. This condition is not inconceivable, as there is always difficulty in seducing skilled labor from urban centres to a rural plant.

CONCLUSIONS.

Having analysed more or less exhaustively the various methods of management which diverse manufacturers have adopted in the hope of thereby employing their plant to maximum pecuniary advantage, we see that only those systems comprehending a knowledge of the labour unit, a large daily task, and a bonus for its successful accomplishment, are compatible with maximum efficiency. By directly producing a large increase in manufacturing profits, the employment of such a system, obviates the temptation to employers to combine for the purpose of keeping wages down, or - what is an insidious equivalent - of keeping prices up. And it is not only the employers who prosper under scientific management, but the employees also, through the supersession by practical co-operation of the open or implied antagonism that now prevails.

The amount of accumulated wealth in the world is by no means a fixed quantity; and the rate at which the average standard of human comfort improves is essentially a function of the rapidity of production of new wealth. Whether or not this standard is to advance, stagnate or retrogress therefore depends principally upon the success of the average employer in increasing the productivity of his working force - either by the application of new inventions, labour saving devices, by educating his employees, or by actually inducing them to work harder.

It is an observed fact that the average worker accomplishes most when set a definite large daily task, if provided with

ample instructions as to the best means of attacking it, and an alluring incentive to complete the ~~wa~~ task. The precise method of remunerating labour is immaterial, provided only that it embody the principle of rewarding efficiency and not penalising it. In other words, the only effective stimulus to most rapid production of new wealth is an equitable method of distributing it amongst all the individuals who are co-operating to create it; and, since increased efficiency is so greatly to the manufacturers' interest, he should be not only willing but thankful to pay high wages to all who can earn them.

To introduce either of these utopian systems into any plant is a laborious and intricate process. Efficient organizations cannot be built up in a day, and are not to be secured for the price of an incompetent one. In few plants however, is it more profitable to introduce the whole of the Taylor system than certain elements of it. The Gantt system has the advantage of greater susceptibility to compromise at the precise point where the saving effected by further improvements or exactitude would just fail to reimburse the firm for the cost of instituting them.

Perhaps the principal objection to the Gantt system is the fact that the necessity of standardizing machines, appliances and methods; of training functional foremen and making time studies, presents a task of such gigantic proportions as to render a proper establishment of the system consistent only

with the employment for a time of several experts. It is so far applied in only a comparatively few isolated plants - though with conspicuous success in each.

Where a combined objection to having his methods subjected to the scrutiny of an outsider, suspicion of innovations, inertia and pressure of business prevents a manager both from himself introducing scientific management into his plant, and from having it introduced, it were well to adopt the Halsey system. The results obtainable under it are not comparable with those which accompany the Gantt or Taylor systems, but it can be instituted without fear of opposition, and drifts slowly towards maximum efficiency.

As day work is the only practicable system for such work as pattern making; and as piece work is without disadvantage for such operations as putting labels on bottles, packing soap, etc., it is obvious that every system of management has its especial sphere of superiority over all others. It is not only possible, but often profitable to employ all at once in the same plant.

To attempt a diagnosis of the nature and tendency of a process of evolution which is going on before our very eyes ever constitutes a difficult problem, through lack of the proper perspective. As regards the present trend of industrial development, however, there are palpable straws to guide us in discovering its direction. At the recent freight rate investigation in Washington, a number of representative railroad magnates

testified that they have exhausted every known means of eliminating inefficiency. After them followed, for the other side, a succession of industrial engineers, who were unanimous in flatly contradicting the above assertion. One of them, perhaps more optimistic than the rest, stated his firm conviction, that the application of the principles of scientific management throughout the railroads of the United States would effect a saving to them of a million dollars per day. Be this as it may, the defeat of the railroads at this investigation indicates, if nothing else, that the apotheosis of the financier is approaching obsolescence, and that the engineer is to be his legitimate successor as "Captain of industry".

It is only compargtively recently that industrial engineering has acquired an acknowledged standing, but the popularisation, subsequent to the above investigation, of the gospel of efficiency proclaims the fact that industrial history is in the making. This propagandism, however, is not an unmixed blessing, as the incomplete and incompetent systematiser is certain soon to be abroad in the land. Caution is therefore expedient at this stage or never, lest by two ready general application of its superficially essential features only, the underlying principles of scientific management be neglected, and the whole doctrine discredited by the consequent failure. If, however, its acceptance do not become too suddenly general all should be well. "With equity as a basis" says Gantt *

*Address to the National Civic Federation, New York. Jan. 12, 1911

"efficiency grows apace, and together - each inducing the other - they will usher in a period of continuous prosperity and harmony, such as the world has never seen".