Modern scientific management is the result of continued application of methods that were planned to achieve certain definite results. Plans were made before operations commenced, and careful note was taken of all results. The process had modest beginnings, and followed the era of large industrial enterprises, specialisation, standardisation, and studied division of labour. The organisation of industrial enterprises was previously empirically considered, when, in 1903, F. W. Taylor presented much arresting data in a paper entitled "Shop Management" (Proceedings of the American Society of Mechanical Engineers).

The "scientific method" has been used considerably in the sciences, and this method was gradually applied to industrial management. Investigations and experiments were made, and data were collected, recorded and classified. Step by step, by observation and experiment, the foundation is laid upon which continued development is attained in the particular subject. The methodical building of fact on fact, organising the facts into knowledge, is one of the chief objects of useful thought, and is best accomplished by the scientific method.

Trained engineers were used not only in the production section, but also on the management side. Problems such as plant layout, operation, planning, etc., were investigated by specialists, and a great impetus was given to planned production. The tendency of Australian engineering practice to-day is toward specialisation, the various sections under specialists, who closely study every detail and make their efforts along scientific lines. The various efforts must be co-ordinated, and this means that the modern manager must study this feature of management and have the proper perspective view of the whole of the work under his control. This consideration forms the basis of this lecture, and an attempt is made to present thoughts and data that will be useful to those engaged in engineering manufacture.

(2) Organisation.

Even in small works there should be some form of sound organisation and routine, and the successful continuance of business should not hinge on one man. The various sections should be defined and arranged so as to give maximum scope to each, with the necessary co-ordination between all. The type and extent of the organisation will depend on the extent and
class of the work to be done, and an arbitrary classification is as follows:—

(a) Jobbing work; where quantities per order are one or few; where the various jobs are not to standards; where each job must be studied individually as to methods and costs.

(b) Batch production; where certain lines more or less standard are put through in quantities to a special lot order; or where they fill market demands for a certain period.

(c) A combination of the first two classes.

(d) Continuous production of the same article or articles.

The successful working of the business will depend largely on the organisation adopted, and, as confusion and delay would follow radical changes, too much care cannot be given to this feature.

There are many functions covered in the activities of a business organisation, some of which are as follow:—

(a) Direction—
   (1) General policy.
   (2) Organisation.
   (3) Control.

(b) Financial—
   (1) Planning.
   (2) Records and statistics.
   (3) Handling of capital.

(c) Sales—
   (1) Market study.
   (2) Product study.
   (3) Sales methods.

(d) Manufacture—
   (1) Design.
   (2) Material control.
   (3) Layout and equipment.
   (4) Production methods.

These functions apply to small businesses as well as large concerns.

In order to get into some detail in this lecture, it is proposed to deal particularly with Section (d)—Manufacture.

(3) Notes on Manufacture.

(a) Design—Even in the business doing jobbing work, the design of the product very often supplied by the customer is of great importance as it affects the method of manufacture. In the business which designs its own lines, this fact is often kept
in mind; but, wherever the design is done, due attention should be paid to the fact that the article has still to be efficiently and economically manufactured.

The elements of a good design are function, appearance, and ease of manufacture. The article must be capable of performing the desired service; and the designer therefore arranges parts, materials and sizes, primarily with performance in mind. Appearance is carefully studied for sales reasons. Finally, well-studied attempts are made to attain minimum cost on material and processing. Very often a few hours spent by a designer familiar with modern production methods will result in a saving of hundreds of hours in manufacture. Where designers have access to workshops, they can, by observation and contact, keep up to date on modern shop methods, and by recourse to current technical literature can watch the rapid developments which are now occurring in shop practice. May I set out one example of where a minor change in design saved much trouble in manufacture. The job was a large number of adjustable shelf racks of mild steel angle and tee construction, electrically welded, and on the vertical angles and tees were welded 160 small flats, serving as shelf rests, as shown on Drawing No. 1. To locate and hold these rests for welding proved rather difficult, as the jigs considered obstructed the welding operation. After consultation with the customer, the shelf rests were punched to shaped and slotted form, and the angles and tees were notched to receive them. The rests were then tapped into their correct locations and firmly held in the notches, and the welding was a very simple job. Drawing No. 2 shows the original design and fixing of shelf rests, above, and the final method, below.

(b) Material Control—Most engineering manufacture can be described as the processing of raw materials, mainly metals, and the procuring, handling and controlling of material should be treated in a scientific manner. In a business where set quantities of certain lines are to be made, an accurate estimate can be made of the material required; and then it is solely a matter of finance as to the purchasing.

But where the business is possibly a combination of jobbing work and batch production, the engineer in charge needs some foresight in order to purchase wisely. Sometimes it is best to buy in large quantities, as at a time when volume of business is small, when there is much unemployment, when labour and management are efficient, when interest costs are low, or at a time preceding a wave of prosperity. Buying large stocks is somewhat speculative, but can result in not only good profits, but ensures material at a later date, when supplies become scarce.
The best policy, however, is buying which is regulated to suit present use and fairly definite prospects. Small stocks and quick turnover is sound policy, and it is here that the training of the engineer should produce good results. The quantity of material to be used directly on work in hand and in view is generally accurately known, and thus this material is procured without any fear of loss. It should be noted that due allowance must be made for unavoidable waste, such as offcuts, etc., and things of this nature should be allowed for in the estimate and cost sheets.

It is not often that the figures from a visual stocktaking correspond with continuous stock lists. With highly competitive prices, a loss can easily be incurred, due to uncalculated waste, especially on large quantity orders. The economical use of small pieces of material is difficult to arrange, mainly because of handling and storage costs. Material should be stored, so that its issue can be controlled and its movement to the various locations easy and rapid.

It is quite possible to arrange, and it is a sign of good management, when even in the small jobbing shop the various small finished parts, etc., are boxed and taken to the job in progress, rather than having workmen walking from job to store to job. Management should see that workmen have, as far as possible, all the required material and tools conveniently near by.

There is another class of material which is used in the process of manufacture, and that is the "indirect" supplies, material which is used in the processes, but which does not appear in the finished product. A careful study of this material is necessary to accurately know costs. It is not sufficient these days to know profit or loss by the bank balance at the end of a period. To deal effectively with this matter, a good start is to keep in detail a record of the use of this material. With the data then available, foremen can be advised where to look for wastage or how to get better use of the material, certain modifications to the variety or quantity may be effected, and a budget can be evolved which will keep the value of indirect purchases to a figure which will not upset the factory overhead charge. Also this data will facilitate better buying. A set weekly or monthly value on indirect purchases, which is so fixed to give, together with other fixed indirect costs, the proper factory overhead, is quite a logical practice; and it eliminates to a large extent the chance of unperceived losses. It is helpful to cost a product solely as a factory production cost, so that investigation can readily be made with a view of improvement of actual production methods. If matters of a purely financial and controversial nature can be
kept apart from a factory cost detail, it is much easier to compare manufacturing efficiency.

For instance, if the business purchases 100 tons of steel in January at £13 per ton, and this material is used in production in July following, the factory cost sheets should show this material at a higher value, as determined by the financial section. The manufacturing section, in reality, would purchase such material from the financial section.

Further, to obviate controversial figures on interest and depreciation, building and plant could be considered as rent or hire, the charges being determined by the financial section.

A factory cost sheet would then comprise:

1. Raw material purchased.
2. Finished or partly finished material purchased.
3. Direct labour costs.
4. Indirect labour costs.
5. Indirect material costs.

Studies of indirect material costs in an engineering works of about 150 men provide data which can be set out as a general guide as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost of Indirect Material</th>
<th>Cost of Direct Labour</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Rent or hire of buildings</td>
<td>7½%</td>
<td>7½%</td>
</tr>
<tr>
<td>(2) Rent or hire of equipment</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>(3) Power</td>
<td>7½%</td>
<td>7½%</td>
</tr>
<tr>
<td>(4) Sundry</td>
<td>17½%</td>
<td>17½%</td>
</tr>
<tr>
<td>Total</td>
<td>52½%</td>
<td>52½%</td>
</tr>
</tbody>
</table>

These charges may be added in an even proportion to direct hours recorded, but to enable production improvement or fault to be picked out in detail, it is necessary to use a system of centre costs, where the indirect costs are allotted in varying proportions according to the value consumed in the various sections or centres as defined.

It is not now proposed to say more about the allocation of indirect costs, but rather to emphasise the necessity of close examination of their value. Item (4) is the one which comprises the variable expenses, and should be particularly studied. The following figures may give some idea of general costs on some purchases grouped in Item (4):—
### Notes on Engineering Shop Management.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost per Man Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen and Acetylene</td>
<td>1.5d.</td>
</tr>
<tr>
<td>Electric Welding Rods</td>
<td>0.82d.</td>
</tr>
<tr>
<td>Grinding Wheels</td>
<td>0.1d.</td>
</tr>
<tr>
<td>Files</td>
<td>0.08d.</td>
</tr>
<tr>
<td>Drills and Taps under ½ in.</td>
<td>0.3d.</td>
</tr>
<tr>
<td>Cotton Waste</td>
<td>0.15d.</td>
</tr>
<tr>
<td>Lubricating Oil</td>
<td>0.06d.</td>
</tr>
<tr>
<td>Cutting Oil</td>
<td>0.1d.</td>
</tr>
<tr>
<td>Soluble Oil</td>
<td>0.7d.</td>
</tr>
<tr>
<td>Paint, etc.</td>
<td>0.3d.</td>
</tr>
<tr>
<td>Paint Brushes</td>
<td>0.02d.</td>
</tr>
<tr>
<td>First Aid Material</td>
<td>0.25d.</td>
</tr>
<tr>
<td>Sundry</td>
<td>1.62d.</td>
</tr>
</tbody>
</table>

**Total** ................................................. 6.0d.

An approximate relation between the total of Item (4) and direct wages is 17\%.

If this cost is scheduled after due investigation, it is then possible to fix a definite monthly charge, and calculate in a reasonably accurate and safe general manner the total factory cost.

This would then be as follows:—

Direct materials, plus direct labour, plus indirect fixed labour based on booked man-hours, plus indirect fixed material based on booked man-hours. A high factory overhead is not a sign of bad management. Average figures for medium general engineering shops are as follow:—

\[
\begin{align*}
\text{Indirect Labour} & \quad = \quad 30\% \\
\text{Direct Labour} & \quad = \quad 82\frac{1}{2}\% \quad \text{of direct wages booked}
\end{align*}
\]

(c) **Layout and Equipment**—

(1) **Layout**—In determining a new factory layout, or an alteration to that of an existing factory, an analysis should be made of the products and method of manufacture. Greater efficiency can often be attained by a fresh layout of an existing plant even in the same building, as the faults are more readily perceived; and, using data and experience, a far better layout can be arranged.
ARRANGEMENT OF ADJUSTABLE SHELF RACK.

DETAIL SHOWING REVISED DESIGN OF SHELF RESTS, as fitted to Adjustable Shelf Rack.
It is on record that the Western Electric Co., U.S.A., after a relay out of plant and installation of a suitable handling system, were able to cut down waiting raw material by 45%, thus reducing investment on the same; the floor space occupied after rearrangement was 15% less, and time lost between operations was reduced by 80%.

The layout must be considered to suit the particular case, but the following fundamentals appear to be common:—

(a) Detail study of methods of manufacture and division of operations.
(b) Study of raw material quantities, storage position, methods of handling, and route through the processes.
(c) Placement of equipment which may be either in type groups or functional groups.
(d) Layout of passage ways, incidental storage space, etc.
(e) Location and size of various storerooms.
(f) Provision for increased capacity; expansion without interruption or confusion.

The advantages accruing from proper layout are mainly:
Savings on material handling time; operators' handling time; time saved generally by convenience, orderliness and cleanliness; minimum loss of material and parts; and a "flow" of production that is well defined, and can be readily studied and checked. As a guide for preliminary calculations on space required in average general engineering works, the following figures are submitted:—

Machine Work . . . . . . 150 square feet per operator
Forging Shop . . . . . . 200 " " "
Heat Treatment . . . . . 200 " " "
Welding . . . . . . . . . 150-200 " " "
Assembly . . . . . . . . . 120-180 " " "
Painting . . . . . . . . . 200 " " "
Woodwork . . . . . . . . 200 " " "

(2) Equipment—It is not always possible to have the latest modern machinery and the ideal layout. The position often is that the best must be done with comparatively out-of-date equipment under anything but good conditions. Ingenious methods can often do much with older tools, overcoming most disadvantages excepting breakdown, maintenance, etc. Progress in metal working machinery is moving fast; and when we hear of a tool that completely machines one 6-inch (155 m.m.) shell every 30 seconds, we look askance at some of our equipment. However, obsolescent machinery is common even in the more highly developed industrial countries. In U.S.A. in 1930 48%
of the metal working equipment in use was over ten years old. In 1935 the figure was 65%; and in subsequent years, 61%, 62%, and 70% respectively.

In the latter years, by the way, less than 50% of the U.S. machine tool output went to improve American plants, where ordinarily 80% would be so directed.

Where quantities are being handled, older machines can be specially set up and used on one or two operations only—process work. Special attachments can be devised, a greater power input can be attained by V belt drive, widening of cone pulleys, etc.; and such tools as floating cutters may be used to obtain accuracy. Incidentally, Drawing No. 3 shows an arrangement of a Floating Double Cutter Bar with a Fine Adjustment.

The trend of production equipment is from the general to the special purpose; from the engine lathe to the combination
NOTES ON ENGINEERING SHOP MANAGEMENT.

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turret lathe; from the universal miller to the gear generator and hobber; right up to the multi-cut machines, the automatic and special purpose machines. The variety and high capacity of modern machine tools tend more than ever to divide manufacture into special sections, and lead further towards low price mass production.

In the jobbing and general engineering works this feature makes itself felt; and here also management must carefully consider the scope of its activities, and quite possibly specialise. It is said that obsolescence is a factor dependent on the machine itself, the nature of the business in which it is used, the degree of activity, the prospects of future business, and the likelihood of change of design in the product.

As a point of interest, the following statistics are given showing (1) the percentage of equipment in U.S.A. in 1940, grouped in machine types, that were over ten years old, and (2) the percentage of equipment over ten years old arranged in industrial groups, and the amount of money spent by the groups on new machine tools, 1935-1939.

(1) Percentage of Equipment—Machine Types, over ten years old, U.S.A., 1940—

<table>
<thead>
<tr>
<th>Machine Type</th>
<th>% Old</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boring Machines</td>
<td>75%</td>
</tr>
<tr>
<td>Broaching Machines</td>
<td>60%</td>
</tr>
<tr>
<td>Drilling Machines</td>
<td>70%</td>
</tr>
<tr>
<td>Gear Cutting Machines</td>
<td>45%</td>
</tr>
<tr>
<td>Grinding Machines</td>
<td>68%</td>
</tr>
<tr>
<td>Honing and Lapping Machines</td>
<td>45%</td>
</tr>
<tr>
<td>Lathes</td>
<td>78%</td>
</tr>
<tr>
<td>Milling Machines</td>
<td>80%</td>
</tr>
<tr>
<td>Planing Machines</td>
<td>90%</td>
</tr>
<tr>
<td>Presses</td>
<td>75%</td>
</tr>
<tr>
<td>Shaping Machines</td>
<td>85%</td>
</tr>
<tr>
<td>Shearing Machines</td>
<td>85%</td>
</tr>
<tr>
<td>Welding and Cutting Machines</td>
<td>35%</td>
</tr>
</tbody>
</table>

(2) Percentage of Equipment—Industrial Groups—over ten years old, and amount of money spent by Groups on new machine tools, 1935-39—

<table>
<thead>
<tr>
<th>Industrial Group</th>
<th>% Old</th>
<th>Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural Implements</td>
<td>67%</td>
<td>1,771,000</td>
</tr>
<tr>
<td>Aircraft and Aircraft Engines</td>
<td>38%</td>
<td>4,204,000</td>
</tr>
<tr>
<td>Motor Vehicles</td>
<td>60%</td>
<td>20,787,000</td>
</tr>
<tr>
<td>Motor Vehicles Bodies and Parts</td>
<td>65%</td>
<td>12,067,000</td>
</tr>
<tr>
<td>Material Handling and Power Equipment</td>
<td>75%</td>
<td>3,114,000</td>
</tr>
<tr>
<td>Industrial Electrical Equipment</td>
<td>70%</td>
<td>6,084,000</td>
</tr>
<tr>
<td>Engines, Turbines, etc.</td>
<td>70%</td>
<td>2,489,000</td>
</tr>
</tbody>
</table>
(d) *Production Methods*—The following remarks are directed more towards the psychological aspects of management rather than details of processes.

The fundamental function of management is to get the highest efficiency from the workmen employed. Two things enter into this: they are the proper use of efficient tools and the co-operative spirit of the worker. Workmen vary in abilities and possibilities, but each man must be encouraged to do his best; and this is a function of management, to guide and encourage. In a factory where there is a lack of orderly procedure, a condition quickly noticed by workmen, the possibility of inspiring men is remote. The duties and authority of the various leaders must be clearly and definitely set out in such a manner that understanding and co-operation can begin at the top. Frankness should be used so that fear and jealousy shall not hinder the efforts of the individual. A broad routine should be established to lessen the attention required to recurring detail. The section leaders, or foremen, are then more free to concentrate on their particular problems, teaching, guiding and encouraging their men, and themselves receiving the same kind of help from the management. Even when planning, etc., is done by a special department or specialists, the modern foreman has still a complex and important job.

The foreman should have all the necessary data, general and technical, made available to him in written or printed form, such as—

1. General description of work.
2. Drawings, material lists, specifications.
3. Records of similar jobs.
4. Quantities required.
5. Delivery instructions.
6. Notes on particular features and operation suggestions.

This last item is an opportunity for personal contact to be maintained by the manager. Not only should details of individual jobs be sent out, but a continuous summary should be available, particularly if the foreman has planning to do.

One of the things which undermines the workmen's confidence is when a rush job or even ordinary work lies around after
being finished. Nowadays men notice and criticise between themselves the muddling and confusion of the management. In this way, then, the foreman can keep up the interest of his men, who will always respond to orderly progress.

The personality of the foreman must enable him to lead and inspire; his technical knowledge must be superior; and his demeanour pleasant, but firm.

His training should comprise practical experience in the workshop, drafting office, inspection, rate fixing, etc., and he should be well paid.

Thus a very important function of management is the continual supervision and training of foremen.

A certain plant manager once remarked that at last they had their foremen really interested in human relationships, and that it wasn’t their materials at fault, but rather their methods. Even films are now being used to attain results along these lines, and shorts are being widely shown, having titles such as—

The Foreman as Manager.
The Foreman as Trainer.
The Foreman as Leader.
Letting Men Know Where They Stand.
The Reprimand.
The Grievance.

Typical suggestions, illustrated by film, with voice comments, are prepared for foremen, some being as follow:—

(1) Spot the Trouble.
(2) Figure Out What to Do.
(3) Get the Man’s Co-operation.
(4) Show Him How to Improve.
(5) Follow Up.

To help the foreman to use scientific methods in his attempts to assess the capabilities of his men, for instance, management can give him details of methods used in other places, one of which is described by A. L. Kress, of the National Metal Trades Association, U.S.A. The main headings of this “Employe Rating Report” are as follow:—

(1) What has he done—
   (a) Quality of work.
   (b) Quantity of work.

(2) What can he do—
   (a) Adaptability.
   (b) Job knowledge.
(3) Can you rely on him—
   (a) Dependability.
   (b) Attitude.

Information of this nature will definitely help an intelligent foreman and will also be appreciated. The foreman is the link between management and men; and every effort should be made by example and precept to bring the foreman (and with him his men) into the spirit of strenuous yet pleasant co-operation, which should also characterise the management. With regard to actual processes, which rapidly change and improve, the management can help greatly by supplying the latest relevant information.

The revolutions per minute, or linear speeds of all machine tools, should be charted, if not marked on the machine, and clear information as to the theoretical cutting speeds and feeds given for the various metals and tools.

Copies of the relevant charts should be conspicuously placed at the various machines, so that the operators also may be interested in the proper and efficient use of modern tools.

Extracts from current technical literature, sales literature, if carefully chosen and distributed, can go a long way to awaken interest and maintain enthusiasm amongst employes.

Conclusion.

Efficiency in modern engineering shop practice demands active co-operation between management and workmen. Management has moral obligations to employes, and there should be no conflict between this aspect and profit making. The executive engineer, by technical training taught to think logically and to some extent dispassionately, must combine scientific management with the practice of human relationships. He must be the common citizen as well as the engineer business man.