MODERN MACHINE METHODS.

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There is a rapidly increasing tendency to minimise hand labour, and to reduce manufacturing to purely machine operations by the aid of accurate tools and fixtures combined with properly adapted machines. Admitting this, it follows that the lines on which manufacturers will work in the future will mainly be in the direction of perfecting methods of machining.

It is with respect to machine operations, where accuracy combined with cheapness of product is secured, that this Paper deals, contrasting modern developments with those methods where accuracy is secured only by laboriously expensive hand work, or where machine work is performed on tools of comparatively simple design, unaided by highly developed tools, fixtures, and gauges. It is not, however, assumed that automatic machine operations are invariably more economical than hand work, as doubtless many a sadder and wiser manufacturer who has invested in complicated expensive machines can testify. It is, however, beyond dispute that the producing power of the individual, aided by the labour-saving automatic machine, is practically unlimited, whilst we have long since reached the limit of production of the skilled worker, making use of only simple

machines and hand tools. A high degree of accuracy is possible by either the old or the new method; but accuracy combined with cheapness is only possible under new conditions, whilst interchangeability is commercially impossible, except in those establishments fitted with the best machines, tools, and gauges.

Strictly speaking, there are few, if any, mechanical operations that may be called new since the time when the planer and milling machines superseded the chisel, and the power lathe and the drilling machine replaced the bow stick. Turning, milling, planing, grinding, and boring are as "old as the hills." It is the latter-day developments of these operations in which the progressive manufacturer is interested, developments which have practically taken place within the last twenty years, some of them within the last five years. It is proposed to touch briefly upon the different methods in respect to the latest practice only, and to deal finally with the workshop reforms which in some cases follow, and in others must precede, the introduction of new methods, before such methods can be successfully adopted.

The range of subjects is so large that in most cases ambiguity has been risked for the sake of brevity. Descriptions of methods of working have not been possible, and an attempt only has been made to mention the most important points to which modern manufacturers must give attention. Technical details as to constructive features of machines have been avoided. The chief aim has been to make the Paper suggestive to those who are considering economical methods of manufacture.

Gauges.—It is altogether too commonly supposed that the extensive use of accurate gauges is only economical where either highly accurate work is called for or parts are to be made in large quantities. Neither supposition is correct. In nine cases out of ten where even only one piece is concerned, that piece can be produced more cheaply and better with the aid of proper gauges than by the old-fashioned method of "fitting," or by measuring with micrometers or calipers. There will be the additional advantage of pieces being practically interchangeable. Again, where comparatively

coarse work, as for instance in some parts of a loom, is permissible, the use of suitable gauges is desirable for the reason that, no matter how loose the fits may be, it is necessary, to save work in erecting, to secure interchangeability and to keep sizes within certain limits. All this can be accomplished by means of the "limit" gauge, whether used for large or small dimensions, for inside or outside work, or for running or driving fits. Although the "limit" gauge in certain forms has been in use for years, particularly amongst gun and small-arms makers, it is surprising how little its advantages and use are known and understood by manufacturers for every-day work or all sorts. It is impossible to enumerate or describe the various forms of limit gauges which can be adopted in nearly all engineering works, but manufacturers will find the subject well worth investigation.

When the advantages of working with limit gauges are better understood, the system is sure to be extensively adopted for general engineering purposes, and limit gauges will supersede, except in a few cases, the ordinary standard plug and ring gauges. Even where the best gauges, of the ordinary sort, are used, work is in reality finished within certain "limits." When only standard gauges are used, however, these limits are never known; dimensions are made in accordance with the skill, judgment, or experience of the workman. With the limit-gauge system, it is only necessary to determine what the allowable limits are to be and to then make use of a maximum and minimum gauge, by which sizes are kept within the prescribed limits. For inside cylindrical work the form of gauge used is shown in Fig. 1 (page 12), for outside work those shown in Figs. 2 and 3. With these gauges, comparatively unskilled labour will (aided by the proper outfit) quickly learn to produce work accurately within limits of 0.0006 inch when using the external limit gauge and within limits of 0.0016 inch when using the internal limit gauge. These limits are none too close for a large percentage of ordinary engineering work and close enough for interchangeability, even in fine machine work. The adoption of limit gauges is in itself desirable, but of course the most economical results cannot be secured without also giving consideration to the outfit of machines and tools. It does not follow that grinding

is necessary either for inside or outside work. The above limits can be kept to either in lathe or screw-machine work, and holes can be finished in steel, brass, or cast-iron with reamers.

It is an erroneous idea to suppose that because comparatively rough work is in question, comparatively rough gauges are "good enough." This may be true, as in the case of working gauges for unfinished material, but it will be rarely found profitable to follow this principle where machined surfaces are to be dealt with. Carefully finished hardened gauges, accurate to within 0·0001 inch, are none

Limit Gauges. Examples from Table 1.

FIG. 1. *Internal.*

FIG. 2. *External Running Fit.*

FIG. 3. *External Keying Fit.*

too good where working surfaces are in question. A finer degree of accuracy than this is not demanded, except in comparatively small work, as for instance, in tools connected with the manufacture of watches. It is proved that 0·0001 inch is a limit to which hardened gauges can be made without too great an expense. It is desirable not to go below this degree of accuracy for working gauges (never in the case of standards), as errors multiply rapidly, and four or five times this limit means that in many cases work must be rejected.

The following Table 1 of limits given is one which is adapted to a large range of work :—

TABLE 1.—*Internal and External Limit Gauges.*

Limits of tolerance expressed decimally in inches.

INTERNAL LIMIT GAUGES.

(See Fig. 1.)

Diameter of Holes. (Nominal.)	Go in.	Not go in.	Total limit of Variation.
$\frac{1}{4}$ inch to $\frac{1}{3}\frac{3}{8}$ inch.	- 0.0004	+ 0.0004	0.0008
$\frac{7}{16}$ inch to $\frac{1}{2}$ inch.	- 0.0006	+ 0.0004	0.0010
$\frac{3}{4}$ inch to $1\frac{3}{16}$ inch.	- 0.0006	+ 0.0006	0.0012
$1\frac{1}{4}$ inch to $1\frac{1}{2}$ inch.	- 0.0008	+ 0.0006	0.0014
$1\frac{1}{2}$ inch to $2\frac{1}{8}$ inches.	- 0.0008	+ 0.0008	0.0016
3 inches to $4\frac{9}{16}$ inches.	- 0.0010	+ 0.0008	0.0018

EXTERNAL LIMIT GAUGES, for running fits.

(See Fig. 2.)

Diameter of Shafts. (Nominal.)	Go on.	Not go on.	Total limit of Variation.
$\frac{1}{4}$ inch to $\frac{1}{3}\frac{3}{8}$ inch.	- 0.0004	- 0.0010	0.0006
$\frac{7}{16}$ inch to $\frac{1}{2}$ inch.	- 0.0006	- 0.0012	0.0006
$\frac{3}{4}$ inch to $1\frac{3}{16}$ inch.	- 0.0008	- 0.0014	0.0006
$1\frac{1}{4}$ inch to $1\frac{1}{2}$ inch.	- 0.0010	- 0.0018	0.0008
$1\frac{1}{2}$ inch to $2\frac{1}{8}$ inches.	- 0.0012	- 0.0020	0.0008
3 inches to $4\frac{9}{16}$ inches.	- 0.0014	- 0.0024	0.0010

EXTERNAL LIMIT GAUGES, for keying fits.

(See Fig. 3, page 12.)

Diameter of Shafts. (Nominal.)	Go on.	Not go on.	Total limit of Variation.
$\frac{1}{4}$ inch to $\frac{3}{8}$ inch.	+ 0.0004	- 0.0002	0.0006
$\frac{7}{16}$ inch to $\frac{1}{2}$ inch.	+ 0.0004	- 0.0002	0.0006
$\frac{3}{4}$ inch to $1\frac{3}{16}$ inch.	+ 0.0004	- 0.0002	0.0006
$1\frac{1}{2}$ inch to $1\frac{7}{8}$ inch.	+ 0.0004	- 0.0004	0.0008
$1\frac{1}{2}$ inch to $2\frac{1}{8}$ inches.	+ 0.0004	- 0.0004	0.0008
3 inches to $4\frac{1}{16}$ inches.	+ 0.0004	- 0.0004	0.0008

Light Milling.—The field of operation for the milling machine has materially widened within a comparatively short time. Improvements in design and increased skill in the manipulation and care of tools are the two factors mainly responsible for its success. It has largely displaced the planer and shaper; it produces highly finished and accurate surfaces, and makes substantial savings in hand labour; it is designed with a view to adaptability in making short runs. In many cases it is found profitable to set up a machine for a run on ten or a dozen parts. Stability and quickness of manipulation are the chief characteristics of the modern milling machine as compared with those of older design. Wherever it can be adopted it usually scores over the planer or shaper as a labour saver, for the reason that in nearly all cases it can be served by unskilled attendants who can keep from two to four, and even six, machines in operation; whilst with the planer or shaper it is not very often the case that one operator can advantageously attend more than two machines.

One of the simplest and most effective methods is neglected to an astonishing degree, even by those who have large milling equipments; that is, taking a roughing and then a finishing cut, not hurrying the machine too much on the finishing cut. The milling machine is too often regarded as a means for merely

removing metal instead of as an instrument for producing accurately finished surfaces where little or no hand work is necessary. In many cases five minutes more on the machine would make a saving of ten minutes fitters' work, files would be saved and greater uniformity secured. It should not be forgotten that the wrongly designed, badly made, rarely sharpened milling cutter largely assists in keeping the milling machine in disrepute, when otherwise it might rise to the rank of a valued ally.

The adoption and profitable use of the milling machine is often impossible on account of the lack of exact knowledge as to the composition of cast-iron, and for want of proper treatment of castings for the removal of sand and scale. A large percentage of castings which are used could be soft if cupola mixtures were properly regulated. This would allow fast speeds and feeds for the milling cutters, without breakages or too much wear, instead of the comparatively slow planer cuts where castings are hard. There is little comprehension of how much the want of laboratory work stands in the way of the adoption of the milling machine. The pickling of castings alone makes it possible to increase the product of milling and planing machines, saves cutting tools, and consequently makes good work easier. Milling in many cases easily reduces costs 50 per cent. when compared with planing.

There are three essentials to economical results in milling :—

- (1) Up-to-date machines.
- (2) A not too niggardly supply of good milling cutters and tools.
- (3) Good tool-makers who know how to keep machines and tools in the best condition.

The following may be mentioned as a few of the most interesting milling operations which are not as widely adopted as they will be when their advantages are better understood.

The Vertical Milling Machine or, what amounts to the same, the Horizontal Machine, performing operations with the end mill, produces in many cases very satisfactory results both in speed and accuracy. There is a good variety of excellent machines, both of the vertical and horizontal type, now on the market for this class of work.

A most valuable machine, comparatively little used, is a combined vertical and horizontal machine with long table. For taking roughing cuts with fast feeds, inserted tooth cutters with Mushet blades give good results.

The Circular mill, either on simple or complicated forms, effects great savings, and one attendant can keep six machines in operation. It can also be run in connection with other milling machines, reducing costs in many cases 50 per cent. and 75 per cent., and competing with the best turning machines in accuracy as well as in costs of operation, Plate 1. On castings with a chemical composition suitable for change gears, pulleys, hand wheels, and similar parts to those shown in Fig. 6, circular milling is accomplished with the cutter running at a surface speed of over 50 feet per minute and work feeding 4 inches per minute on the periphery.

Heavy Milling.—The anticipated annihilation of the Planing Machine is not yet a reality, as some milling machine enthusiasts have from time to time predicted, and for heavy work the honours are now fairly well divided between the miller and the planer. Where rough but comparatively true surfaces only are required, what is known as the rotary planer turns out remarkably cheap work. It has the advantages of requiring little attendance and of turning out work two or three times faster than the planer; the cutters used are mostly of the inserted teeth pattern with self-hardening steel. Another profitable use to which the heavy mill has been put is in "roughing out" work, particularly on castings which are to be accurately finished afterwards on the planing machine. The author has known cases where this operation effected a saving of 75 per cent. in time. The rate of feed which can be commonly made use of varies from 2 inches to 6 inches per minute. One particular case which he has in mind as an illustration of profitable milling is that of roughing out lathe-beds. The cutter is perhaps 23 inches wide, and removes from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch of metal with a feed of about $3\frac{1}{2}$ inches per minute, the peripheral speed of cutter being about 45 inches per minute. Lathe-beds are roughed out in this manner at about a fourth or a third of the labour cost

when done on the planer, Fig. 7, Plate 2. In this case the beds are afterwards allowed to stand about two weeks to "season," then a light finishing-cut is taken by the planer, and then they are ready for being scraped. The regularity of cut varies of course with the material, whether it is hard or soft, accurate to size or not, or whether sand has been thoroughly removed from castings. Pickling and compositions of castings of course largely affect the possibilities of heavy as well as of light milling. Splendid results of heavy milling are attained by taking roughing and finishing cuts; surfaces of complicated shape up to 20 inches to 24 inches in width are finished outright on the heavy mill, and are then ready for being scraped. Good gains are made over the planer, in some cases even when on short runs. Cutters are sometimes expensive, even costing £25 and £30, often more, but they are good investments as labour-saving tools. The variety of heavy milling machines now on the market is large, so that good selections can be made for all classes of work.

The adoption of the milling machine is not as extensive as it should be, for the reason that often an apparently formidable investment in cutters is necessary. The milling cutter, however, should be looked upon as any other labour-saving tool. It is not so much a question of how much does it cost, as how much does it save, or how much does the article cost which it turns out.

Planing.—The Planer is a much neglected, long-suffering machine, too often found in such dismal, unfavourable quarters that any attempts to improve either the accuracy or quantity of its product would be of little avail. Daylight and good foundations are commonly wanting in the planer department. Most of the improvements connected with the latter-day practice in planer work are seemingly of little importance, but when added together give a substantial total. They can be briefly enumerated.

A quick return stroke is a feature of all up-to-date planers. This is now rarely less than three to one on machines up to 36 inches capacity, and on smaller sizes four to one is common. Where castings are of good quality and the machine is well designed,

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cutting speeds are maintained of from 25 to 30 feet per minute and even up to 40 feet. Where castings are hard, either through design or ignorance, cutting speeds are necessarily lower. There is an immense amount of planing being done at cutting speeds of from 12 to 18 feet per minute which could be done at the rate of from 20 to 25 feet. All planers of 24 inches capacity and upwards should have two heads and larger sizes, three and four. One of the most highly productive planers the author has seen is a 24-inch machine with four heads and a 24-feet bed; it runs a close race with fast milling machines. It is claimed by a well-known machine-tool manufacturer that good savings are effected by the use of variable speed countershafts with which all their planers are fitted, as they can vary the speed of planers at will in accordance with the quality of material, length of stroke, and depth of cut. The author has seen in but one shop a simple device which saved considerable time; it was a brake in the form of a wooden shoe, which pressed on the fast running countershaft pulleys when the belt was thrown off. All the best types of planers are quickly manipulated by an easy working lever by which the machine can be started, stopped, or reversed. Few planer hands realize the time saved by good holding-devices, clamps, dogs, wedges, and quickly adjustable blocking pieces. Where any quantity of parts are to be planed, properly arranged jigs are of as much importance as for the milling machine. Block templates which clamp to planer bed are extremely useful devices for complicated shapes. An illustration of this gauge as used for lathe-beds is shown in Fig. 8, Plate 2.

Electric chucks for thin parts are the latest and most useful innovations. An exceedingly simple and useful little tool is the block gauge. It is cheap, lessens the chances of mistakes being made in measuring, and saves time in setting tools. The practice of periodically levelling the planer beds is astonishingly neglected, yet it is absolutely essential for good work.

The magnetic clutch driving mechanism, Fig. 9, promises to be a most important improvement in planer construction. This consists essentially of two magnetic clutch discs A, which are revolved in opposite directions and at speeds corresponding with the forward

and return stroke of the planer table. The current is automatically switched by dogs on the table to either one clutch disc or the other. They alternately attract and grip discs B, shown in section, which are connected by a sleeve, and which slides endwise on the driving shaft of the planer to which they are keyed. Reference to drawing will show that these discs are so made that fly-wheel effect is reduced to a minimum. This arrangement makes it possible to reverse a planer table with a motive power very little in excess of that required to drive it. With the ordinary belt-drive the amount of power consumed at the moment of reversal is from 75 to 100 per

FIG. 9. *Magnetic Clutch applied to driving an 84-inch Planer.* (Riddell.)

cent. in excess of that necessary to move the table when under cut, whereas with the Riddell electric clutch drive on a 72-inch planer the increase in power is only about 15 per cent. The mechanism is practically noiseless and reverses more accurately to a line than with a belt drive.

Grinding.—Grinding is probably the most ancient of all mechanical operations. As an operation by which accurate surfaces are cheaply produced, it is, however, a development of the last few years. The Plain and Universal Grinding Machine, in its latest form, is now a manufacturing machine as much as the lathe or

milling machine ; its use is no longer restricted to the "tool room" or for finishing hardened parts. It is conceded by those who use the grinder extensively and are expert in manipulating it, that it is the cheapest as well as the best machine for producing, mechanically, correct cylindrical surfaces where good work and interchangeability are desirable. This is true respecting soft as well as hard steel, cast-iron or bronze. The turner and the file cannot compete with the grinding machine and the limit gauge. The author believes it is safe to state that (excepting in heavy work) the grinding machine and the turret lathe will in the near future absorb 50 per cent. of the lathe work now performed by skilled turners. Parts can be roughed out on lathes by unskilled attendants, each running from two to three lathes, allowing from 0.006 to 0.008 inch on parts up to 4 inches diameter for finishing, and then accurately finished almost to the nicety of a gauge on grinding machines, one operator keeping two of these machines at work. For good cylindrical grinding, machines of extreme stability are necessary to resist vibration ; they must be of the very best workmanship and capable of handling a large stream of water, by which the work is kept at an even temperature. Accurate limit-gauges are of great assistance as measuring instruments in the grinding department, for they can be more readily used in many instances than micrometers or vernier calipers.

Surface grinders, where accuracy is necessary, are not much used except where comparatively small areas are in question. Where accuracy is not of much importance, they will be found effective for a great deal of work, and more economical than hand polishing. One man can keep from four to five machines in operation. They are best when arranged with exhaust pipes for removing dust, as the present machines are not constructed to be used with a stream of water. As for planers, electric chucks are again "the latest" and most useful accessories to surface grinders.

Where accuracy is required on flat surfaces, except those of small dimensions, nothing in the way of a machine operation has been devised to take the place of hand scraping, or, where hardened surfaces are in question, hand lapping.

The most striking example of advanced practice in cylindrical grinding is that of work recently done on a machine capable of finishing parts up to 18 inches in diameter and up to 8 feet long, carrying a grinding wheel 24 inches in diameter with a 2-inch face. It is recorded that a 4-inch shaft 3 feet long can be finished on this machine in six minutes. The shaft is first rough turned with a 12-per-inch feed, and left 0.01 inch above size at the bottom of the tool marks. Parts up to 7 inches diameter are rapidly finished, the limit of variation being 0.001 inch. Knowing that results like the above have been accomplished, few manufacturers can neglect to consider seriously grinding as an important method by which costs may be reduced and quality of work improved.

FIG. 10.—*Adjustable Reamer.*

Chucking.—Chucking is an American term used to designate that class of work in which the part is held in a face plate chuck in either a vertical or horizontal turret machine, and is operated upon by a series of tools which finish a cylindrical hole. Comparatively true cylindrical surface, cheapness of operation, and interchangeability are virtues sufficient to recommend a proper system of chucking to enterprising manufacturers. Its adoption in accordance with the best practice need not be restricted to those who make only in large quantities or turn out very close work. Whether there is one piece or 500 to be “chucked,” whether the “fit” has 1-64th inch or 2-1000th inch play, the system is profitable. In the same manner that milling is specialised to secure accurate flat surfaces at a low cost, so is “chucking” specialised for the purpose of securing accurate cylindrical holes with comparatively unskilled machine attendants. “Chucking” machines, with proper outfits of boring tools, are as

FIG. 13.—Tools used in Vertical and Horizontal Chucking Machines, Plate 3.

Chucking and Boring Tools.

(See FIG. 13.)

For Vertical Chucking Machines with 4 Holes in Turret.

1. For chucking from the blank :—

a. c. i. j., or b. e. i. j., or a. b. e. k., or a. c. k. l., or b. e. k. l.

2. For chucking cast holes :—

*d. f. i. j., or d. e. i. j., or d. f. k. l., or d. e. k. l.***For Vertical Chucking Machines with 5 holes in Turret.**

1. For chucking from the blank :—

a. b. e. i. j., or a. c. i. j. l., or a. b. e. k. l., or b. e. i. j. l.

2. For chucking cast holes :—

*d. f. i. j. l., or d. e. i. j. l., or d. f. k. l., or d. e. k. l.***For Horizontal Chucking Machines with 4 holes in Turret.**

1. For chucking from the blank :—

b. e. g. h., or c. g. h. l., Machines with rest.

2. For chucking cast holes :—

*d. e. g. h., or d. f. g. h., Machines without rest.**e. g. h. l., Machines with rest.***For Horizontal Chucking Machines with 6 holes in Turret.**

1. For chucking from the blank :—

a. b. e. g. h. l., or a. c. g. h. l.

2. For chucking cast holes :—

d. e. g. h. l., or d. f. g. h. l.

much a part of a modern engineering equipment as are milling machines with their outfit of cutters and arbors. One prominent English manufacturer told the author that the introduction into his works of a chucking department revealed the fact that he had never before made holes that could be called round. The best system calls for a series of tools, usually varying in number from 4 to 6 for each diameter, the final operations in most cases being performed by an adjustable reamer which takes out about 0.004 inch, Fig. 10 (page 21), all holes being tested by the inside limit gauge, Fig. 1 (page 12).

For cast-iron, when parts are not too light weight, the vertical machine is best adapted, Fig. 11, Plate 3. One operator can in most cases attend two machines. Other operations, such as facing and turning, are often to advantage combined with chucking work. For steel work where oil is used and light parts or parts with a long hole, the horizontal machine is better adapted, Fig. 12. As in many other operations which are specialised, comparatively unskilled labour can be employed, but the highest skill is required to supervise and keep machines and tools in proper working condition. The tools ordinarily used consist of under-size twist-drills, boring tools, three-lipped chucking drills, four-lipped boring tools, roughing reamers, finishing reamers (adjustable) and facing tools; a part or all of these may be used, in accordance with the work and available machines, Fig. 13 (pages 22 and 23). The best shop organisation demands a department equipped with chucking machine, tools and gauges, to which every part within the scope of the department should be sent. The results are a reduction in the costs of boring, a higher degree of accuracy, and the attainment of interchangeability.

With a proper outfit, holes up to 3 inches diameter can be easily finished by comparatively unskilled workmen, to within from 0.0005 inch to 0.0010 inch of standard size.

Turning.—The lathe has been and will continue to be one of the most important machines in the equipment of an engineering establishment. The principal improvements in design to be noted in the modern lathe are quickness, ease of manipulation, and rigidity.

There is also a growing appreciation of the value of a lathe possessing the best quality of workmanship, even when used for comparatively rough work. Referring particularly to light lathe work, recent developments in other machine tools have taken away from the lathe a large amount of work for which it was formerly thought that this machine was indispensable. Except in special cases, the boring of holes is now largely relegated to the chucking department. The accurate finishing of plain parts, and, in many cases, of parts of considerable complication, is done in the grinding department. Where repetition, even of small quantities, is possible, parts up to 2 feet long and 2 inches diameter, are sent to the turret machine department. It is now recognised that it is poor economy to make a polishing bench of a fine screw-cutting engine lathe. It seems pretty well assured that in the future the lathe will be largely used as a roughing-out machine. Following this line, a great deal of work can be done by unskilled labour, one man keeping two or three lathes in operation. Stiff lathes, fitted with double tool post and with pump and pans, so that the work can be flooded with soapy water, are found to be as a means of reducing parts much cheaper than smith work. For instance, soft machinery steel spindles can be reduced $3\frac{1}{2}$ inches in diameter at one operation by means of two cutting tools, which would have a feed of about 0.007 inch per revolution. Table 2 (page 26) is interesting as showing possibilities in this direction.

It is in many cases one man working three pieces in the lathe department *versus* three men working on one piece in the forge shop. All the modern innovations which are either supplanting or improving lathe work, such as chucking, grinding, screw-machine work, polishing and roughing, are accompanied by a reduction in costs of manufacturing, the employment of less skilful machine attendants, an increase in the number of machines that one man can attend and better work. It should be mentioned that the various processes of treating turning tools may revolutionise lathe construction. Speeds, feeds, and strains must all be recalculated. Cutting speeds from 80 feet to 120 feet per minute are now quite common. Where the lathe is used for roughing out, from 0.006 to 0.008 is sufficient

TABLE 2.—*Tool Speeds for Cutting Soft Steel, etc.**

No.	Material.	Diam. before turning.	Diam. after turning.	Depth of cut.	Revs. per minute.	Cutting speed, feet per minute.		Feed per minute.	Feed per rev.
						At outer circum- ference.	At bottom of cut.		
1	{Soft machinery steel.	inches. $5\frac{1}{4}$	inches. $1\frac{3}{4}$	inch. $1\frac{3}{4}$	27	feet. 37·1	feet. 12·25	$\frac{3}{16}$	0·007
2	" "	$1\frac{9}{16}$	$\frac{9}{16}$	$\frac{1}{2}$	297	121	43·5	$1\frac{1}{4}$	0·006
3	Tool steel.	$3\frac{1}{4}$	$2\frac{3}{4}$	$\frac{1}{2}$	30	29·4	21·5	$\frac{3}{16}$	0·010
4	" "	$2\frac{1}{2}$	$1\frac{5}{8}$	$\frac{2}{16}$	45	29·4	20·25	$\frac{7}{16}$	0·010
No.	Material.	Original Diam.	Depth of cut.	Revs. per minute.	Cutting speed, feet per minute.	Feed per minute.	Feed per rev.		
5	Cast iron.	inches. $4\frac{1}{2}$	inch. $\frac{1}{8}$	37	feet. 41	$3\frac{1}{8}$	0·085	Roughing cut.	
6	" "	$4\frac{1}{4}$	$\frac{1}{32}$	100	111	$3\frac{1}{2}$	0·035	Finishing cut.	
7	{Soft machinery steel.	$4\frac{3}{4}$	$\frac{3}{32}$	23	28·5	$1\frac{1}{8}$	0·081	Roughing cut.	
8	" "	$4\frac{3}{4}$	$\frac{1}{32}$	63	78	$2\frac{1}{2}$	0·04	Finishing cut.	

* "American Machinist," 29th September 1900.

to leave for finish grinding. Roughing limit gauges are useful for this work.

A summary of the latest practice in connection with lathe-work would include the following:—

- (1) Chucking or boring transferred to the turret chucking machine.
- (2) Finishing transferred to the grinder.
- (3) Repetition work (even for a dozen pieces) transferred to the screw machine.
- (4) Polishing transferred to a separate department.
- (5) A great deal of forge work transferred to the “roughing out” lathe.
- (6) Castings like hand wheels, flanged or grooved pulleys, bevel wheels, etc., transferred to the circular milling machine.
- (7) A great increase in cutting speeds.

Polishing.—The establishment of a polishing department is apparently a custom more honoured in the breach than in the observance by most engineering works, even where this work could be specialised to good advantage. A well-arranged polishing department is one of the best examples of simple organisation that could be selected, for the reasons that its equipment is cheap, costs of operations are reduced, and quality is improved. This work only needs to be classified. Let any manager walk about his shops and observe polishing operations going on here and there. It is most probable that they are being done by skilled turners or fitters on expensive machines, when the work could be done by a comparatively unskilled hand with an inexpensive apparatus. A gain would also be realised in time of operation and quality of finish, if all polishing was done by men trained by constant practice. The downfall of many an accurate engine-lathe could probably be traced to surplus charges of emery, administered by the combined turner and polisher. A comparatively cheap and simple apparatus for removing dust from the polishing department would probably have the effect of inducing better grade men to become interested in this class of work, which is

important both in respect to the quality and appearance of finished parts.

Gear Cutting.—The advocate of cast gears has few arguments as far as costs are concerned when confronted by the results of modern automatic gear cutters. Every form of gear cutting can now be done on automatic machines. One operator can keep from three to five automatic spur-machines and from three to ten automatic bevel-gear cutters at work. The latest practice in gear cutting is really confined to the following latest designed machines; fully automatic spur-gear cutters, with rapid return stroke to cutter spindle carriage and accurate dividing mechanism, which in some cases cut up to five teeth at once; the fully automatic bevel-gear planing machine and the fully automatic bevel-gear milling machine which develop theoretically correct teeth (one operator attending up to ten machines); the spur-gear shaper and the modern rapid cutting worm-gear cutter, in which the taper hob is used. Accurate cutters are comparatively cheap; means for testing the accuracy of finished gears are simple and cheap, but are not often seen in modern shops. Even in large shops this department is not sufficiently specialised. Gear cutting is an art, and calls for special study if accuracy and cheapness are to be combined.

Turret Machines.—The leading characteristics of the modern screw-machine or turret lathe is its adaptability for comparatively short runs. Largely on account of this feature, it is rapidly encroaching on the field formerly held by the lathe. The lack of skill and training in properly maintaining and using turret machine tools is the greatest obstacle to its more extensive use in all classes of manufacturing, both of the automatic and hand type. It is pre-eminently the machine demanding the brains and skill of the high grade tool-maker, a functionary wanting in 80 per cent. of our engineering establishments. A large amount of lathe work now done by skilled men is sure to be shortly done on the turret machine by comparatively unskilled attendants who will eventually beat the trained turner, in respect to output, accuracy and uniformity.

This applies to work like studs, bolts, cast-iron and brass parts. Where a good tool-maker is available, it pays in many cases to set up the turret machine for, say, twenty parts when operated by hand and for several hundreds when the machine is fully automatic. The author is aware that in many cases the turret machine has been and is a failure in competition with hand labour on simple machines, but he is sure that this is often where a low standard of workmanship exists and where interchangeability is practically unknown. In brass goods, especially, the demand for cheap work is rampant and, of course, the supply is not wanting. The introduction of the best class of turret machinery would assist to put on the market a superior article at very little if any advance over the rubbish now sold, where the loss of even the simplest part necessitates the purchase of an entire apparatus, so little is interchangeability practised. The great advantage in the modern turret machine lies in the possibility of using operators who, in a few weeks, can turn out accurate, uniform work in competition with lathe hands who have served several years apprenticeship. The common disadvantage to the modern turret machine is the lack of tool makers, who are necessary for keeping machines in good working condition, and the almost universal want of understanding on the part of employers of the value of such men, no matter what wages they may command. For this reason turret machines, which are an unqualified success in one shop, are often condemned as useless in another.

The variety of turret machines, both hand and automatic, is large; simply to enumerate them would require too much space. Different types have been dealt with in the recent Paper by Mr. Ashford.* The subject is an important one, and in spite of that which is a bugbear to many manufacturers—investment in tools—these machines are slowly but surely encroaching on the field now so largely held by the plain lathes operated by skilled turners using, in most cases, simple tools.

The Vertical Boring Mill.—The loss of time and the inconvenience suffered in many shops by the want of a vertical boring mill is

* Proceedings 1901, page 259.

considerable. In many respects this machine is nothing more than a surfacing and boring lathe "stood on end." When fitted with a turret slide it forms a machine whose virtues are too little known. Like its horizontal prototype, it suffers from the lack of care on the part of intelligent tool makers. With properly arranged tools its field of usefulness is very large.

The small type of machine with 27-inch or 30-inch face plate and turret slide is especially adapted for chucking operations, for the boring and accurate finishing of holes to limit gauge, and also for facing operations. Work is rapidly chucked, the successive tools are quickly brought into play, and one man can, in most cases, attend two machines. For general work, the vertical mill has the advantages of extreme rigidity and the ease with which work is set and held in place. With these features heavy cuts are possible, and inaccuracies do not occur on account of "overhang." It is practically impossible to construct a horizontal machine with spindle surfaces and face-plate rigidity that can compare with the vertical mill. It is now made with nearly every feature common to the lathe where a *tailstock* is not required; it is adaptable for boring, facing and turning, and is provided with full sets of change gears for thread cutting. It is not infrequently the case that one vertical boring mill does the work of two facing lathes, whilst giving more accurate work and effecting a considerable saving in shop space.

Drilling and Jig Work.—Drilling is prehistoric as a mechanical operation, and still flourishes in its primitive glory in a great many manufacturing establishments, as far as equipment of machines and tools is concerned. As previously mentioned, a large manufacturer recently told the author that on going into the matter of adopting limit gauges and a modern set of chucking or boring tools, he found that a round hole was not made in his works. Like many others, he had never thought that "drilling" was a class of work which should be specialised as much as milling, turning or any other operation. In many shops where it would be found profitable to overhaul the drilling department, one would find (1st), the cheapest machines that can be bought having power enough to revolve the spindle when

boring the maximum hole of their respective capacities ; (2nd), the cheapest drilling tools that can be purchased (or forged) ; (3rd), a total absence of jigs or sets of tools, even when parts are made in quantities or accuracy is desirable. Strictly speaking, to do work better than "good enough" is wasteful, but it is surprising to what an extent the nominally "good enough" principle alone rules, even in the many shops where the best class of drilling would be cheapest, all things considered. The many advocates of the cheap drilling machine would do well to note that it is economy to do better work in drilling and boring than is commonly supposed ; that cheap rough work can be done on a good drilling machine, and that good cheap work cannot be done on a cheap drilling machine.

Weight and price alone considered, there is no machine tool on the market to compare with what can be purchased in the shape of a drilling machine ; this is the temptation to continue in the old way. Those who would work on modern lines must, however, consider where interchangeability and good work are called for ; the far-reaching economy of having holes truly cylindrical and accurate to size ; that such holes cannot be made on cheap, low-priced drilling machines, with primitive drilling tools ; that it pays many times to take work away from the drilling machines entirely, and to finish holes on the modern chucking machine ; that satisfactory results from jigs and fixtures, unaided by the accurate drilling machine, are out of the question : that with proper jigs and fixtures the highest class of work can be done on the good drill by the lowest paid labour, and that this means savings in the fitters' work. A good deal of work formerly thought to be only possible on the horizontal boring mill is now being jigged on the upright drill with profit, even for small quantities—drilling, reaming, facing and tapping.

The usefulness of the drilling machine is greatly extended by properly designed jigs, Plate 4, and it is in connection with such tools that the greatest benefits of the accurate drilling machine will be realised. Many jigs, however, are the merest make-shifts and are seemingly designed as rough laying-out boxes or plates, not as tools for turning out accurately finished work. What are fully as important as the jig itself, but wanting in the majority of cases,

are proper boring and finishing tools. It is probably true that, except by the sewing machine, small-arms, ordnance and ammunition makers, the economy of the drill-jig is, with but comparatively few exceptions, little understood; perhaps this accounts somewhat for the continued prosperity of the makers of cheap drilling machines. There are surprising results awaiting those who have not looked into the details of their drilling work.

Portable Machines.—Like many other mechanical operations, portable machine work is not new, but it has recently been extensively developed in large engine works and in the manufacture of electric motors and generators. It is of course mainly applicable to heavy work, particularly of bulky or weighty parts where the surfaces to be machined are small, compared with the part itself.

For a great deal of this work it is found cheaper to carry the machine to the work rather than carry the work to the machine. Where it is most completely carried out, floor plates of large area are made use of. The General Electric Company at Schenectady have one plate 175 feet long by 20 feet 6 inches wide, Fig. 15. This is made up of sectional plates 8 feet 4 inches wide by 20 feet 6 inches long, Fig. 16 (page 34). The depth to the bottom of the ribs is 10 inches. In new works now being erected by the Allis Engine Company, floor plates 250 feet long are being made.

Nearly all modern portable tools for heavy work are driven with separate electric motor. They consist mainly of drilling, milling, slotting, and planing machines. All are arranged with eye-bolts so that they can be readily lifted by overhead travellers. Many of the machines are of far less weight than the parts on which they operate. The principal advantages connected with their use are:—

- (1) The ease and facility with which they are transported, compared with the parts on which they are operating.
- (2) A less expensive machine is possible than would be required in case it was big enough to embrace the parts.

FIG. 15.

End' of one section of Floor Plate 175 feet $\times$ 20 feet 6 inches.

(3) Tools are rarely idle, as they can be operating upon one piece while another is being set, and can be brought at once to the work.

(4) Several machines, like boring, slotting, milling, &c., can be operating on one piece at the same time.

FIG. 16.—*Foundation of Floor Plate.*

(5) Parts do not require resetting for different operations, often more expensive than the machining itself.

Small Tools.—The small tools referred to are those which are indispensable to the successful working of ordinary machine tools; for example, cutters, reamers, taps, dies, arbors, boring tools, and gauges. It is remarkable how little attention these important

articles receive, even from those who are users of the best class of machinery. Many a valuable labour-saving machine tool is an utter failure, or only half a success, largely on account of ignorance in selection or care of the tools. Throughout the world there is a scarcity of tool-makers who understand these little articles. The labour-saving machine is nothing without them, yet scores of manufacturers have sunk capital in badly designed, inaccurately made, uncared for, never inspected small tools. The subject is a big one, and space allows but brief mention of the questions that the modern manufacturer should put to himself. Are the small tools of the right design, so that cuts are easily taken without too severely exerting either operator or machine? Are they well made and within reasonable limits of accuracy? Without accurate tools it is impossible to employ low-priced wages for high-grade work. Are they made of the best material, having in view wearing qualities on a particular class of work? Are they kept in the best working condition, sharp and in good repair? Output and quality will fall off if they are not. Are they "scrapped" when past their useful age? Are they cared for in well-arranged tool stores, or does each workman foster his own "kit," add to, take from, sharpen, repair and inspect? It is safe to say that many shops are stocked with ten times as many tools as are necessary, simply for the want of proper stores. One large shop recently found that two tons of tool-steel could be dispensed with by arranging tool stores, instead of allowing each man to retain his own complete outfit. Better cut down the quantity and improve the quality. Are they ever inspected? How many taps or reamers cut to size? How many arbors run true? How many teeth in milling cutters cut? How many gauges guaranteed to 1-1000 of an inch when new (note the degree of accuracy) are no longer accurate to 1-100 of an inch, are neither round, square nor oval? How many "home-made" tools are nearly as good as those that reliable makers can supply, or as cheap? Last, but not least, how many establishments have a good head tool-maker who is familiar with the latest practice, knows the best forms of tools for different classes of work, and appreciates the value of keeping tools in the best working conditions? How many take the trouble to

train such men, give them the opportunity of studying what others are doing, or pay them sufficiently to induce them to put their brains and intelligence into this work which demands thoughtful application and the highest mechanical skill? Modern manufacturing cannot be carried on unaided by well-cared-for cutting tools of the best quality. The higher the output per machine and man, the greater the importance of the tool question.

Tool-Room.—By the term “tool-room” is meant an equipment of the best grade of machine tools and small tools necessary for the maintenance and supply of the special tools and fixtures, which are used for manufacturing purposes. In an old-fashioned plant this equipment might mainly consist of a forge and a grind-stone. In a highly organised plant making an extensive use of labour-saving machines, fixtures, and jigs, it must consist of the most accurate machines, such as the universal mill, engine lathes, shapers, boring machines, drills and grinding machines, and also of accurate gauges, the equipment varying in size and variety in accordance with the main plant.

It seems curious, but it is a fact, that many manufacturers do not realise that complicated labour-saving machines and tools, constituting a highly productive outfit, rapidly degenerate unless the means are at hand for constantly regenerating. They will invest in expensive machines which plain figures show are profitable, but will leave works, managers, and foreman nearly destitute as to the means of keeping up the plant. The object of fast working machines and accurate tools is to save hand-labour. Labour-saving outfits fail in a measure to replace hand-labour if accuracy is lost sight of. Cutting tools will wear, and whether they are adjustable to gauge or of fixed dimensions, the allowable limits for wear are really very small, if we expect labour-saving tools to compete with the skilled worker. The need of constant renewal is obvious. To attempt this renewal unaided by the very best appliances is uneconomical.

Many manufacturers attempt tool-room practice in a groping sort of fashion, a lathe here and there, a milling machine occasionally made use of when not employed in regular work, and a standard set

of gauges purchased in an unguarded moment, and carefully kept in the office under lock and key. A few who have fairly good outfits make the mistake of turning their tool-rooms into manufacturing establishments of those articles which could be purchased more cheaply and better from a trustworthy maker. Those who proceed on this plan are liable to be constantly behind in respect to the latest design of tools, for the reason that they come so little in contact with those who make a special study of tools and the best ways of producing them.

Others have a vague sense of the need of a tool-room, but do not see that this equipment calls for everything of the best. They try to economise in the purchase of outfit, and must surely therefore only attain indifferent results. None but machines of the highest accuracy should be allowed in the tool-room. The worst offenders of all are those who try to economise the wage account chargeable to tool-room. The very best skill and intelligence obtainable should be employed in this department, for on it rests a good part of the responsibility of producing a large or small output. Whether the plant is highly productive or not depends largely upon the head tool-maker. To expect brains and intelligence of a high order to seek employment where the wages are low is contrary to all laws of supply and demand. American manufacturers, who generally recognise the value of a proper tool-room, commonly pay from 12s. to 16s. per day, and even 20s. per day, for good tool-makers.

Erecting Department.—Probably in no department of mechanical work are the contrasts between old and new methods more striking than in erecting or assembling. In the new method, machining is done accurately to dimensions; in the old, machine and tools are mainly used for removing metal, and reliance is placed on the fitter for proper working fits. In the new, accuracy and interchangeability of dimensions are maintained by a suitable equipment of gauges and the establishment of limits; in the old, there is a variety of sizes depending upon the skill and judgment of individuals. In the new, the time necessary for “setting up” a particular piece of work, or “lots” of work, is reduced 25, 50 per cent., and even more.

below that taken in the old shop. In the new, the number of fitters is strikingly small compared with the abundance of this class of helpers necessary in works running on old lines. The model erecting department, therefore, is one in which fitters' work is reduced to a minimum, and where the least possible amount of time is occupied in assembling. These results are, of course, only possible when the best methods of machining are practised, when jigs and fixtures are used as much as possible, when a proper equipment of gauges is installed and a system of inspection is amplified.

Testing and Analysing Material.—In view of the fast machine operations, the increasing demand for accuracy and the exacting requirements in respect to material under which the engineer often has to work, it is wonderful how little the ordinary manufacturer really knows about the structure, composition, and capabilities of the material which he is continually buying, manipulating, and selling. A testing machine here and there (crude enough as a rule), a few laboratories connected with schools and scientific public institutions; the rest is guess-work. A change of foundry foreman, or the transfer of patronage to another steel maker, often demoralises a whole establishment, results in the ruin of expensive machines and tools, and in the scrapping of costly finished product.

The advantages of possessing a well-equipped laboratory and testing department are many and far-reaching compared with the sole disadvantage—expense, and they bring quick returns for a small outlay. In the first place, raw material, pig-iron, scrap, coke, steel, copper, brass, &c., should be bought to specification. The result would be emancipation from the slavery of "brands." This is in itself a considerable advantage to the buyer. A control of cupola mixtures can also be undertaken which will give definite results in castings. Steel, iron, and other materials can be selected independently of the recommendations of the maker, who too often answers a complaint with the assurance that more expensive material must be purchased, when perhaps cheaper would be better. Not alone in the purchase of material, but in the manipulation as well, is the analysing and testing engineer of value. Castings must be,

properly treated, and be of the right mixtures to allow rapid and accurate machining. Recently a case came under the author's observation where the product of a milling machine was increased 30 per cent., simply by improvement in the quality of material. Many concerns are using *hard* material which is necessary for certain parts but uncalled for in other cases, because they have no definite knowledge to enable them to vary cupola mixtures. If they had, they would increase the speeds of machining in a large percentage of their work. Material should be studied with a view to selecting that which is most suitable for the purpose, bearing in mind its suitability for being rapidly machined. This cannot be accomplished with the haphazard methods commonly employed. The establishment of laboratories is confidently put forward as a suggestion worth the serious consideration of mechanical engineers. It will pay, in nearly all cases, for those employing 1,500 hands, in a majority of cases for those employing 1,000, and in some where under 1,000 are employed.

Where the size of a shop does not warrant the expenditure necessary to support its own department, several manufacturers can easily combine and contribute to the support of a fully equipped laboratory. Where the last course only is feasible, petty jealousies and nonsensical isolation, which are so prevalent amongst manufacturers, will probably stand in the way for some time to come. There is, however, no practical reason why every mechanical engineering establishment in the United Kingdom should not have a testing institution at its command which could be constantly made use of. The realisation of this state of affairs would be of incalculable benefit to the industries and commerce of Great Britain.

The following Table 3 of chemical specifications is one suitable for a large variety of light machinery castings which can be rapidly machined, are close grained, have good wearing qualities, and take a good finish.

Shop Fittings.—Good fittings play a not unimportant part in shop economics. They are too often looked upon as articles of

TABLE 3.—*Chemical Composition of Light Castings (Iron).*

	A. Mixture for thin castings under $\frac{5}{8}$ -inch thickness.		B. Mixture for castings of an average thickness of $\frac{3}{8}$ inch.		C. Mixture for castings $1\frac{1}{2}$ to 2 inches thick.	
	Limits allowed.	Analyses desired.	Limits allowed.	Analyses desired.	Limits allowed.	Analyses desired.
Silicon. . . .	2.45 to 2.65	2.55	2.30 to 2.50	2.40	2.15 to 2.35	2.25
Sulphur . . .	0.07 to 0.10	0.08	0.07 to 0.10	0.09	0.08 to 0.12	0.10
Manganese . .	0.30 to 0.70	0.40	0.30 to 0.70	0.40	0.30 to 0.70	0.40
Phosphorus . .	0.70 to 1.00	0.90	0.50 to 0.90	0.70	0.40 to 0.80	0.60
Combined Carbon	0.30 to 0.50	0.40	0.30 to 0.50	0.40	0.30 to 0.50	0.40
Graphite . . .	2.90 to 3.20	3.10	2.90 to 3.20	3.10	2.90 to 3.20	3.00

For very heavy castings a mixture containing about 2.00 Silicon should be used,
other elements same as mixture C.

luxury, only to be made use of by faddists instead of as possessing a practical value as means of saving time and maintaining order and cleanliness. Among the more important are included : well-designed work benches, Fig. 18, Plate 5 ; shop stands for workmen who are machine attendants ; cans and buckets for waste and rubbish ; properly designed racks for holding parts, Fig. 19 ; carefully arranged receptacles for tools and gauges, Fig. 17 ; and racks for holding rough material. Stores for rough materials, partly finished work and finished product should be most carefully studied. Simple and easy methods of fastening countershafts and main shaft hangers should be devised, Fig. 24, Plate 6. Means of transportation—whether cranes, railways, or trucks—should of course receive special attention. Machine-shop floors deserve far more thought than they usually receive, Fig. 20, Plate 5. Means of heating and ventilating, Fig. 23, Plate 6, are, as well as floors, absolutely essential to the modern shop, for without them it is impossible to properly keep fine machines, tools, and gauges in good condition. Comforts and conveniences for workmen are fast becoming necessities in the modern shop, as they help in attracting and retaining the best and most intelligent workpeople, Figs. 21 and 22.

Organization.—Most shops, even the newest, are in a way organized without much analysis or systematic study of the latest methods. Volumes have been written on shop organization, and there is room for more volumes. Every item, which it is proposed to mention here, is capable of being expanded into a separate treatise. The main items which must receive attention from the modern manufacturer are as follows :—

(1) The adoption of the most economical methods of manufacturing, and machines best adapted to the product, as well as the best forms of small tools and proper gauges.

(2) The specialization of manufacturing operations both in respect to equipment and supervision. This is largely regulated by the quantities that are to be made. Where the quantities are small, different parts must go through the same sets of machines. Where transportation would be costly on account of weight of parts or

the quantities are large, separate parts may command a complete outfit. Care should be taken not to have too many machines or varieties of work under one foreman. Many successful manufacturers state that no foreman should have charge of more than forty to fifty men.

(3) The placing of departments in the best positions relative to each other, so as to facilitate transportation and progress of work.

(4) The possession of shop fittings and structural features best adapted to the product and to the comfort and convenience of the workpeople. How far an investment in this direction will pay cannot always be shown in cold figures, but the recognition of its importance is growing, and several modern manufacturers have installed elaborate arrangements without the slightest claim to philanthropic motives in all that they have done for their employees.

(5) The installation of a system of inspection by which quality of product is kept within desired limits. This is strangely and commonly neglected, but it naturally follows the adoption of modern machining operations which are largely performed by unskilled men, using the best forms of cutting tools and gauges and producing interchangeable work. "Every foreman his own inspector" is no longer workable in the modern shop.

(6) The adoption of methods by which exact costs of product are known and work in progress is constantly under control. "I fear no competition except from those who do not know what their work costs them," said one manufacturer. "I try to make a date of delivery gospel," said another. Needless to mention both the above are rare specimens of shop managers.

(7) The establishment of a system of training and instructing employees. Most manufacturers work on the Micawber principle of waiting for "something to turn up" in the way of skilled employees. This is slipshod, unsatisfactory, and shortsighted. It is the natural concomitant of badly equipped, poorly arranged, comfortless, and low-waged establishments, having no features of equipment or management sufficiently attractive to retain an intelligent, self-respecting workman after he is well trained.

(8) The best selected plant is often but a partial success, and not infrequently a total failure, for the reason that it is put down without sufficient consideration in respect to organization. The author is being repeatedly told by manufacturers that certain machines which he knows are effective labour-savers in constant operation would simply be smashed to pieces if they tried to put them to work. This might occur, chiefly for the reason that their shops are arranged utterly regardless of the fact that it pays to specialise operations, to group machinery according to the nature of the work, putting over each group a competent foreman who thoroughly understands the class of work which he is supposed to supervise. The majority of shops, in their effort to eliminate high-waged employees (always the most profitable), employ too few foremen. They put one man over too great a variety of work and give him too many men to supervise. From forty to fifty men is the ordinary limit for a good foreman. Many shops have one foreman in charge of as many as 150. He must be a combined expert in turning, milling, planing, grinding, etc., do his own tool making, cost keeping, and inspecting, all for 50s. a week. This is an incomprehensible situation, no matter what salary may be paid, demanding an experience and training impossible of attainment in these days of "second splitting" operations performed on highly developed machines. Specialization of operations, as well as of product, is necessary for the most economical manufacturing. When work is classified in accordance with the best practice, namely having its plant arranged with a view to a thorough supervision on the part of foremen, and having an orderly progress of parts, cheaper and better work will be the result, and responsibility can be more easily located in the case of mistakes.

Extensive Application of Modern Methods Possible.—There is a widely spread and erroneous idea, particularly amongst European manufacturers who would emulate American manufacturers, that the latest methods cannot be economically adopted except where work is thoroughly standardized, specialised, and made in large quantities. Advantage of every method which has been mentioned, with the

exception perhaps of jig and fixture work, can be taken where none of the above conditions exists, not even excepting that which practically amounts to interchangeability. One hole is more cheaply bored in a chucking machine than in a lathe. It is more easily made to a limit gauge than when the skill of a workman in setting his calipers has to be trusted. One spindle is more cheaply finished in the grinding machine than in the lathe, quality duly considered, and again is more easily finished to a limit gauge than to calipers, with the employment of less skilful labour. With the quickly adjusted, easily manipulated milling machine, any amount of work can be more cheaply milled than planed, even where only a few pieces are to be worked. Inspection, good equipment of gauges, tool stores, the latest machines and small tools are necessary, whether one piece or 1,000 pieces are in question.

The idea that big quantities and standard work are necessary before modern equipment begins to play an important part in the economics of manufacturing is the delusion of those who have grasped but a small part of the problem.

Apprenticeship Question.—Unquestionably one of the most serious obstructions to the introduction and successful working of new machines and methods is the lack of knowledge and understanding of modern machine methods on the part of workmen. This is not due so much, as is commonly supposed, to the restrictions and regulations of trade unions, as to the ignorance, bad management and want of foresight on the part of the masters. The fact is that men in a great many shops accomplish wonders, considering the opportunities given them to learn and the appliances with which they are expected to work. Within a comparatively short time, methods of manufacturing, machines and tools, have undergone an almost revolutionary change. This change has been so great and rapid, that men who served as apprentices under the old *régime* are ignorant of new methods, and have not the necessary training to manipulate successfully and supervise the most economical working machinery. Many of them are as much at home in a really modern shop as “Alice in Wonderland.” It is not at all surprising that

they shake their heads at strange new machines and doubt the tales of the American "Mad Hatter." It is well to ask the masters who grumble if they themselves are familiar with the latest methods of machine work; if they are familiar with the advantages of the subdivision of labour and departmental work; if they know the value of skilful, intelligent tool-makers, and are familiar with the best machines and appliances. These are items which must be studied by the masters and, side by side, should be considered: how shall they instruct and train men in the proper use and care of machines and tools? In other words, systems of apprenticeship must be inaugurated and maintained which teach men how to work in modern ways. Do not work apprentices on old-fashioned machines with out-of-date tools, letting them take years to learn to perform certain operations which a man from the street with three weeks' practice can do better and quicker on a modern labour-saving tool. Many shops are having endless trouble from trying to work new machines by men trained on the old lines, neither masters nor men comprehending their duties. It is the duty of masters to establish modern systems of apprenticeship arranged in accordance with new methods. It is the duty of men to try to adapt themselves to these new systems. It is wasteful and foolish for all to insist that a man must serve from four to five years before he can become a proficient turner, when we know that in a few weeks a labourer can learn to operate two grinding machines and produce cylindrical surfaces that it is impossible for the most skilful turner to duplicate, either in regard to quality or cheapness. This is not saying that it is unnecessary to train men to become good turners; it is, however, unnecessary to train them to perform many operations which are superseded by new methods of working. The same comparison can be made between the screw machine and the lathe, and the milling machine and the planer. Chuck and jig work supersede boring and drilling. Men must realise that the new ways have come to stay. Masters will wait in vain if they think the technical school can ever take the place of rational training in that best of all schools, the shop itself. Many employers are beginning to realise that there is but one way to get good men, that is, to make them. A modern system

of apprenticeship naturally divides itself into three broad classes:— (1) Training of men who wish to become skilful in special operations like turning, planing, etc. (2) Training of men who wish to become merely machine operators. (3) Training of men who are necessary for supervising and keeping plant in a high state of efficiency. By the old methods, men are largely trained to become skilful in turning out a certain product. By the new methods, the highest skill is employed as supervisor of labour-saving machinery which turns out the product in a practically finished state. This calls for a radical change in the systems of apprenticeship.

Politicians and writers are raving over the technical schools of Germany. Speaking as one who has for years been in contact with the product of the German technical school, the author has no enthusiasm nor admiration for their methods; at least, as far as mechanical progress is concerned. Technical education as taught to-day is useless except to a very small percentage of our mechanical workers. There is an immense amount of talk about scrapping old machinery, buying new plant and planning new shops, whilst the most important factor of all—men—is left to shift for itself. Yet all are asking the question where can I get good men? Train them, is the answer. The means for doing this are in the hands of every manufacturer. In your own shops, on your own machines, with your own instructors, in your own time; neither municipalities nor governments can do it for you. Manufacturers must establish systems of apprenticeship which include workshop experience under educational guidance.

Plate 6 shows three illustrations of shop features which are taken from one of the most recently erected machine-tool establishments. These are given to call to mind features which do not usually receive attention, but which are being more and more recognised by modern manufacturers as economic factors of shop organization.

The Paper is illustrated by Plates 1 to 8 and 8 Figs. in the letterpress; and several examples of machine work were exhibited at the Meeting, Figs. 32 and 33 (page 47), and Plates 7 and 8.

Discussion on 17th January 1902.

The PRESIDENT expressed his belief that the Paper brought forward a large number of points in workshop practice, which demanded the most careful consideration of Mechanical Engineers at the present time. It also brought forward points on which it was quite legitimate to hold more than one opinion, and it therefore gave all the elements for a good discussion. He expressed the thanks of the Institution to the author for the Paper, and for the trouble he had taken in bringing such a large number of samples of work done on the various machines, Figs. 32 and 33, and Plates 7 and 8.

*Samples of Grinding Work exhibited at Meeting.*FIG. 32. *Small parts, full size. (Brown and Sharpe.)*

FIG. 33.

Cylinder of Various Materials. (Landis.)

Mr. ORCUTT drew attention to the large field covered by the title of the Paper, and the difficulty of arranging the matter so as to deal with the many subjects. He had been obliged to cut down the matter, in order to keep it within compass. His aim had been to make the subject as far as possible practical and not too theoretical, and in selecting the items which made up the Paper he was guided, firstly by the importance of factors in the production of good and cheap work; and, secondly, by those things which his own experience showed him, generally speaking, did not receive sufficient attention. Many things had to be omitted, such as systems of rewarding labour, especially the premium system which was now receiving a great deal of attention. There was present at the meeting one of the best exponents of that system, and he hoped Mr. Rowan would give the members the benefit of his ideas on the subject, which was an important and far-reaching one. Cost-keeping, which went with the premium system, trade union troubles, masters' combinations, economics, and social life, were all subjects affecting workshop practice directly or indirectly, but it had been impossible to deal with them. In attempting to cover a large field it had been necessary to make general statements, and general statements were open to misinterpretation, as in many cases they were without explanation or qualifying details, and he asked the members not to forget those facts.

Mr. J. HARTLEY WICKSTEED, Vice-President, pointed out that there was a paragraph in the Paper comparing the output of heavy milling machines with the output of planing machines, in which it was stated that the author had known of cases where the operation of heavy milling effected a saving of 75 per cent. in time. A particular case, which the author gave as an illustration of profitable milling, was that of roughing out lathe-beds. The lathe-bed illustrated in Fig. 7, Plate 2, was one with V's upon it and was a small lathe-bed, although it was a so-called heavy milling machine. If those beds had to be turned out in duplicates, there would be a great saving of attention to the machine in having a milling cutter properly arranged to plane the V's at the proper distance apart. An

ordinary English lathe, however, was not made with V's, but with flats, and he wished to make a little comparison between what could be obtained from a good English planing machine on an English lathe-bed, and what could be obtained in planing flat surfaces by the milling machine. It was possible to plane with a planing machine ten superficial feet per hour with one tool box, and it was not necessary to run the machine more than 22 feet a minute, which enabled lathe-beds of good hard metal to be planed. It was not necessary to make them of soft metal for the purpose of saving the tool. If that was run out, it might be thought that he was allowing for a very coarse feed, but that was not so; he was only allowing for a feed of $\frac{1}{8}$ -inch, which was not coarse in comparison with many of the feeds seen in the work exhibited by the author. He was, however, allowing for cutting both ways on the planing machine, because there was no reason why, when planing a plane surface like a lathe-bed and other things, the driving power, wear and tear, and time in running the machine back, should be wasted with an idle stroke. It was perfectly simple and easy to make the planing machine cut both ways. By doing so, he had found that it was possible to rough over and leave an approximately true surface at the rate of ten superficial feet per hour with one tool-box. On a heavy milling machine, say a lathe-bed with two faces, each six inches wide, a foot of width was planed, although the milling tools might be 20 inches wide, that was to deal with certain seatings on the end parts; the main part of the work was a foot wide. If the milling machine was proceeding with a feed of 3 inches a minute, it would take four minutes to mill a superficial foot, which worked out at 15 superficial feet per hour. As he had said, it was possible to plane with one tool-box 10 superficial feet per hour, but in planing a lathe-bed there would be two tool-boxes on the cross-slide, and therefore the lathe-bed would be planed at the rate of 20 superficial feet per hour.

There was another rather important difference between the principle of milling and planing. A milling tool approached the work across its face, and if it encountered a small amount of work to remove, say one-quarter of an inch, the machine would spring less

F

(Mr. J. Hartley Wicksteed.)

away from the work than it would do if it encountered half an inch or three-quarters of an inch. Where it encountered more work to remove it would spring more, and the surface it would leave would not be approximately true. The planing machine tool cut chiefly on its side; it was cutting along a furrow. The point of the tool was uniformly stressed in an upward direction, but when it came to a deeper part of the furrow it received more pressure laterally and sprang more sideways, but not from the finished surface of the metal. Therefore, after the roughing cut, the work would be more approximately true from a well-formed planing tool or tools than from milling tools. But in proportion as the roughing cut was approximately true, the next cut would be more or less true. If there were sensible irregularities in the roughing cut, there would be microscopic irregularities in the second cut. So much was that the case that, if the roughing cut was not fairly true, it would be necessary to take three cuts before obtaining a true surface. He did not share the view which appeared to be taken by the author in speaking of the planing machine as being superseded by the milling machine. He had taken a case out of the Paper wherein a case could be made out for the planing machine. He exhibited a double cutting tool box, Fig. 34 (page 51), to show how two tools could be conveniently held in any strong planing machine, and cut both ways with an over-run of not more than six inches. But in dealing with heavy work—armour-plates for instance—which had to be planed all over the surface, there were many planing machines in England in which there were two cross-slides facing each other, in each of which there were eleven tools, so that the planing machine had as many cutting edges as the milling machine. A similar arrangement of a large number of tools closely set together was used for planing the side plates of locomotives. There were thousands of tons of plates planed every week for all kinds of purposes, ship-building, boiler-making and bridge-building; those plates came from the plate mills varying at the edges a good half-inch. Some parts of the plates would only just finish to the requisite width, while other parts would have half an inch of stuff to remove. The planing of plate edges was done on a very large scale indeed, and what was called in

the Paper rotary planing machines had been made for the purpose of planing the plate edges. A large number of plates were cramped on a table, and rotary cutters were made to revolve and reduce the stuff off the edges. Heavy milling machines weighing 60 to 70 tons had been also made for edge milling. But the great bulk of the work of planing plate edges today was done by planing and cutting both ways. People had tried the other, but the very people who had had a fancy for the other and had given it a fair trial, when buying

FIG. 34.

Double-cutting Tool Boxes for Planing Machine. (Buckton and Co.)

new machines went back to the planing tool and planing both ways. The reason was not altogether the difference between planing and milling, but partly that in order to make the milling at all economical, it was necessary to have a bunch of plates four or six inches high operated upon simultaneously. To adjust those plates one on top of the other, so as to clean up all the way along, takes longer than doing the plates one at a time, and for that reason nearly all the plates planed were planed one at a time with double cutting tools on planing machines.

MR. JAMES ROWAN thought the first paragraph of the Paper gave a correct statement of the direction in which engineers of this

(Mr. James Rowan.)

country were now tending. There was no denying the fact that machine work was rapidly taking the place of handwork, and although there was practically nothing new brought forward in the Paper, yet there was a very clear indication of the methods which should be adopted by manufacturing engineers. The use of gauges and grinding he looked upon as two of the leading features of the Paper. Limit gauges had not been used until lately to any great extent, but now they were being rapidly adopted, and the use of them could not do otherwise than help to produce good work. Grinding was also being rapidly adopted, and in many factories would prove a valuable addition to the turning lathe. The tool-room was another modern machine method which was rapidly being adopted, and rightly so; testing and analysing of materials by private firms would in the course of time be largely adopted. All these improvements did not come at once; they came slowly but surely. There were many workshops which had adopted quite a number of the modern machine methods mentioned by the author, and these shops were rapidly increasing in number. The author had, in many respects, unequalled experience, and had had a careful training; no one was better acquainted with the subject of modern machine methods than he was, and so long as he confined himself to general statements he excelled. In many instances, however, he had condescended to figures and statements which were surprising. For instance, the author spoke (page 16) of the heavy milling machine having "the advantages of requiring little attendance and of turning out work two or three times faster than the planer;" and later went on to say (page 17) "The planer is a much neglected, long-suffering machine, too often found in such dismal, unfavourable quarters that any attempts to improve either the accuracy or quantity of its product would be of little avail. Daylight and good foundations are commonly wanting in the planer department." Then further on the author said (page 18) "There is an immense amount of planing being done at cutting speeds of from 12 to 18 feet per minute which could be done at the rate of from 20 to 25 feet per minute"; and later on (page 30) "It is not infrequently the case that one vertical boring mill does the work of two facing lathes,

whilst giving more accurate work and effecting a considerable saving in shop space." A statement was no proof, and when the author stated that milling work could be done two or three times faster than in the planing machine, it required to be qualified by surrounding circumstances. As a matter of fact, in general work he himself would question this statement altogether. It was hardly right to quote exceptional cases and advance them as averages. The planer was not a much neglected, long-suffering machine; the planer was a good machine, and was often as well located in workshops as other machines. It was not the speed that controlled the output of the machine; it was a combination of feeds, speeds, and depth of cut, and in giving the capacity of a machine for doing work these elements should be taken into account all together. The question of doing work on different machines was a comparative question. The cheapest way was the right way, provided the work was equally good, and before determining which was the cheaper way, very accurate cost-keeping was required. It was often the want of accurate cost-keeping which deceived people as to the cost of producing articles. Again, consider the two machines: the vertical boring mill and the surface face lathe, if they were of the same size and both powerful enough for the work to be done, could be run at the same speed, and the same feed could be taken of each; there was no saving to be gained beyond the fact that, if a job required to be lifted into the machine by a crane, it was lifted on to the vertical boring machine and the crane removed, while on the face lathe the job required to be hung by the crane until it was fixed up and set to some degree of accuracy. It was in this that the boring mill had the advantage over the facing lathe; but any engineer would hardly credit that the boring mill would do double the work of the face lathe. No more accurate work could be produced in the one than in the other, and the one occupied as much floor space as the other. With modern machines the cost of the erecting department would be greatly reduced. Not only should the cost of that department be greatly reduced, but infinitely better work should be produced.

The author had enumerated the fittings which tended towards shop economy, but even in that it was necessary to be careful.

(Mr. James Rowan.)

Workshops have been built in America and other places, magnificent monuments to the capital at the disposal of the designer, but altogether disproportionate to their output. Buildings had been erected which might stand for a thousand years, and the lavatories and conveniences for the men were so numerous as to be altogether unnecessary. In one large workshop in America, built a few years ago, one washstand basin was provided for every man. The latest addition they have made provided one washstand basin for every ten men. The author also referred to the number of men under one foreman, but the speaker could not understand how any foreman could take charge of even 40 or 50 men. Then the author was good enough to take it for granted that a foreman in this country with 150 men under him received a salary of 50s. per week; inquiries would show the author that he was entirely wrong in that statement.

Towards the close of the Paper (page 43) the author wrote as if the manufacturers in this country were not in the same street with the American manufacturers. A friend of the speaker's who visited America in the summer of 1898 wrote: "After all I have not seen a place in our own line of business which is better equipped with machine tools or buildings than our own." That was written by a marine engineer, and similar statements were made in other letters. It would be found that in any well managed modern workshop with good tools the tendency would be to standardize work. Big quantities of similar articles were not necessary; in fact in some businesses, such as the manufacture of marine engines, they were impossible, yet it was quite possible to standardize marine engines, and it was now being largely done. The tendency would also be to allocate work of a similar description to definite machines. On the other hand, if standard work was being produced in a well managed modern engine factory, the tendency would be to provide special machines for doing the work. The author had left out a great many points which might have been introduced with advantage; but no purpose would be served by referring to them now. The principal element, that is, the human element, might have been more efficiently and more clearly dealt with.

With regard to the apprenticeship question, he considered the author had gone off the lines a bit, and that a little study of the question would satisfy him that the apprenticeship arrangements in this country, as far as engineering was concerned, were very good. There was one feature in the Paper which Mr. Rowan could not help referring to, as it permeated the whole of it. He took it that the author in speaking of manufacturers, and employers, and workshops, referred to those of this country, unless otherwise mentioned; it was the absolute want of knowledge of modern machine methods of workshop managers. The author could not refrain from expressing his complete confidence in American manufacturers and workmen. A few examples might be quoted from the Paper, amongst others (page 27): "Let any manager walk about his shops and observe polishing operations going on here and there. It is most probable that they are being done by skilled turners or fitters on expensive machines, when the work could be done by a comparatively unskilled hand with an inexpensive apparatus." "The lack of skill and training in properly maintaining and using turret machine tools is the greatest obstacle to its more extensive use in all classes of manufacturing, both of the automatic and hand type. It is pre-eminently the machine demanding the brains and skill of the high grade tool-maker, a functionary wanting in 80 per cent. of our engineering establishments." Further on the author says (page 30): "In many shops where it would be found profitable to overhaul the drilling department, one would find (1st), the cheapest machines that can be bought having power enough to revolve the spindle when boring the maximum hole of their respective capacities; (2nd), the cheapest drilling tools that can be purchased (or forged); (3rd), a total absence of jigs or sets of tools, even when parts are made in quantities or accuracy is desirable." Then later on (page 32): "It is probably true that, except by the sewing-machine, small-arms, ordnance and ammunition makers, the economy of the drill-jig is, with but comparatively few exceptions, little understood." Later on (page 36): "Many manufacturers do not realise that complicated labour-saving machines and tools, constituting a highly productive outfit, rapidly degenerate unless the means are at hand for constantly

(Mr. James Rowan.)

regenerating. They will invest in expensive machines which plain figures show are profitable, but will leave works, managers, and foremen nearly destitute as to the means of keeping up the plant." The Paper was teeming with paragraphs such as these. It might be granted that many of the sad conditions which the author deplored existed; some of them might be found in one shop and some in another; but it was hardly possible they could all exist in any one shop. He did not believe that the workshops in this country were in such a miserable condition as the author would have us believe. Judging from the workshops he himself had visited in the neighbourhood of the Clyde, he would say that many of the modern machine methods advocated by the author were in use; and if the author believed that the workshops were in the condition indicated by him, then there was an enormous outlet and an enormous work for tool-makers to do. He congratulated the author on his Paper, and recommended every employer to study it carefully. The condition of our own workshops (according to the author) were laid painfully bare; he had skilfully advocated modern machine methods, and if the methods suggested, or even some of them, were adopted where they had not been in use, good results would follow.

Mr. DANIEL ADAMSON said that another objection to milling the edges of plates in stacks was that most of the plates had to have bevelled edges, which did not lend itself to working in stacks. The author mentioned as a fact that grinding for cheap and accurate production was only a development of the past few years, but he had overlooked the Lancashire textile machine makers. A few days ago he was in a works engaged in that class of work speaking to men who had been in the trade for from forty to sixty years, and they did not know of any other system of producing spindles for cotton machinery than by grinding. The spindles were taken from the black forging and ground. He exhibited a spindle, and said that, although the makers had tried emery wheels for grinding these, they found grindstones more satisfactory. Emery wheels were used for pointing the end of the larger spindles, the machine being very similar in action to lathe centre grinding machines. The

spindle-grinding machines could deal with spindles up to 44 inches long. The makers knew nothing about working to limits of 1-1000th of an inch in diameter, but they gave the speaker certain data from which he was able to find out that the limit allowed was 1-2000th of an inch, and as the portion of the spindle which had to be so accurately finished was taper, it made it more difficult to work to such a fine limit. It was necessary that the spindles should be accurately finished, because they had to be interchangeable and to be perfectly straight and balanced for running at high speeds. Spindles like the sample exhibited ran at from 8,000 to 10,000 revolutions per minute. Therefore any little irregularity in the assembling of the parts would prevent the spindle running satisfactorily. From 50,000 to 100,000 spindles were finished every week in Lancashire by grinding from the black forgings. The labour cost of the sample he showed was under 3*d.*, including forging, grinding, and straightening. Members who were at the Paris Meeting in 1889 would perhaps remember that at Decauville's Light Railway Works the tapering ends of the rails were being ground to form points and crossings in preference to planing, an example of rough grinding in use ten or twelve years ago.

The author spoke of turret lathes as though they were in course of development at the present time, but they had been used in the textile machinery works on a certain portion of the revolving spindle known as the flyer for at least twenty years, and for ten years turret machines of English manufacture had been used on work similar to a sample he exhibited which fitted on to the small taper spindle already shown. The labour cost on this did not exceed 1*d.* each. The makers were just commencing to make the same thing on automatic machines with magazine feed, but they were doubtful whether they would be able to make them as economically as with the hand-operated turret machine with one man to each machine—although with the automatic machines one man looked after six—on account of the smaller output per machine and the great initial outlay and greater wear and tear of the automatic machinery. The author mentioned that it was often a case of one man working three pieces in lathes versus three men working one piece in the forge,

(Mr. Daniel Adamson.)

and the speaker would like him to explain what class of work required three men in the smithy that could be done on automatic machines. General experience seemed to be that for the satisfactory working of automatic machines softer material was required than with the hand-operated or semi-automatic machines. Softer material lent itself to economical production, but it was not so suitable from the point of view of wear and tear, and to use hard material in the automatic machines reduced the rate of production so much as to render the machines impracticable. Another point not to be overlooked in working up pieces from the bar was the waste of material that took place. With suitable arrangements for forging, it paid to forge in Lancashire, even if only six per cent. of the material could be saved by so doing; and he thought the author ought to have made some allusion in the Paper to such economical methods of forging which had been used for at least the past fifty years in this country.

Discussion on 31st January 1902.

MR. H. F. DONALDSON said he had not expected to be called upon quite so early in the evening, but the author (who, he thought, was a man who, when he had made up his mind, generally obtained what he desired) had written to him asking him to speak on the subject, and therefore he had come more or less prepared to do so. The author had embarked upon a subject which represented a very wide sea, all the shores of which could not be thoroughly explored either in one meeting or two meetings, or even in a dozen meetings of the Institution. What the author had to say upon the subject had reference largely to the United States, with perhaps just a little of Germany; he had laid himself open to the charge of drawing conclusions and figures which would not bear very close examination, if they were to be used as true comparisons. Every one welcomed criticism, but the basis of that criticism should be solidly founded.

It did not do to bring any special pleading in the matter of figures, and to quote the worst time in some practice against the best time in another practice. It did not do, either, to quote any times without saying something about the material employed. Mr. Wicksteed had referred (page 48) to a particular instance of figures quoted for planing versus heavy milling. It seemed to Mr. Donaldson a very apt example to bring forward, especially with regard to those particular points which probably had struck several of the members.

Mr. Adamson had produced a specimen of grinding work done, as he said (page 56), by ordinary grindstones, work which had been carried on for many years and with great accuracy; but he (Mr. Donaldson) did not think that the author or anybody else was going to claim that grinding was a new thing. Mr. Adamson, if he recollected what he said rightly, informed his audience that when he asked the men engaged upon the work what limits they were working to, he gathered that they did not know anything about 1,000ths of an inch. It seemed to the speaker that that was a point which the author brought clearly before the Institution as a point which the members would do well to take heed to. The work of grinding those particular spindles could be more expeditiously and economically carried out, and at least quite as accurately, if high and low limit-gauges were used. That could not be gainsaid, especially by those who had tried working to a high and low limit, instead of with a pair of calipers or simple gauges. Personally he could say nothing with regard to heavy grinding, because up to the present he had had no practical experience of it beyond a small trial in endeavouring to prove the suitability or otherwise of a more extended trial. In the Paper (pages 25, 38 and 39) there were references made to the softness of metal. Looking at some of the machines from the United States and at the practical experience gained from their use, he thought it was one of the dangers of American machinery that ease of working in manufacture, sometimes to a most undue extent, sacrificed the life of the machine for which the material was to be used. He mentioned a case of practical experience where a machine had been at work only for a few months, and its screw already

(Mr. H. F. Donaldson.)

showed very serious signs of undue wear. That was not due to want of care, but to the softness of the material of which that particular screw was made. He therefore thought that any recommendation which the Paper might contain, to reduce the quality of metal used in order to obtain easier working, was open to grave dangers.

The author also referred to the laying out of shops, and gave a summary of the latest practice in connection with lathe work, which if adopted would necessitate a very considerable re-organisation, if not an actual re-building of the whole of the factory. Several new departments were recommended for introduction. In most works in this country, and probably in all countries, it would be found very difficult in existing works to sandwich a new system of working in the middle of an old shop. If it were possible to lay out works anew, there were many things manufacturers would be most happy to adopt; but with an existing equipment, if there was a small gain on paper to be obtained by a re-arrangement, it would want very careful looking at to see if it would pay to pull down workshops and build new, in order to introduce new systems. It appeared to him to be a question of pounds, shillings, and pence, taking it on the broad principle; and it was often desirable to have ocular demonstration that there was a saving, before it was possible to embark on a very large outlay. On page 28 there was a rather important word left out. In speaking of the question of cut gears, he understood the author meant accurate cut gear. There were quantities of gears on the market which were by no means accurate, and which were no better, and in many cases worse, than the old cast teeth.

The introduction into shops in this country of tool-rooms was a thing to be highly commended, and a greater extension of that was most desirable. The old grindstones should be eliminated from the workshop floor, and the workmen should be supplied with tools that could be depended upon, which should be always ready for them. An expensive workman engaged upon accurate work should not have to go away to grind tools. That could and should be done for him, and experience showed that after a few months he would get to appreciate the fact of always having a tool ready to his hand. With

regard to making tools, there was a point about which he was not at all clear as to the author's meaning. The author said (page 37): "Those who proceed on this plan"—that was, making their own tools in their own tool rooms—"are liable to be constantly behind in respect to the latest designs of tools, for the reason that they come so little in contact with those who make a special study of tools and the best ways of producing them." If a workshop had a properly equipped tool room, he himself could not but think that they would be as competent to make tools of all shapes, sizes, dimensions and kinds as their productions required; and, except possibly for gauges which were special, the tools were generally speaking best made by the authority under whom they had to be worked.

On pages 41 to 43 there were eight maxims, all of which were good. There was, however, one point upon which he was not quite in agreement with the author, who practically grouped his machines of like nature together, and transported his work from place to place and shop to shop, following his chucking machine or his lathes or milling machines, or whatever it might be. Each of those operations necessitated transportation of the article being worked upon. That might do very well for some class of work, but he could not agree to its being applied to all classes of work. In most cases he favoured the least transportation possible. It might be slightly more expensive in the first cost of equipment, as it meant a few additional machines perhaps, but his view of an arrangement of a shop was that the work should follow a definite route, always passing forward, never crossing in its own track, and that the machines to enable that to be done should be placed in order to meet the sequence of operations aimed at. Of course he was speaking of a specialised shop.

With regard to the education of apprentices and of the grown-up workmen, so far as the education of the apprentice was concerned, the principle which seemed to underlie the author's recommendation was the return to the old apprenticeship of a hundred or more years ago, when young fellows were taken as apprentices and bound under penalty for a period of time. They were personally taught—that was the point he wanted to make—

(Mr. H. F. Donaldson.)

they were personally taught by those to whom they were apprenticed. Those who had anything to do with the employment of labour owed a duty to their successors, that they should at least improve upon the technical or working education of the apprentices, so as to bring them more up to date, in the same way as some were endeavouring to what was called modernise their shops. Both the education of the apprentice and the education to new methods of grown men were very desirable, and all that was possible should be done to help them forward for the good of the men, for the good of the employers, and for the good of the trade of the country.

Mr. JOHN I. THORNYCROFT, Member of Council, thought the last point Mr. Donaldson had mentioned was the most important one, and, together with the improvement of the shops and the proper arrangement and collecting of tools most suitable for each particular purpose, deserved very careful attention. As had been pointed out by Mr. Donaldson, the tools must be the right tools and in the right order so that the work went through the shop as directly as possible. Unfortunately, engineers were frequently called on to do things that were very different, and what was in their shops varied so much, that not only the shops varied greatly, but the work in any one particular shop at different times. In a factory like the Royal Arsenal or Enfield, the work was of a more constant nature, and permitted of exactness and the use of limit gauges more conveniently than was the case with general work. He believed the Paper was one that called for admiration and consideration in every way, and thought it was a fact that the method of limits was applicable to a smaller number of articles than was previously supposed.

Lieut.-Colonel R. E. CROMPTON, C.B., said that he was much interested in the Paper, as he was one of those who had a modern shop, having been able to rebuild his old works on modern lines, after the fire which took place nine years ago. Since then he had recently completed another shop on still further improved lines, but before doing this he had spent much time in seeing the best works, not only in England but in foreign countries. He agreed in the

main with the author's ideas. He had come to the meeting generally to hear what objections would be raised by English engineers to the general points of the Paper. He considered the author had made very few mistakes. He agreed with him on the limit gauge question, which made it much more easy to produce accurate and interchangeable work than the old but more expensive system of working to single accurate gauges. This older system depended for its success on the skill of the workmen. Working to limit gauges was one of the steps which engineers were taking to reduce the number of fitters, and to reduce the cost of erection. It was only where limit gauges were used throughout that this ideal was reached. It was curious that the Birmingham district, which used to have the name for turning out large quantities of goods, not of specially accurate workmanship, now had within the district several of the best organized shops for turning out thoroughly interchangeable work, and where the limit gauge system, worked by a well organized viewing department, was to be found in its most complete form. The full advantages of the limit gauge system could not be reaped until a viewing department was organized, not consisting of a few inspectors but with a full staff of manager, foremen, under-foremen down to the women and boys, who actually handled the material and used the limit gauges.

Turning now to the question of tool rooms. He had never been without a tool room, and therefore found it difficult to understand how a shop could be run without one. He could not agree with the remarks of the last speaker, that the proper use of the tool room was to make tools of all classes. He considered rather that its correct use was to keep existing tools in order, to serve them out to the workmen, receive them back, and put them into thoroughly accurate order before serving them out to another workman. The only tools which ought to be manufactured in a tool room were the jigs and templates, which were tools peculiar to the special business of the firm. Sometimes, no doubt in urgent cases, it was advisable to make a few milling cutters, drifts, and reamers, but generally these could be bought better and cheaper from firms who made a speciality of making them.

(Lt.-Col. R. E. Crompton, C.B.)

Referring to the author's remarks on the use of portable machines, he, as an electrical manufacturing engineer might supplement it by pointing out that the peculiarity of modern large dynamo machines was the great amount of time that must be spent on the armatures, which were pieces of circular work, sometimes as large as 20 feet in diameter, and worth when finished £3,000 or £4,000. Much of this large cost was due to the amount of labour which had to be expended on the armature, much of this again having to be done by machine tools. It could be readily understood that so long as the armature itself had to be worked at in the old style of lathe, only a few men could be got to work on it at a time. The hub had to be prepared in one lathe, then the arms got into position, with a possible return a second time to the same or another large lathe, then the core plates were put on and the slots trued out, and then it had to go into another tool to have the windings put on. This transfer from tool to tool, all of them of large size, made not only the labour itself, but the upkeep of the plant which had to be employed excessively costly. The most improved modern practice adopted by American, German, Swiss, and English engineers was to up-end the shaft on a planed surface table forming part of the shop floor, and then to carry on a number of operations simultaneously around it, by bringing up tools by means of the overhead traveller and setting them to work round the armature. None of these portable tools were of very large size, and it could be readily seen that the total capital value of tools employed by this method could be greatly reduced, and the total time taken in the shops reduced to one-fourth of the old figure. No doubt this principle of using portable tools could be used in many other pieces of machinery, on which large tool work had to be carried out.

The author did not say much as to the lighting of modern shops. He personally felt very strongly on this point. He was convinced that no good work could be carried out in a shop which was not perfectly lighted, both by day and by night. He had paid particular attention to this subject himself, and he thought that in this one respect English shops were perhaps a little in advance of those of

their foreign competitors. He personally thought that the shop with the weaving-shed roof, adopted from the textile factories, gave the most perfect form of lighting. A good deal depended on the proportion of the incline and vertical glazed-roof surfaces, but if this were properly carried out with a north light, there ought to be equal lighting all over the shops, both in summer and winter, and no shadows would be thrown. As an instance of how much depended on such equal lighting, the vertical spindle lathe, of which the author said so much in his Paper, could not be used to full advantage if side lighting were employed, for it would be readily seen that, with side lighting from windows in the wall, the shadows thrown prevented rapid and accurate chucking on the vertical spindle lathe almost as much as on the ordinary surfacing lathe, but with even shop lighting the vertical spindle lathe had great advantages in the speed of accurate chucking.

He agreed with the author that it was not necessary to wait until large quantities of standard work were required before introducing most of the improvements put forward in the Paper, as a very small number of repetitions were sufficient to make the improved system pay. Lastly he wished to point out that after all this question of whether the system paid or not was the crux of the matter. In his own, the electrical business, Germany had erected some of the largest and finest shops in the world; enormous capital had been spent on them. They were splendidly equipped with tools, their methods of manufacture were supposed to be, and were in many respects, as perfect as possible. Their system of taking out costs was good and correct, but still he had his doubts whether, in view of the ever-varying work that had to be carried out in electrical engineering, the capital expenditure which had been incurred was justifiable; in other words, he asked himself the question, had the German engineers ever fairly debited their costs with fair interest and maintenance charge on their gigantic plant? He believed that if this had been done as fully as it ought to have been, many German firms would have found that they were manufacturing at a loss. He went on to say that, after all, the main object of these modern methods and the capital expenditure they involved was that of reducing as far as possible the

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number of highly trained workmen, that is, the fitters, from the modern mechanical engineering workshop. He did not say that the highly trained fitter was not a good workman, but his position in the future ought to be in the tool room rather than working on the goods themselves. For this purpose a limited number of workmen must go through the training once considered necessary for all fitters, and probably the masters should go through the same training themselves; but the work could be now done so much better and cheaper by a more profuse use of plant which would be worked by an intelligent labourer, but not by labour requiring the same length of training as a fitter did. He was attempting to carry this principle out in his own works, but of course he felt that he was a very long way off the needed perfection. He was one of those who believed in women's labour, and the women should be set to work on tools of the very highest class, and under such conditions he had seen work turned out in Birmingham which was second to none.

Mr. WILLIAM WEIR asked the indulgence of the members in saying a few words on the Paper as he was not a member of the Institution, and as he thought it might be looked upon as youthful temerity for him to address a meeting of this character. As, however, during the last three years he had had an opportunity of putting in force in a new engineering workshop a large number of methods advocated by the author, he believed a few words on the subject might be of interest. It appeared to him that the Paper had suffered a little in general value from its evident restriction to considerations of conditions applying chiefly to engineering works doing fairly light manufacturing work. He considered that in this country the owners and managers of shops of that nature were and had been for some time alive and very progressive; and the shops over which the cloud of conservatism had loomed most largely were those doing heavy and more general work. It should be always remembered that those shops formed probably the largest portion of the engineering trade of this country. It was a truism to say that the tendency was to specialise; but the general shop was, and he believed it still would be, the one which had done and would do the original

pioneer work in new lines of progress. By progress he did not mean progress in methods, but progress in research, in design, and in invention; and he trusted that in specialising, and in the desire of of being up-to-date in ways of doing work, engineers would not allow those considerations to blind them to the necessity of always keeping in view improvements in the design of their manufactures. If the British engineers could hold the position they had held until now as the best designers and the best engineers, as distinguished from the best shop managers, and at the same time give more attention to their shop practice than they had done, there was no reason to fear for the future of the industry.

The modernising of an old establishment doing work of a heavy or general nature, the maximum rate of profit of which was comparatively small, was a matter which required the exercise of very great discretion, and in his opinion very much could be done without any very heavy capital expenditure. First he would say, let there be more light in the shops; and that could generally be obtained without more windows — by washing the present ones. Then, cleanliness and order, to secure which the main necessity was a good floor. Expenditure on that floor would pay an excellent dividend in any shop, as it was possible to secure transport of parts up to about two tons at a minimum cost by the use of flat-wheel bogies. His experience had always been that shop railways were only required for heavy work, and, with a good floor with flat-wheel trucks, it was possible to take work anywhere, which was not the case with the usual "industrial railways." Then, better organisation was required, and the introduction of a system of remunerating labour in a better manner, say a premium system. There was also necessary a reasonably accurate and simple cost system. Next, more and better small tools and suitable arrangements for keeping them in order was desirable. If cleanliness and order were introduced into a shop, it would secure a wonderful amount of floor space for a tool-room or tool-stores. In his opinion those four items were the essentials in modernising a shop, and that their introduction must precede in every case "modern machine methods." Their cost of installation was comparatively small, but they secured a far higher

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rate of interest on the expenditure than could be secured by putting in improved machines. It was his conviction that old shops which had those features, or where those features had been attended to, and shops in which a fair average excellence of machine tools existed, would be the shops which could be depended upon for a better return on their capital than new shops in which every known labour-saving appliance had been installed, and which on that account bore on their shoulders the burden of a very heavy capital. In those remarks regarding the modernising of an old shop, he had in his mind a certain machine shop on the Clyde, which in about three years had changed from the old and in many ways uneconomical shop into what was certainly now one of the best equipped and best organised marine engineering works in this country. Speaking of the new shop, he had in mind a comparatively new marine engineering works in America, built at a very heavy cost to save the largest possible proportion of wages to workmen. The American shop obtained 30 per cent. more for its marine engines than the shop on the Clyde; but it could not pay a dividend, and would not pay a dividend until its original capital had been halved; while the shop on the Clyde would, he believed, be always a good investment.

The author said (page 29): "the loss of time and the inconvenience suffered in many shops by the want of a vertical boring mill is considerable. In many respects this machine is nothing more than a surfacing and boring lathe stood on end." He would like his remarks on that subject to be taken as applying to machines taking work up to 50 inches in diameter only. Presuming the surfacing and boring lathe was fitted with a turret head—in fact it was as up-to-date a boring and facing lathe as the vertical machine was an up-to-date boring and facing mill—where was the gain with the vertical machine for chucking operations and facing? The one machine appeared to him to be in every way as good as the other. For purely facing operations or boring large diameters, such as cylinders having a bell mouth, the horizontal machine was handier to work, as, on account of the compound rest, the workman could use both his hands at one time, and watch his tools. In the case of the vertical machine he was compelled to stand back from his work, and

could only use one screw at a time, and must then take the handle off and shift it on to the other screw. That appeared to be a defect inherent in the machine for general work. Reference had been made to the extra power with which heavy cuts were possible with the vertical boring mill. It appeared to him that the tendency in shop practice was or ought to be to secure castings or forgings which would not require heavy cuts; and, as a general rule, he found that Scotch built boring and facing lathes were made with superior power to take all reasonable cuts at a fair rate of speed. The author said (page 30), with regard to the vertical machine that: "inaccuracies do not occur on account of over-hang." That might be granted for a vertical machine; yet the most accurate machine-work on fairly heavy engine parts done in this country, or, in fact, in almost any country, was done on properly designed horizontal boring and facing lathes. He therefore could not see that for general work up to 50 inches diameter the vertical machine was able to do the work of two facing lathes, if those lathes were fitted with turrets. In manufacturing work with special tools, the tools could be fitted as satisfactorily and do their work quite as well on a horizontal machine as on a vertical machine.

Speaking with regard to particular labour-saving machines, it had always appeared extraordinary to him that the most valuable labour-saving machine which he had in the works with which he was associated, although it had been on the market for about sixteen years, had been only adopted by a comparatively few firms; and strangely enough its adoption had been almost nil in what were termed up-to-date shops. The machine he referred to was called on the Clyde the horizontal, drilling, tapping, and studding machine; and consisted roughly of a large bed-plate on which to carry the work, a vertical standard sliding on the bed, carrying on it a drilling saddle which could move up and down the standard. Those machines had been in use for many years now, and their value was very great. Take an awkward casting which required four settings, say, a pump end. In a pump end at the first setting it was necessary to drill, tap, insert, and trim thirty-two $\frac{3}{4}$ -inch studs; on the next setting the workmen had to bore three 1-inch holes, and also drill, tap, and stud

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eight $\frac{3}{4}$ -inch holes; and at each of the next two settings he had to bore twelve $\frac{3}{4}$ -inch holes. There were no jigs or fixtures, and the holes were all marked off. One man and one labourer did that work in $2\frac{3}{4}$ hours, including the procuring the studs from the store, setting up, changing, and delivering the casting with the nuts all in position on the stud. He had occasionally wondered why people could get on at all without that machine; and he was sure there was no shop in this country of any size in which it would not prove an invaluable labour-saving appliance. He could not say why it had not been adopted, except that it had not been advertised and put before people, and that it was not of Trans-atlantic origin.

In conclusion, he wished to say how much he had appreciated the Paper, which contained very little open to criticism. He was sorry, however, that the author had written the Paper, as with his experience he could have written a far better book on machine shop practice. The Paper was too much in too little. The object of his remarks had been to counsel moderation in modernity; secondly, to point out what improvements should precede modern methods; thirdly, to ask for the up-to-date boring and facing lathe more consideration before discarding its use; and lastly, to claim for a Scotch-built and designed machine-tool the property of being the biggest labour-saving device in any shop using the most excellent types of American or Continental labour-saving machine-tools.

Mr. J. R. RICHARDSON thanked the author very much for the great trouble he had taken in preparing so valuable a Paper. The President had expressed his opinion that it was a subject on which there might be a great diversity of ideas, and there was no doubt that that was so. Colonel Crompton had said that one of the reasons he had attended the meeting was to hear what English manufacturers had to say for themselves; he, the speaker, had come in defence of the English manufacturers. The Paper was really a severe criticism of English methods, comparing English methods most unfavourably with the methods in America. The English method appeared to be to have tools which would do anything they were wanted to do, but not doing the work so cheaply

as it might be done; the American method was the system of having tools and plant so arranged that whatever was done was done in the cheapest possible way, the tool being of comparatively little use for anything but the one thing for which it was made. Of course this was putting the case very broadly indeed. The author stated (page 17) that the adoption of milling machines was not "as extensive as it should be, for the reason that often an apparently formidable investment in cutters is necessary. The milling cutter, however, should be looked upon as any other labour-saving tool. It is not so much a question of how much does it cost, as how much does it save." Further on in the Paper, the author said (page 44): "The idea that big quantities and standard work are necessary before modern equipment begins to play an important part in the economics of manufacturing is the delusion of those who have grasped but a small part of the problem." Mr. Richardson was afraid that he must rank himself among the deluded ones. Many years ago he introduced automatic and semi-automatic machinery for the manufacture of all small parts, such as pins, studs, small brass details, nuts, and things of that sort, used in very large quantities. They did not take up much room, and it was not a serious matter to hold a twelve months' stock. But in large engine details the question was rather different. There were very many engine details, where the work of the milling machine would be very much cheaper than by the old-fashioned slotting machine, as far as the question of wages was concerned. Was that the only thing to be considered? Some years ago when this country was flooded by gentlemen from the other side of the Atlantic, who were anxious to show English manufacturers how to manage their works and make large fortunes, and incidentally to buy American machinery to do it with, a gentleman called upon him with regard to milling machines. This gentleman said, "If you will allow me to walk through your shops I have not the slightest doubt that I can pick out a large number of pieces you are tooling, and show you how you can save 50 to 75 per cent." He was always very glad for anyone to show him anything like that, and gave the required permission. The gentleman went at once and found six or eight pieces which he took as samples, and

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said he would give estimates for machines, cutters, and everything necessary for doing the work, and actually guaranteed the time for doing the work. The results all came out practically alike, and one illustration would suffice. He exhibited a template of a lever used in one class of engine. It was set out by the fitter, and slotted all over by hand. The slotter worked the machine round the curves following the fitters' marks. There was nothing automatic about it, and the total labour of slotting was about 1s. 7d., the time being one hour and twenty minutes. The American's estimate for doing the work was 30 minutes, practically a clear saving of 66 per cent. That looked very nice on the face of it, but the machine to do the work was to cost about £250. Besides that, the American wanted to supply two sets of milling cutters at something like £30 a set. Only four of the levers were used on an engine, only one particular engine used them, and they were only good for one size; the result was that, although the turn-out of the whole works averaged three engines per day, the total saving upon these levers would be simply 13s. per annum.

Only a few weeks ago he had been approached by a gentleman introducing moulding machines, who showed him some fascinating photographs and drawings of what the machines were doing. To see a foundry floor covered over with hundreds of boxes, and to be told that one standard machine did them in a day was delightful. He said he did not think they could use ordinary patterns, and one of the visitors told him that they did. Mr. Richardson said he thought they had to be mounted in a certain way, and was told that they had to be put on plates, and a stripping plate had to be provided. He asked whether that was not a serious question with a large variety of patterns, and was told not, because there were always in every works a great number of patterns in regular use, apart from those only used occasionally. He took the party into the factory, and showed them the patterns, pointing out some 17,000 patterns in one store, and explaining that there were five other stores containing patterns not used so frequently; the American guessed that that machine was not exactly suitable for that class of work. It was not that English engineers

did not understand American methods, but that Americans did not as a rule understand the conditions which obtained in large engineering works in England having a big general practice. There must be a large run of work. Even the most enthusiastic Americans had told him that a large quantity was not needed, that it could be done perfectly well with a dozen, but very often a dozen was a large quantity. Not only was it necessary to have on his catalogue 500 different types and sizes of steam-engines, but an infinite variety of mining and general machinery; and in addition his firm was expected to do anything required, and had to do it even if it only had to be done once. He did not wish anyone to gather that he was in the least degree opposed to modern methods; full, semi-automatic machines, turret lathes, vertical boring mills, flat, cylindrical grinders, hydraulic, pneumatic, and electrical power plants, and a testing and analysing laboratory had all been installed under his directions, and he thought that even the author would not take exception to the lighting and ventilation. Though up to the present his firm had not been fortunate enough to discover "foremen who were experts in turning, milling, grinding and planing, and who could do their own tool-making, inspecting, and cost-keeping at 50s. per week."

As far as his experience for several years in America went, he thought the Americans were deserving of the very greatest credit for the accuracy with which they turned out their work. Fire-arms, bicycles, sewing-machines, and things of that sort were turned out in very large numbers finished most beautifully without the use of the fitter. That was due to the accuracy of their jigs and limit gauges, and the excellent system in the works. In larger work, where hand-labour had to be used, very great accuracy was shown. Quite recently he was building a large engine, the shaft of which had to carry an American armature. The specification was American, and specified that the armature was to be forced upon the shaft by hydraulic pressure, not less than 50 tons nor exceeding 80. The armature came over to this country, and fitted dead true into its place with a pressure of 65 tons. That spoke very well for the accuracy with which that armature was bored in America, and it

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also spoke equally well for the care with which the shaft was turned in England. Speaking of American specifications, he thought sometimes the Americans overdid them in their desire to appear extremely accurate. He remembered not very long ago it was specified that a certain key was to be driven home with a ten-pound hammer, but they neglected to name the length of the shaft, or the strength of the man who was to strike the blow. Some years' experience had shown him that even the very best known and largest American firms were not always so prompt in their deliveries nor so accurate in their construction as they would have English manufacturers believe. He had known works, not hole-and-corner works, which had exceeded their promised time of delivery by over twelve months, and when the machinery arrived and was put together discrepancies arose, discrepancies not of 1-10,000th part of an inch, about which they talked so glibly, but of a considerable proportion of a foot.

Mr. LEWIS H. RANSOME said he had not come to discuss whether English manufacturers were better than the Americans in the way they turned out their goods, as he thought the results would speak for themselves. He had come as a shop manager to ask a few questions on points that struck him as being of great interest in the Paper. The first, the question of limit gauges had been answered by Colonel Crompton, and it appeared to him that this system appealed to common sense. His firm had been hesitating for some time whether to adopt it or not, and if any member present had used limit gauges it would be interesting to know what his experience of them had been.

The chief thing that had struck him and filled him with a certain amount of disquietude was the speed with which the author said some of the machine tools could be worked. In many instances his firm had not attained such speeds as were mentioned in the Paper, but he was anxious and willing to learn; perhaps the author or some other member could enlighten him as to how such results were arrived at. With regard to circular milling, the author stated that it could be done on cast-iron with a cutter having a

surface speed of 50 feet a minute and a feed of 4 inches a minute. That was much better than anything they could do in his works, and he did not mind admitting it. The average cutting-speed in their own shop was 35 feet a minute, and on cast-iron they could get up to a feed of $1\frac{3}{4}$ or 2 inches. That was the best speed at which they could turn out good work, and he thought it would be of great interest to most of the members to know how it was done in America, what quality of steel was used, and how it was tempered to turn work out at the rate spoken of. He wished also to know whether the author, in giving this rate of production, allowed for the five minutes extra in the machine shop for excellent finish, which would save ten minutes in the fitting shop spoken of later on in the Paper.

He was very much interested in the question as to the advisability of putting two or more speeds on the planing machines. That was a question his firm had not settled. When he was in America he saw a good many factories working with two speeds, but he could not get any definite information as to results. His firm were running their planing machines at a standard rate of about 18 to 20 feet a minute, and when planing wrought-iron he thought it would be better to drop to a speed of 15 feet. If any member present was running his planing machine at two different speeds, it would be very interesting to hear his experience of it. It seemed that with a standard speed, if a quicker output was desired, it could be got over to some extent by taking a coarser feed and a deeper cut, and in that connection he might mention that they had a large planing machine in their works to which a tool-holder had been fitted with four tools. With that tool a feed of a quarter of an inch could be taken, removing as much as half an inch in depth at one time with one cut. The only drawback was that occasionally, when the work sprang under the excessive pressure, it was necessary to take a second finishing cut. In finishing, a feed was taken about three quarters of an inch with a flat tool, and it paid better to run twice over the work with a finishing cut than to spend less time in roughing it out and finishing with one cut.

Another interesting feature in the Paper was the question of grinding. He had no hesitation in endorsing the author's view as to

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the economy effected by grinding in preference to finishing on small work. Since his firm had put in a universal grinder he reckoned they saved 25 to 30 per cent. of time, and got a much better finish. The time of the lathes was saved, the files saved, and the spoiling of the machine by the use of emery, and the work was done a great deal quicker. But his firm did not grind at anything like the speed the author mentioned in the Paper, although they would like very much to be able to do it. The author said that a shaft 4 inches in diameter and 3 feet long could be ground up, removing the hundredth part of an inch in six minutes. He was almost ashamed to say how long it took him to grind it compared with the figures given in the Paper. He did not doubt for a moment that the metal could be removed, but the thing was whether the shaft when finished at this speed could be run afterwards at a speed of 800 or 1,000 revolutions a minute, which was an average speed for their shafts to run at.

He was greatly interested in the tool-room question; and having lately started new works and beginning with a clean slate, it might not be waste of time to mention his firm's experience in this direction. In their old works at Chelsea there was no tool-room, and the new works were started without a tool-room, but provision was made for adding one afterwards. The first thing they did was to collect all the old tools about the shop, and they cleared up 3 tons 5 cwt. of useless tools. A considerable time was spent in doing these tools up and putting them in thorough order, with the result that they had not bought any tool steel to speak of for nearly twelve months. They then arranged a system of messengers for the tool-room, as no workman was allowed to go into the room for his tools. Messenger boys were provided, and there was a system of bells in every department. The bells had an indicator in the tool-room, and a blue print showing every standard tool was hung up by each bell. Every tool was numbered and described. The boy who took the order did not need to know what tool he was bringing, because it was kept in a bin with a standard number over it. The workman rang the bell, and when the boy answered it, he asked for tool number so and so. The result was, he estimated, that five men's time was saved. He used

to total up the number of men he saw hanging about the tool-room previous to this system, and generally there were five to six all day long. Now boys were employed at 4s. and 5s. a week running about the shop in the place of men getting 36s. to 38s. He was not ashamed to say the idea was obtained from America, but it had been developed.

There was one other point in connection with foundry practice, and that was the necessity of having someone who could analyse cast-iron and coke. In a foundry of moderate size it was not perhaps possible to afford a chemist; he did not know what a good chemist would cost. His firm was absolutely in the dark, until it made the castings, as to whether the brands ordered contained the same component parts as similar brands ordered previously. As a matter of fact he knew that they did not. Then it was not known what the coke was. Only a fortnight ago, tempted by a lower price for coke, his firm purchased some, with very disastrous results. If someone had been on the spot who could have analysed that coke it would have paid well, and he had been wondering whether it would not pay for neighbouring foundries who were not large enough to keep their own chemist to combine and run a chemist between them. There was one thing he wished to touch on in conclusion which did not refer to the particular Paper under discussion, but to papers in general. The manufacturers in this country were a great deal too thin skinned. Judging by the discussions he had attended or read, the papers on improved methods of manufacture were read by British manufacturers very much from a defensive point of view. He maintained that this was a mistake. What was wanted to be obtained from these Papers was information. Manufacturers did not want to get up and prove that they were cleverer than anybody else, or to tell the author their own methods were better than others they were not familiar with. Results would prove this. They did not want to tell him, if he stated that he could do work quicker than the English manufacturers, politely, but unmistakably, that he was a romancer. They wanted to discuss and find out if his statements were borne out by facts, and if they were, manufacturers should learn from them. If they were not, then there was no harm

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done. No doubt manufacturers had learned a great deal lately from America and the Continent. English manufacturers had been ahead for a great many years, and he believed and trusted they would maintain their position, but they would not do it by shutting their eyes to what was going on outside this country.

Mr. ROBERT BRUCE said he appreciated the Paper, which was the product of the author's experience in workshop management, both in America and Europe. They in England should be glad to profit by such experience and suggestions as were conveyed in the Paper, for though engineering had sprung up in this country and had practically led the world, there was certainly no monopoly of engineering talent in this country.

The author had laid before the Institution much very practical information and suggestive matter, which would not be lost upon that section of the membership directly engaged in workshop management. Already in many workshops in this country the views and methods embodied in the Paper had been adopted to a large extent with gratifying results, and doubtless, as it became widely read and understood, its influence would be felt amongst users of machine tools.

Mr. DAVID CARNEGIE, speaking of limit gauges, thought it was generally understood that the principal advantage was in being able to use the gauges with practically unskilled labour. He quite agreed with Mr. Ransome that, where the limits amounted to five-thousandths of an inch, unskilled labour could use the gauges successfully. Gauges to much finer limits, as described in the Paper, could also be advantageously used by mechanics. It was, however, necessary to couple with the use of limit gauges that of an inspection branch. In having the work inspected limit gauges could be used, and it had been found from many years' experience that interchangeable parts could be made successfully in that way.

With regard to milling tools, he had found that a great saving was effected by the use of milling machines for producing tools, say cutter-bar tools. They could be moulded to shape and hardened

without going near the fitter, and work could be produced by such cutters which could be gauged within reasonable limits. With reference to the tool room, no workshop could be looked upon as fully equipped, unless the tool room was under proper guidance. Someone had said that the tool room should exist mainly for storing tools, or that only small tools should be made there. It was necessary to distinguish, he thought, between a tool room and a tool store. The tool store was simply a place from which various tools could be issued to messengers or operators. All tools as far as possible should be made in the tool room. A system had been successfully carried on for two years, where tools had been ground by universal grinders, and handed out properly ground to the required angles for the various materials, and thus a great saving was effected by the use of the tool room or store in that way.

MR. ALFRED J. HILL, in answer to Mr. Ransome's question (page 75) as to the advantage of two speeds for planing machines, said he had recently adopted two speeds to all his planing machines with very good results. He thought the speeds Mr. Ransome mentioned for cutting wrought-iron were very low indeed. For cutting cast-steel, his firm were running their planing machines at about 18 feet a minute, and for cast-iron and wrought-iron 27 feet a minute. He thanked the author for his Paper, which he thought fulfilled the chief aim the author had in view, that of suggestion to those who were considering economical methods of manufacture. He thought, however, the author had gone in rather for a counsel of perfection. As a manager of shops he should be only too glad to follow in many respects the lines indicated in the Paper, and would like to know whether the author knew of a shop in this country where one man was working six milling machines. With regard to grinding, it was recorded that a 4-inch shaft 3 feet long could be finished on a grinding machine in six minutes. There was a specimen, Fig. 31, Plate 8, somewhere about this size, though certainly rather larger, but it had been ground in forty-five minutes, and he thought that sounded a more reasonable and practicable time than the six minutes mentioned in the Paper.

Mr. ROBERT DUMAS said he was lately in the States where he saw some planing machines fitted with the Reeves variable speed countershaft, and planing was being done on cast-iron at the rate of 38 feet a minute. He would not mention the place where he saw it, as the article being planed was the standard of a milling machine, and it might not be thought altogether a recommendation that it was possible to plane cast-iron for that purpose at that speed. As to whether in this country there were six milling machines worked by one man, he could assure the members that there such was the case, but he would not mention the name of the factory for very obvious reasons.

Discussion on 21st February 1902.

Mr. E. J. CHAMBERS could not help saying how very pleased he was when he read the Paper. He had not had the pleasure of attending the previous meetings, and was very disappointed that he could not come; he thought, however, that the author was working on the right lines. Although he could not subscribe his name to everything the author advanced, he still felt that it was the kind of Paper necessary to be brought before the Institution. With regard to the care necessary when one began to dogmatise as to which machine in a shop was best, he remembered some years ago making a machine to do a certain work. He went on with the work and developed it, and as soon as he got one machine to work he started another, and he thought he was going on splendidly. The machines did their work very well indeed, and he thought he would be able to carry all before him. But unfortunately in one of his weak moments he started scheming another way of doing it. The first method was in the turning shop, the second in the smith's shop. Most works had a smith's shop, a foundry, and a turnery, and various other shops, and unless a manager gave each shop a look in, it was not quite fair to the works generally. He happened to start scheming in the smith's shop, and found it was wonderful what the smith could do by simply sticking to it. After having spent several hundred pounds in designing lathes to do a certain particular work, he found

not only that he could do that work under the hammer in the smith's shop very much better, but also very much cheaper. Consequently one had to remember that there were other departments which could produce work to a wonderful degree of perfection, and that work could be well done even in the smith's shop by only devoting attention to it, work which would knock the bottom out of any suggestion for cutting metals off by a lathe. He remembered one gentleman he was associated with many years ago, who said it was always cheaper to cut metal off with a lathe than it was to go to the trouble of making dies, and forging it under the steam-hammer or in special stamping dies. It struck him at the time that it was perfectly true, but both of them lived to see that by developing knowledge and experience of dies and stamping they could beat the lathes, and that they could not always cut the material off as well or as cheaply as it could be done in the smith's shop. Therefore they had to go back to the smith's shop again. It was that which he wished to caution the author about. Although he liked his advice very much, he still felt that it had to be qualified, by remembering that when one shop had been beaten, that shop must be called upon to beat back, and that was the only way to get perfection.

Mr. F. G. WRIGHT said he had taken great interest in the Paper, and he wished to ask the author one or two questions on the subject of apprenticeship. He assumed that the author's remarks referred to shop apprentices, that is, youths apprenticed with the idea of becoming fitters, turners, or erectors, and continuing at these trades. He wished to know whether the author proposed that, in addition to these apprentices, youths should be apprenticed to the working of milling, planing, drilling, and other machines, and should be kept entirely upon such work.

The PRESIDENT said the Institution had received from Mr. Dean a written communication containing interesting data as to the extent to which grinding was being done at Swindon, and he asked Mr. Wright whether he could tell the Meeting anything about the practice there?

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Mr. WRIGHT said that at the present time in the locomotive works there was grinding machinery for finishing off rough forgings, and special machinery for grinding piston-rods, valve spindles, solid spindles, and so on. He did not know that there was anything different from what other large locomotive manufacturers had at the present time.

Mr. T. HURRY RICHES, Vice-President, said that Mr. Wright was aware that his—the Taff Vale Railway—Company had some grinding machinery, and they had found a very material saving in a great deal of the work in consequence. So far as repairs were concerned, at one time they turned down old piston-rods, but they did not dream of doing that now. The piston-rods were put in the grinding machines and brought to a very fine surface indeed. Metallic packing was used, and it was quite a common occurrence to run engines two years on the line without requiring to touch them. In addition, with regard to the whole of the motion, whether holes or pins, the old practice was to soften and in many instances to close more or less oval holes, and then having drilled them or bored them, harden them again, and then lap them out; but that practice had been given up for a long time. Now the case-hardened rod or pin, as the case might be, was taken and put into the grinding machine, cut up, and the job made as near perfect as possible. There again it was found that the saving in the fitting up of a motion was very material indeed. Further than that, the whole of the new piston-rods were finished with a grinding machine, instead of as in the old days finished in a lathe. The whole of that work, whether new or old, was dealt with entirely by grinding machines. All the rough steel castings were ground, either with stone grinding, corundum, or emery machines or wheels. The only thing to take care about was when the grinding was finished to clean the hole or the pin just a little, just enough to wipe the emery or corundum off which might be left by the machine. It would be found that the cost of repairs or the cost of making new work was distinctly decreased.

He quite agreed with Mr. Chambers that the method of machine shop work and management now required very careful watching.

Having set one's self to perfect one shop, as soon as it was considered that that was right, then a good works-manager ought to begin on the next shop, and see if he could not make it better. He was quite satisfied, he might fairly say, that he had some of the best American and modern machines in the Taff Vale Railway shops of any shops in England, although they were only small shops. He could say very positively that there was a great deal of work which professedly was done cheaper by turning—for instance, cutting bolts out of solid bars or cutting other things out of solid bars—which could be in many instances much better done in the smith shop, particularly where there was a large amount of duplicate work. Stamping, if properly done, could enormously decrease the cost of manufacture; and so it was from shop to shop. Taking the boiler shop for instance, drilling, reaming, caulking or chipping required really constantly revising. If they were to go from one point to the other to improve one shop and then another, and then bring the other shop up to that, there was a constant and steady process of improvement and development. In his opinion that was the only way to keep ahead or on a level with other nations, and in fact, as Mr. Chambers said, to keep pre-eminent. As soon as one shop was ahead of the others, the others should be brought up to it. He had been asked by the President whether he ground to new standards. The new standards for motion pins and holes naturally would be smaller than the repair standards. But it was found very much better to slightly increase the standard for repair work, as compared with new work, than it was to bring the old work down to the standard of the new work. It was very much better to have a second standard a little larger that would take the work through.

Mr. ORCUTT, in reply, said he first of all wished to clear away a personal matter raised in the discussion by those who criticised the Paper. He believed his countrymen had one failing, that they were never able to disguise themselves, and he was suffering from that. He was sorry, not that he should like to try to conceal his identity, but he thought little would be gained by making the *national* question one of prominence. Those who had

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criticised the Paper most sharply had assumed somewhat, and stated rather plainly he thought, that the Paper tended to be a eulogy on American methods and an indictment of English workshops. That was far from his object, and nothing whatever was gained by it. The object of the Paper was to present what he considered to be the best practice, in many cases extreme practice. The Americans had a very good motto, which said "Aim at the stars, though you stick in the mud"; and he thought that manufacturers should always work in this spirit. Naturally in dealing with the matter he had American leanings, as he had had a large experience in American shops as well as in English and German shops; but at present he was domiciled in England, all his friends were in England, and his home was in England, and he had the interests of the English shops and industries at heart. He thought some of the members would testify that the interest he had in industrial progress in England was in no way connected with selling machinery. One thing he had learned in a long residence of thirteen years in England was the labour-saving virtues of plain speech. He had tried to use plain speaking in the Paper, and he proposed to use it in the reply. After he had gone over the points which had been brought up by those who took part in the discussion, he proposed to say briefly and exactly what he thought of English workshops.

In the first place Mr. Wicksteed brought up the question of milling (page 48), and seemed to assume that the example brought forward of milling lathe-beds would not apply to flat milling; but it seemed to Mr. Orcutt that that was a question which must be always studied. It might be true in some cases, and it might not in others, that milling would be better than planing. If he were attempting to finish English lathe-beds quickly and cheaply in quantities, he would resort to vertical milling with large milling cutters with inserted teeth, and he thought nothing could beat it. In his own shops screw machine beds were milled which had a flat top section. They never went to the planer at all; they went direct from the miller to the scraper, and only two cuts were made. With regard to a large cutter on a broad surface springing, it certainly would spring if the machine was not adequate to take the strain, and so it

would in the planing or any other machine not sufficiently rigid. A great trouble with milling was that in many cases the machines were not powerful enough. Machines were used of slight construction, and then condemned when they had not had a fair trial. Mr. Wicksteed also thought that three cuts might be necessary to finish a lathe-bed. He never made three cuts; it was not found necessary. There was one roughing cut on the milling machine, and one finishing cut on the planing machine to bring it true, and then it went directly to the scraping machine. Mr. Wicksteed very rightly brought up the question as to the milling machine superseding the planing. This was not yet accomplished, although many predicted it; and it never would be so. Both types of machine must be used, and always would be used. He thought members should make use of the figures (page 49) given by Mr. Wicksteed, which were valuable as showing the speed at which planing could be done, particularly with the cutting on both strokes.

Next came Mr. Rowan (page 52), who also criticised statements as to milling-machine work, and wrongly, because Mr. Rowan was probably thinking of large work, whereas the Paper, while dealing with that, was principally devoted to light milling, and the instances mentioned in the Paper were very largely in connection with that class of work. Mr. Rowan questioned that milling machines worked two or three times faster than planers, and said that such cases must be exceptional. There was no question whatever, as many of the members could testify, that in a great many cases where it was applicable, it beat the shaper three or four times, particularly as to labour cost. One man could very often easily attend four milling machines, while it was not usual for one operative to attend as many planing machines. Mr. Rowan also thought that the planer was not such a long-suffering machine as had been assumed, but the author would like to have the privilege of taking him into some works into which he had been, when he thought he would change his mind a little in that matter. The cases of course could not be mentioned and no names could be given, but they could be easily verified, and they occurred over and over again. Mr. Rowan very rightly made the point that the cost of a piece of work did not depend upon the

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speed at which it was cut entirely; there was the depth of the cut and so forth. Of course in the output the quality of the iron very largely regulated the speed at which the work could be done. Feeds, speeds, and depth of cuts certainly regulated the output, but work at fast cutting speed would make it possible to increase all round.

Mr. Rowan brought up another very good point in respect to cost-keeping (page 53). He, himself, thought the value of accurate cost-keeping was not understood as much as it ought to be, and that cost-keeping was not carried out as it should be. If it was done properly, there were some revelations in store for some manufacturers. Mr. Rowan was specially informed in connection with that matter, and anyone interested particularly in the question should see his works, which he always threw open to those interested. Again, Mr. Rowan spoke of the vertical boring machine as compared with the face plate lathe (page 52), and did not see the advantages of the former. That question was almost as eternal as the flat-bed lathe versus the V bed, but there were points in favour of both machines. When Mr. Rowan made the statement that no engineer would credit that the boring mill did double the work of the face lathe, he (Mr. Orcutt) thought he could bring forward any number who would testify that it did. In some classes of work it was especially applicable. Fig. 35 (page 87) illustrated one of the points, and to that drawing he called attention. It showed what was usual in some constructions of the vertical-boring machine, as made by one of the leading makers. It represented the face plate of the machine and the conical bearing on which the main weight of the spindle and face plate was taken. He thought it only needed common sense to see that it had features which it was impossible to embody in the lathe for certain classes of work, particularly where heavy parts were to be operated upon. The construction as shown had a self-centering tendency, so that the combined weight of table and spindle, as well as the work, tended to preserve, not to destroy, alignment. In fact, it was impossible to get results on the lathe which could be obtained on the vertical boring mill for that very reason.

Mr. Rowan very rightly warned the members to be careful in making too elaborate shop fittings and so forth; making the shops

too nice and comfortable. He did not know whether Mr. Rowan was fishing for a compliment or not, for if he was, he deserved it, and he proposed to give it to him. Mr. Rowan had one of the finest shops in the kingdom; he had a very fine fitted engine room; shops laid out with splendid floors—clean orderly shops; fine tool stores and factory fittings. In fact, from Mr. Rowan's warnings and criticisms he rather thought he had a good thing, and would not mind throwing his competitors off the scent. Speaking of that question, which was certainly important, and one in which all mechanical

FIG. 35.

Boring and Turning Mill Table, with Conical Bearing. (Bullard.)

engineers were interested, one was always met with the statement that it did not pay. It was a large question. But the thing was, whether a man wanted to fit up his shops better or not, he would have to do so before long. Conditions were changing. The engineering business was not the dirty trade it was thought to be by some. To his mind it was one of the highest professions to which men could apply themselves. It must not be forgotten that good shops, good surroundings, good fittings, comfortable clean places, helped to retain a good class of employees, a matter with which there was always some difficulty. If good men were to be retained, they must be given good salaries. The standard of living was increasing, the workmen demanded much more than they did

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even ten years ago. They must have better surroundings, better pay, and better facilities. Education was creeping in, giving the workmen new ideas—and very rightly, because it was progress. Wages were increasing. The purchasing power of money was increasing. All those things pointed to the necessity, whether a man would or would not, of making shops better. He thought it would pay very well to consider the question. Another point was with regard to the heating of the shops, and keeping the tools and machines in good condition. He hardly thought it could be proved, but some cases were very glaring in the impossibility of keeping plant in good condition, on account of moisture, which rusted and destroyed everything. Another advantage in having up-to-date shops was that it put one in a better position to deal with business, both in good and bad times.

Mr. Rowan made a statement that he could not understand how one foreman could take charge of 40 to 50 men, and the author thought that occurred owing to his looking at the matter from too narrow a standpoint. It was very easy for one foreman to take charge of 40 men in a light manufactory and very often even more, but perhaps 50 was about the limit. Mr. Rowan was rather indignant to think that a foreman worked for 50s. a week. He himself was very pleased by that, because he thought it was a hopeful sign. He wished Mr. Rowan's indignation would extend to every member of the Institution and every shop in the land, until such a thing as a 50s. foreman did not exist. He must say though that it was not a fact. He knew, and many of the members would confirm it, that it was the deliberate policy of many manufacturers and employers not to pay more than 45s. He had confirmed that by enquiries of large manufacturers. He did not approve of it. If it was done, he thought it would be soon learnt that it was not the most economical way of managing. Mr. Rowan further made a false assumption from a statement in the Paper. He assumed that the author had said that Americans were not in the same street with this country (page 43). The quotation from the Paper was as follows: "There is a widely spread and erroneous idea, particularly amongst European manufacturers who would

emulate American manufacturers, that the latest methods cannot be economically adopted except where work is 'thoroughly standardized, specialised, and made in large quantities.' That was mentioned not to show the superiority of anybody, but simply to bring out an idea with which he came in contact constantly when dealing with manufacturers. He was met with the statement again and again that new methods, modern methods, could not be adopted—many of which were adopted in America—except the full American idea was adopted of manufacturing enormous quantities, putting down special plant, and standardizing everything. The statement suffered from brevity like a good many others in the Paper, but the idea was to show that that was not the fact. Many labour-saving appliances could be adopted without changing the product of the shop in any way whatever, and many instances could be brought up to show that. For instance, it was easier and cheaper to finish cylindrical parts by grinding than by turning them. How many shops had grinding machines? It was far better and cheaper to bore holes with a good chucking outfit; yet how many shops had that department? It was far easier to turn the work to limit gauges than standard gauges, and yet how many shops adopted that? It had nothing whatever to do with standardizing or special output. His idea in making the statement was to bring that fact home. He had seen many cases, and he thought one was worth citing without mentioning names. He was recently in a shop where they were turning a very large shaft with a great many different diameters on it, and he said he thought the work could be done much easier and much more cheaply by using limit gauges than by carrying a piece sometimes weighing 200 lbs. and fitting the shaft into it. "Well," said the gentleman, "look at the number of diameters on this shaft—how many gauges should I have to have?" The author said, "You had better go to your drawing-office and reduce the number of diameters and then you can adopt gauges easily." There was nothing radical about it; it was simply common sense.

Mr. Rowan further stated that he thought the apprenticeship arrangement as far as engineering was concerned in this country was very good, and did not agree with what was stated in the Paper.

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Again, he thought Mr. Rowan had in mind heavy work, where the apprenticeship question was not felt perhaps as acutely as in the light manufacturing where labour-saving machines were more largely adopted. Manufacturers all over the country were feeling the question very much, the difficulty of securing intelligent progressive workmen in their shops, and he was sure it went back very largely to the apprenticeship question. In doing heavy work where it was simply a matter of a forge tool and a heavy machine, he thought the apprenticeship question did not call for changes as much as it did where fine tool work was depended upon. Experience showed that there was a very wide-spread interest in the matter. He asked Mr. Rowan how many apprentices were trained in the thorough understanding of turret machine work, cutters, milling work and grinding work? How many were thoroughly acquainted with proper boring and chucking systems? How many had an opportunity of practising on jig work; how many went into the tool room to work? All those questions affected labour-saving machinery, especially in work of a light kind, and he thought apprenticeship methods were sadly wanting in giving training on thorough modern lines. He desired to call the members' attention to an Address * which had been just delivered in Manchester by Mr. E. G. Constantine, in which he made very strong statements.

Mr. Rowan stated that his, Mr. Orcutt's, Paper implied an absolute want of knowledge of machine methods in this country and complete confidence in America. He hardly thought that was a compliment. The inference was entirely wrong, and would not bear the slightest investigation. There were many good shops in England, and many bad shops in America. He had taken the best he could from each. One point he thought the members would agree with him was that very few shop managers were acquainted with all the latest shop methods and arrangements. He found that shop managers were as a rule men who rode hobbies, and did not get outside of them enough to attack the question generally. As several of the speakers had shown, it was a very

* Transactions, Manchester Association of Engineers, January 1902.

wide question and an endless one. He wished shop managers could get away from their narrow lines.

Mr. Adamson (page 56) thought the Paper had overlooked the spindle grinding in textile machine work, and he showed a sample of spindle grinding which in itself was a wonderful piece of work, but was hardly relevant to the subject in hand. It was a sample of ancient rather than modern work, having been done on the grindstone by hand instead of on a grinding machine with limit gauges. As Mr. Adamson had testified, they did not know the limits they were working to; they had been making the things for years, and the great skill they had acquired enabled them to turn them out accurately without any modern plant. He was thoroughly acquainted with that work, and considered it a wonderful operation, showing what the skilled hand could do. Like other operations grinding was not new. It was one of the oldest of all. To bring forward that sample, however, was hardly to the point. Mr. Adamson further mentioned turret lathes, and seemed to imply that the Paper overlooked that lathe in the textile industries, particularly in the Manchester district. Mr. Adamson said he had seen turret lathes which had been in use for twenty years. He thought he could show Mr. Adamson some that had been in use for fifty years or even more by the look of them; but they were not modern turret lathes. The turret lathe was not new, any more than the grinding machine. But the modern turret lathe was certainly new, and not as widely used as it should be. Mr. Adamson further wished for an explanation as to forging versus turning. A statement was made in the Paper that in many cases it was three men working on one piece and in others one man working on three pieces. The whole subject of roughing down in the lathe versus forging should be studied carefully. One method might be suitable for one shop, the other again in another. Mr. Adamson seemed to think that the waste of material in turning and reducing pieces was a formidable thing to consider, but the author thought it was as a rule one of the least items in connection with the matter. Mr. Adamson also said that the forging plants were something worth looking at in some districts in England, but he thought Mr. Adamson had made a very unfortunate reference, for of

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all the equipment the author had seen in this country, some of the forging plants for light work were about the worst.

Mr. Donaldson (page 58) brought out some very good points, one of them being that he thought the data mentioned would not bear very close comparison with work in this country. It did not, and was not intended to, but the figures given in the Paper as to speeds and possibilities of turning were possibilities which should be aimed at, and if they were fallen short of, an effort should be still made to come up to them. A great deal of machine work in England was capable of very much improvement if the details were studied. Some of the figures given in the Paper were taken from English practice.

Mr. Donaldson said that a great deal of work was done unaided by tools and machines, which could be done much more cheaply if the proper equipment was at hand. That was true. In many cases where very close work was done, it could still be done cheaper and better if a proper equipment was available. He had had many instances of that. A gentleman who was present that evening had to turn a great many pieces of one sort, and had been turning them to standard snap gauge, but recently he worked with a limit gauge, and gave the work to a cheaper employee, one who had had little experience compared with those who had previously done the work. He found that with the limit gauge piece after piece was turned within 1-10,000ths of an inch, and without any trouble. Before the limit gauge was used, the man was continually questioning and asking if it was close enough to gauge, but with the limit gauge he had no questions to ask, and was doing far finer work.

Mr. Donaldson then brought up the question of soft material (page 59), which was certainly an important matter. The practice of either the Americans or of the English might be condemned or lauded. Both had their faults and each might take a lesson from the other. The greatest fault he thought existed amongst English manufacturers: while the Americans made castings many times too soft, the English made them too uniformly hard. The lack of a laboratory and testing equipment did not enable them to vary the mixtures according to the work. For instance, in steam-engine

practice, in cylinder work, it was perhaps necessary to make the parts hard. But a fly-wheel or other parts might be as soft as possible and could be very easily machined, if they were of a quality that would permit fast cutting. The modern foundry, when large enough to afford it, should support a laboratory by which the mixtures could be varied in accordance with the work, which would result in a large saving on a great many parts, and would give the uniformity that would allow maximum speeds and feeds. Mr. Donaldson further mentioned the difficulties of putting the shops in order by introducing new methods. That was very often done much cheaper and much more easily than was imagined. The author would never advocate anything revolutionary or any big change all at once in any shop, as any endeavour to do that was apt to be disappointing. The first question to be decided was whether a thing was good and whether it could be used, and then the attempt to use it could be made, not in too wholesale a manner, but by altering one detail after another. That would certainly lead to the progress which was to be desired, and without any very great expenditure at first. Besides, it afforded the great advantage of training the men while introducing the new methods, and that part of the matter was always a difficulty. The man must be taught to understand the machine he was using. Mr. Donaldson commended the adoption of the gauge system and appreciated it as much as anyone with the class of work he had to do. With regard to the tool-room, Mr. Donaldson commended it unreservedly, and he was certainly in a position to appreciate that matter. He brought up one point which he, the author, could hardly agree with, although in some cases it would be right, namely, that the tool-room should make everything. That was not true, especially of small shops where they could only afford to maintain a tool-room just sufficient to deal with their special needs, whereas if they went in for wholesale tool-making, they would find themselves behind and waste their energies in making things they could purchase much more easily. Colonel Crompton (page 62), who had a different class of work to deal with, took the opposite view to Mr. Donaldson.

Mr. Donaldson referred to the apprenticeship question, and in answering him he would reply also to the question raised by Mr. Wright

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(page 81). The apprenticeship system of 100 years ago had its virtues. In the old guilds, which were formed for the protection and the monopoly of trade, the features of the apprenticeship embodied in that system were certainly in one respect commendable. One of the most important points was the constant contact that the master had with the apprentice, a thing which scarcely existed today under the factory system. The apprentice lived in the master's house; ate at his table; learned his trade under his master, directly taking his instruction from him; and those were things which did not occur very often at the present day, although such a system should be carried out to a far greater extent than was done. That was one of the good sides of the old system of apprenticeship which might be applied to modern methods. One of the bad sides, which had been handed down from practically the Middle Ages, was the time which apprentices were required to serve in engineering. It was determined that the seven years was none too long to learn a trade, and that view was still held. Why, he did not know. With modern machines a man in a few weeks very often attained a proficiency which it took years to reach before these machines were introduced.

He thought it best to give a short summary of the apprenticeship system which his own works had introduced, and which others had introduced, and that would deal with the question raised by Mr. Wright. There were several courses which apprentices might take. They might choose to become a general mechanic, tool maker, fitter, or a pattern maker, &c. For the machine constructor there was a course of four years. He had eight months each in fitting, turning and screw machine, planing and milling department; the remainder of the four years was divided between erecting, grinding, gear-cutting, smith shop, pattern shop and foundry. The fitter had eighteen months in the fitting department, the remainder of the three years' term being spent in the turning, planing and milling, erecting, gear-cutting, and smith shop. The tool maker, the man who kept the tools and plant in order and maintained the efficiency of the factory generally, had twenty-four months in fitting, the remainder of his three years being spent in the turning, screw, planing and milling, grinding, polishing and smith shop, and in

tempering. The turner had twenty-four months in turning and the screw machine department; the remainder of his three years being spent in the grinding, fitting, and smith shop. The planing and milling apprentice served three years similar to the turner. To become a smith, the apprentices worked also in the hardening and tempering room. The pattern maker had to serve six months in the foundry, and the moulder six months in the pattern shop. That general knowledge was necessary to give the apprentice the means of making his choice when he decided upon his speciality later on. It was the lack of that general knowledge, a knowledge and understanding of each other's departments and work, which caused a great deal of trouble in the shops.

Mr. Thornycroft was kind enough to make a few remarks on the Paper, and especially recommended the chucking system which was most wonderfully neglected in this country; and he was glad to see that Mr. Thornycroft thought well of it. Mr. Thornycroft also alluded to the fact that the general system mentioned could be adopted in a larger number of shops than was generally thought possible.

Colonel Crompton, in dealing with the Paper, first emphasized the viewing department, and that was a matter well worthy of consideration, because if operations and work were to be specialised, the responsibility was largely taken out of the hands of the workers, and that responsibility had to be placed somewhere. Its proper place was in an inspection department. Colonel Crompton also dealt with the tool-room question, taking the opposite view to Mr. Donaldson, as his works were different. He, the author, more thoroughly agreed with Colonel Crompton generally speaking than with Mr. Donaldson. With regard to portable machines, which were important for heavy work, engineers dealing with heavy parts should give attention to the matter, as it was extremely important. Colonel Crompton made one statement with which he could not agree, namely, that the fitter was going out of date. That was not true, and never would be true. Machines might be obtained which performed very accurate work, but that was a long way from getting rid of the fitter. The only thing possible to do was to reduce the fitter's work as much

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as possible, which meant economy in manufacture, but the fitter had to come in for the last touches, particularly in fine work and higher grade work. Repeated attempts had been made to do away with the fitter's work, but in the final fitting, for instance, of sliding surfaces, nothing had yet been found to equal the scraping by hand, or the fine work necessary when dealing with spindle manufacture. The spindles were lapped as truly spherical as possible. The bushes were all bronze and they were formerly scraped at once after they were rimmed; but now they were rimmed and ground, and by the grinding about six hours' work was saved in the scraping. That was a sample of reducing fitters' work. He thought Colonel Crompton was on the wrong tack, as in certain work it would be always necessary to rely on the fitter, and he himself would not like to see him go.

Mr. Weir (page 66) dealt with the Paper in a somewhat critical mood, but brought out some good points. He stated that it suffered somewhat from dealing with light manufacturing, and made the statement that the greater part of the work of this country was dealing with heavy manufacturing. The author had been unable to find any figures which would verify or condemn that statement, but he had a few which bore upon it, and his impression was that Mr. Weir was entirely wrong. In referring to the trades union list, he found in the total metal engineering and ship-building trades in the union, which only represented about a quarter of the workers of the country, there were 338,000 members. Out of those trades, which he should judge would be the large heavy work, there were 65,000, and of the amalgamated engineers there were 87,000. Adding the heavy trades and the amalgamated engineers together, it was even then less than half of the mechanical workers in the union, and he thought it would be safe to say that not more than one-third of the mechanical workers of this country were in heavy trades. That was worth bringing out, because the labour-saving machine and the great changes which must occur dealt more largely with light engineering work than heavy. In the heavy work the tool itself was very often merely a forged piece, while in light manufacturing the tools themselves were everything. Mr. Weir had a very fine shop, which

he had seen a number of times, and he was very glad to have Mr. Weir's confirmation that a good floor actually paid, because that was so often doubted. Those who saw Mr. Weir's shop, and saw the wonderful order in which it was kept and their stores system, would no longer doubt its advantages. Many shops had no floors whatever, and he hardly thought that paid. Mr. Weir criticised the shop railways as useful only for heavy parts. He thought Mr. Weir was wrong, as a proper railway system throughout works, properly equipped, with the right trucks and specially worked-out rails, certainly did pay. The experience of many was quite the reverse of Mr. Weir's.

With regard to the space secured by order and cleanliness, that was another question on the subject of whether it paid to keep a shop in order and clean. He thought it did, and he thought the experiences of many would confirm that view. He had been in two shops only that week, and one was a very great contrast to the other. In one of them when he came out of the works he hardly knew what he had seen, there was such a pile of scrap and old machines, and dirt and dust. In the other it was quite different. It could be seen at a glance what was the quality of work being done and how it was being done, because everything was in order and the shop was clean. Mr. Weir also commended the general shop fittings in the way of work benches, stands for work, and facilities for holding parts, which were certainly worth attention. Many a good machine was unprofitable because it was in bad surroundings; and of course many bad plants were made profitable by keeping them in good surroundings. He also dealt with the question of the vertical boring mill, and had the same antipathy to it that Mr. Rowan had. Mr. Weir stated that for chucking operations the face-plate lathe appeared as good as any other machine, but appearances were very often deceitful. Some work was good for the horizontal machine and some was good for the vertical, and it was the same with the milling and planing. It was necessary to discriminate; but Mr. Weir forgot one point. He thought that the extra power gained in the mill was not of much advantage, but he should not forget that the heavy cut was not the only thing that absorbed power; high speeds and light cuts absorbed

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power also. Mr. Weir also mentioned the studding machine, which was worth bringing forward, as some of the work done by that machine was the smartest he had seen. It was a wonder to him it was not adopted more extensively, but Mr. Weir should also remember that others did the same work with the multiple drilling machines, drilling all the holes at once, and they made the same claims as to economy that he made for his machine.

Mr. Richardson (page 70) was another critic who brought out a few good points. He thought the Paper seemed to be a criticism of English methods, but that was not intended in any way, as the same criticism in many cases would apply to American shops or any others. Mr. Richardson further stated that the methods advocated were only possible where great repetition occurred. He had tried to explain that that was not so, and in the Paper he stated that those who thought it was were under a delusion. Mr. Richardson seemed to pose as one of the deluded; and said that so far as his experience went most modern methods had been adopted by leading works in England. He himself rather doubted that statement, without saying anything further. Again, Mr. Richardson stated that Americans overdid their specifications to magnify accuracy. That was a great mistake generally speaking, and he could claim some knowledge on this point. He thought that many times the aim of the Americans was to see what bad work they could do, and still have it good enough; and that was not a bad idea. Work that was better than good enough certainly was not economical and not called for, and one of the means by which the American did his work just bad enough to have it passed was the adoption of tools and gauges which would assist him to do it. It might be often noticed by visitors to the States that the American, with all his instruments, was doing in some cases work worse than was being done in this country, simply because he thought it was good enough.

With regard to Mr. Ransome's remarks (page 74), he specially commended the spirit in which he had criticised the Paper. If all the Papers read at the Institution were looked upon in the same manner, more would be obtained from them. Mr. Ransome asked how the high speeds of the milling cutters were obtained in the

special case given. In that special case the iron was soft, and there was no call for the iron being hard. It had nothing to do with cutters. The speed mentioned gave a very good finish. Then he asked for the different speeds of planing machines. It was certainly a good thing to have different speeds, and it was very easily arranged by a variable speed counter-shaft. Then there was electric driving. He himself had seen a whole department of planers fitted with variable speed counter-shafts, and a great saving was claimed. Mr. Ransome also asked as to the quality of finish in fast grinding work. He thought he needed no other instance than the sample shown of the Corliss valve, Fig. 31, Plate 8, which was ground in thirty-seven minutes with an error of 0.0005 inch in length, and in diameter an error of 0.002 inch. Nothing more accurate could be required. It was a remarkably fast speed, of course. Mr. Ransome mentioned the collection of 5½ tons of cast steel when he established his tool stores, and that was a matter to be noted. Shops were often equipped with double and treble the amount of tool steel and tools required, simply because they were not kept in order, each man having his own kit.

Mr. Carnegie made one very good point (page 79) in stating that a distinction should be drawn between tool-rooms and tool-stores. Many manufacturers seemed to confuse the two, and some to think they were inseparably linked together. In many cases, especially in large shops, they had nothing to do with one another. Tool-stores were for the handy distribution of tools, and the tool-room was for the keeping up of the tool outfit.

Mr. Hill asked for the name of one shop in this country where one man attended six milling machines (page 79). He had the permission of the manufacturers to give their name, namely, Messrs. Hutchinson, Hollingworth and Co., of Dobcross. That firm had both union and non-union men in the works. Mr. Hill further asked why it took forty-five minutes to grind a certain sample shown, Fig. 31, Plate 8. That was an exception. It was a hollow tube very thin, and in fast grinding the pressures were very great. Forty-five minutes for this piece of work ought to satisfy the most exacting.

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He thanked Mr. Chambers and Mr. Hurry Riches for their remarks, and agreed that it was necessary to make improvements in one department at a time. By the time the whole of the departments had been gone through, it would be found that the first required further improvement, and so it would go on. Progress could only be made by the continued study of details. With regard to Mr. Wright's remarks on the apprenticeship question, he hoped he had given him a satisfactory answer. With regard to the grinding mentioned by Mr. Hurry Riches (page 82), he was glad to hear that this work was being done. The grinding mentioned in the Paper and shown by the samples was really the most revolutionary thing with which he was acquainted in workshop practice. Most workshop improvements were merely in detail, confined to putting in a good machine or tool here and there, and increasing the speed, &c.; but the grinding was really promising a revolution on account of the very fast speeds with which it would finish work. It came to this, that the equipment of any modern shop, where cylindrical surfaces had to be dealt with, must be altered very largely. Instead of considering how many lathes were to be put in, the question would be how many lathes and grinding machines. Mr. Hurry Riches had brought up the point of the smith shop versus the machine shop, and that, of course, must have consideration as well as other problems. He had rarely seen what he considered a good cutting-off department, an up-to-date one. In his own shops one man attended four cutting-off machines. The parts were cut off very cheaply, and in many cases it had been possible to do away with smith work, and do the work much more cheaply by systematising the whole thing.

In conclusion, he wished to thank those who had discussed the Paper, but would like to criticise the critics. It was said he was too general, but he thought his critics were too specific. Most of the critics had taken the standpoint of a special line, thinking of their own work too much. He had tried to avoid that in the Paper, and it only pointed to the fact that the knowledge of manufacturers was usually not general. They did not visit each other's works enough or exchange ideas enough, or open their places freely to those who wished to acquire information and see how things were done. How

many marine engineers thought they could learn anything in a cycle factory? Yet they could. He had never seen a shop yet in which he could not learn something. It was marvellous how many good things were hidden away in very bad shops. He hoped English engineers would change their practice somewhat. They were not liberal enough in exchanging ideas, visiting shops, and throwing open their method for the inspection of each other. If they would do that, it would be to the general good of the whole nation. He now came to the point which might satisfy some of the critics, and wished to state very briefly how he would classify the situation in English engineering. First, he would say that they were advanced in heavy milling, heavy planing, fast turning, and as skilled workers in many lines like ship-building, marine engines, high-speed engines, locomotive work, textile machinery, and cycle work. No one could excel them in those matters, and no product was superior. He thought that was glory enough for one country. Coming to the criticisms, those points which were generally understood but not well advanced were light milling, turret machine work, vertical mills, gear-cutting, which was very rapidly developing. Those points which were neglected by the majority of shops were gauges, chucking or proper boring outfit, grinding, tool-room practice, and use of small tools, and the apprentice question as applied to modern conditions. The next point was those things which were rarely attended to, which included the analysis of material, good shop fittings, and comfort and convenience for men. Those were dealt with in the Paper. There were two more points, which rarely received attention, first, the system of rewarding labour and cost-keeping, and, secondly, the social and economic conditions as affecting the efficiency of workers.

On the motion of the PRESIDENT, a hearty vote of thanks was accorded to Mr. Orcutt for his Paper and reply to the Discussion.

Communications.

Mr. WILLIAM DEAN, Member of Council, sent some memoranda describing the extent to which grinding machinery was in use at the Great Western Railway locomotive works at Swindon, and also furnished particulars of the leading descriptions of machinery.

The tyre grinding machines, referred to by the President (page 81), had been originally introduced to deal with the hardened steel-faced tyres, which had been brought into use about fifty years ago by the late Sir Daniel Gooch. Those tyres were superseded by the solid steel tyres, which had since been procurable; these they were able to turn with the high class tool steel now available, so that the use of the tyre-grinding lathes had been discontinued many years since.

GRINDING.

Slide-Bar Grinding Machine.—All slide-bars are ground. The machine is of the planer type. Upon the bed a box frame is bolted, which holds the slide-bar and also water, which just covers the bar. The work is passed under the emery wheel at a speed of about 12 feet per minute. A side traverse is given to the wheel, and is so arranged that its course is altered at each stroke of the table. The wheels used are of medium grain, and are 12 inches in diameter when new, with a width of 4 inches. Speed is 1,650 revolutions per minute, giving a surface speed of about 5,000 feet per minute. The time taken to grind a bar to a good face is about $1\frac{1}{2}$ hours. The number of bars ground by each emery wheel is about 1,000, the wheel losing 3 inches of its diameter during the work. It is found necessary to keep the bearings always well adjusted, and the water clean.

Piston-Rod Grinder.—The best machine in use at Swindon for this purpose is one in which the rod, which is supported by dead centres on a travelling table, is traversed in front of the emery wheel. The wheel frame being rigidly fixed, the machine is arranged with two stones—one fine, the other medium grain. Either of these can

be brought quickly to the working position without shifting the belt ; this is a very useful feature, as it is possible by this means to use a roughing and finishing wheel. The roughing wheel is, as a rule, only brought into use for a badly scored rod. Care is necessary to get the best results. For instance, if enough water is not used, the side of the rod which has most to come off gets warmer than the opposite side, and it buckles, thus increasing the amount of metal removed from the heated side ; an oval rod is the result.

Countershaft pulleys should be balanced to prevent vibration, The piston-rod is driven by a Clements driver, which ensures an equal drive from two opposite points. Rod revolves at about 140 revolutions per minute. Diameter of emery wheel when new is 1 foot. Revolutions 1,600 per minute. It takes $1\frac{1}{4}$ hours to grind $\frac{1}{8}$ inch off a steel piston-rod 3 inches diameter and 3 feet long. Speed of traverse is about 6 feet per minute. It has been found that if the stone has been run much above 1,600 revolutions per minute that vibrations occur, and show up on the rod.

If the speed is much below 1,600 revolutions per minute, flats are likely to occur on the rod.

Cutting Tools.—All the tools used on turret lathes, automatic and semi-automatic machines, are ground to special patterns, which are supplied by the makers of the machines. No one but the man in charge of the machines is allowed to do any grinding on them. The results are very satisfactory, and the tools last longer, and do better cutting than most of those ground by hand. A rectangular section of tool steel is used, and the tool is generally formed entirely by grinding, doing away with forging, unless for special shapes.

Turners are prejudiced in favour of grinding their own tools, but after a little use they see the superiority of machine-ground tools, and prefer to use them.

On the Gisholt tool-grinding machine, the emery wheel runs at a speed of 1,800 revolutions per minute. The stone is 9 inches in diameter at its largest part. Surface speed is about 4,500 feet per minute.

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Lapping Machines for lapping out holes in case-hardened motion work. This work was formerly done with an ordinary lead lap run between lathe centre, and fed with emery and oil. The lapping machine has successfully replaced this. The main vertical spindle is bored eccentrically. In this is supported a second spindle, which is also bored eccentrically. In this hole runs a well-fitting spindle, upon the end of which a small emery wheel is fixed. The eccentricities of the two larger spindles are equal. It is possible to so lock the intermediate spindle with respect to the outer spindle, that the axis of the inner spindle shall coincide with the axis of the outer one, and, the whole system rotating, the emery wheel will simply revolve upon its own axis.

Should it be desired to lap the largest hole within the capacity of the machine, this is effected by so placing the spindles that the two eccentricities are added together, and the radius of the circle described by the axis of the inner spindle is equal to their sum. Hence, by adjusting and locking the two outer spindles, holes whose radii differ by amounts lying between zero and the sum of the two eccentricities can be lapped with the same wheel, which, revolving at high speed, is slowly carried round the surface of the hole. The spindle is also moved up and down vertically, so that the emery wheel shall come in contact with all parts of the work, so that there are three motions to the machine:—

1. Rotation of the small grinding spindle.
 2. Slow rotation of the main spindle to carry the wheel-spindle round the surface of the hole.
 3. A vertical motion.
- Cutting speed of wheel, about 5,000 feet per minute.

Disc Surface Grinder.—One of the most useful grinding machines they have had is the disc grinder. It is used in the tool shop for grinding up surfaces true and square with each other or at any angle that may be required. Emery cloth is secured to the face of the discs by glue, and it gives excellent results. Different grades of emery are supplied. The diameter of the discs, which are detachable, is 1 foot 6 inches, and speed 1,200 revolutions per minute.

Great Western Railway.
Grinding Machinery at Swindon Works.

	Locomotive.	Carriage and Wagon.
Grindstones 6 feet and over.	23	8
„ 4 feet and under	27	17
Emery Grinding :—		
Tools	27	13
Twist Drills	5	4
Milling Cutters	2	2
Dressing Castings	7	—
Tubes	2	—
Polishing	2	—
Piston Rods	3	—
Nuts, &c.	1	—
Double Lapping (Case-hardened Work)	1	—
Lapping, &c.	1	—
Bench Grinders	4	5
Knife Cutters	—	1
Plane Irons	—	1
Circular Saws	1	—
General	7	1
Mould Irons	—	1
Links, &c.	1	—
Emery Filing and Finishing :—		
General	—	1
Tube Ferrules	2	—
Emery Band	2	—
Cock Grinding	1	—
Buffing	17	3
Slide-Bar Lapping	12	—
Saw-Sharpening	1	4
Whetting Stone	—	1
	149	62
Total	211	

Piston-Valve Grinding on Landis Machine.—These valves, $6\frac{1}{2}$ inches diameter, gave a lot of trouble at first to grind them fine enough for the purpose for which they were required. They are put into the

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bushes a gauge fit. A steady was used on spindle, but with this the results were not satisfactory. The present method, which gives every satisfaction, is as follows :—

A steady is used on the spindle at A, Fig. 36 (page 106), and the portion at B is ground true for about $1\frac{1}{4}$ inches wide. The steady is then removed to position B, and the grinding proceeded with. A thin wheel about $\frac{5}{8}$ -inch thick is found the most suitable, giving better results than those of greater thickness.

Water for keeping the work cool is taken direct from the main, it having been found that if the water was used over and over again, as

FIG. 36. *Grinding Piston Valves.*

is the case when the supply pump attached to the machine is in operation, that a certain amount of grit got on the wheel which caused cutting.

Disc Grinding Machine with Renewable Burrs.—Used for grinding angle iron and other parts of engine frames. The work is traversed across the face of the stones. Nine stones are let into recesses in a disc, and secured by wedges. The wheel revolves at about 800 revolutions per minute. Its diameter is about 2 feet 6 inches over the stones. The bed of the machine has a pivoted table mounted upon the travelling bed. By this means it is possible to present the face of the work to the stones at any desired angle.

Mr. RICHARD B. HODGSON, in congratulating the author on his Paper, wrote that he thought the subject was a difficult, important, and far-reaching one; and it was really remarkable how much valuable matter the author had compressed into so short a space. For convenience he had tabulated his comments, which were intended rather as confirmation of, and addition to, the author's conclusions than a criticism of his work.

Gauges.—For some years past manufacturing engineers had taken advantage of the various forms of gauges, particularly the use of the micrometer for measurements. It was astonishing, therefore, that manufacturers generally, particularly those engaged upon metal-working and the allied trades, had not given more attention to the subject of standardizing their methods. The importance of this was brought forcibly under the writer's notice recently, in relation to the present system of gauging wire and rolled metal sheets. He found that between twenty and thirty wire-gauges, each differing from the other, were now being used in British and American factories; and, considering that each of these gauges was held by one manufacturer or another to be a standard gauge, it would be seen that a great deal of inconvenience and trouble arose when manufacturers were working one with the other. A glance at the gauge table, which he had previously published,* would convince an engineer how great were the troubles that nine gauges would give by their irregular numbers. He would like to know why the Whitworth standard had not long ago been adopted for sheets and wire, or any other work where fine measurements were required.

Grinding.—The use of emery grinding machines has become so extensive in all modern works, and the technical press has given so much attention to American machines of this class, that it was interesting to note British manufacturers were now producing some very smart grinding machines, one of which† provided for a plentiful supply of water to the work when being ground, without detriment to the working parts of the machine.

With regard to grinding flat surfaces, the author would probably know that machines were in successful operation at several large engineering works, dealing with large hardened flat surfaces.

Polishing.—As illustrating the downfall of the engine-lathe, "turners polishing and lapping their own work," the writer knew of one engineering works that made a speciality of steel mandrils used

* "Practical Engineer," 20th September 1901.

† "Engineering," 6th December 1901.

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for drawing German Silver tubes; these mandrils were some 6 to 8 feet in length, and when turned must be polished or lapped, until absolutely parallel and without a scratch upon them. This was carried out in the engine-lathe by using powdered emery and a lead-ring in the form of a clamp, an operation which frequently occupied from twenty to thirty hours. This was an unfortunate waste of time, as compared with the operation mentioned by the author (page 21), where a shaft, 4 inches diameter by 3 feet long, was ground and finished in six minutes.

Drilling and Jig Work.—The manufacture of a cycle or motor-car driving-chain was a good example of what could be accomplished in a good drilling machine, aided by the use of a suitable jig. Such work of course required to be performed within 0·001 or 0·002 inch limit; for taking a block-chain of 1 inch pitch and 52 inches long, which contained 104 holes, a variation of 0·001 inch in each hole would result in a chain being one-tenth inch longer or shorter in the whole length. In some instances, with female labour, this class of work was actually carried out with remarkable rapidity, and so accurately that fifty chains were assembled to their total lengths and did not vary more than 0·062 inch; this was a far better result than was expected from an experienced mechanic upon machine or tool-work, and it was obtained by the use of a small vertical sensitive drilling machine and suitable jig. A point to be observed was that to secure such accurate work in large quantities, it was absolutely necessary that the work be performed upon a vertical machine, and that each hole be drilled twice. The first or smaller drill was to be passed through the work by using the jig; the second or finishing drill might then be passed through without a jig, to ensure the holes being all of the same diameter. The principal points to be observed when drilling small work by jig were as follows:—

- (1) Drill to run perfectly true and at the proper speed.
- (2) Jig to rest loosely upon an horizontal table (not held in a machine vice).
- (3) A plentiful supply of suitable lubrication for the cutting of the drill.

(4) The drill or the work, as the case might be, to be fed forward by lever, pinion, and rack (not by screw and hand-wheel), as by using a hand-lever, the operator had more control over the drill, and less number of drills were broken.

Small Tools.—The use and advantages of a properly organised tool-stores has been so frequently demonstrated in engineering establishments, that it became the duty of British engineers to give expression to their experience in this direction for the benefit of manufacturers other than engineers and machinists. That there was a need for this was instanced by the fact, that in one large works, employing 1,000 pairs of hands, upon recently opening a workman's tool-drawer it was found to contain sufficient tools to supply the greater part of the factory. So deep and well stocked was the drawer that it exhausted six hours of hard work to sort and tabulate the various tools contained therein. This was the more urgent and important, since so large an amount of capital was invested in the tool-drawer of that particular factory, which might be otherwise invested if the works had its own organised tool-stores.

Tool-Room.—Many opinions have been put forth in the British technical and daily press concerning the struggle with American competition. But when the author said that "the very best skill and intelligence obtainable should be employed in this, the tool-room department," he introduced a question that had hitherto received scant attention, but which, if studied thoroughly, would fully repay the efforts of earnest attention, namely, that of the head tool-maker.

Having had the opportunity of studying closely both British and American methods, he could truly say that American engineers and manufacturers did make a practice of carefully selecting their managers, foremen, and heads of departments; they were also ever ready to encourage both the heads and under-workmen to bring intelligence into their work. Taking any first-class American firm, the following was found:—

(1) The works manager must be a thoroughly practical mechanic, or, in other words, a man who has "gone through the mill," having

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learned his trade and being able to compete as a journeyman, but not a man who, so to speak, has merely walked through the shops.

(2) The foreman, or head of each department, must be a man who was thoroughly up to his business; in fact, he must be able if necessary to take hold of the tools from any workman's hands, and instruct him how best to perform a particular operation.

(3) Each workman was paid according to his merit. There was no hard and fast rule as to standard wage; he was paid upon the principle that any workman who, by his superior intelligence, energies, and abilities, could execute double the work was naturally worth better pay. From this it followed that should the employer obtain men of this class, they not only were able to make better profits from the workman's labour, but the greater output was obtained without the use of additional machinery.

(4) At intervals the works manager, foreman, and heads of departments, met the general manager for an hour's consultation; at such times any new ideas, suggestions, and likely improvements, that might tend to benefit the concern and make larger profits, were discussed. Should any workman have a suggestion to make, it was brought before the meeting by his foreman, and properly thrashed out and recognised at the proper time. This and similar arrangements had the great tendency to bring about an esprit de corps between heads of departments and workmen, and created a feeling of individual interest amongst all concerned in the welfare and prosperity of a manufacturing establishment.

The Apprenticeship Question.—This was a very broad and many-sided question. Things have changed much during recent years, and improvements appeared so rapidly in the different branches of all professions, that it was absolutely necessary for each individual to specialise in his own line. As one who had had some experience both as technical teacher and as foreman of departments in various manufacturing concerns, he ventured to offer the following brief suggestions. Taking a youth of fourteen years, his advisers should be careful that they did not encourage him to have too many irons in the fire. He might study many sciences in their

elementary form, but when he reached the more advanced stages he would intuitively find himself deficient in the one science, mathematics, essential to the solution of problems which confronted him. It was not to be expected of any man that he should be a thorough master of both practical and theoretical engineering; it was necessary for the practical mechanical engineer to commence as a shop-lad and gradually pave his way from machine to machine, to find himself at the age of twenty-one years only just ready to go out into the world to engage on new sections, taking him all his time to keep pace with his fellow-workmen.

Assuming that a youth had received a fair school training, including a grounding in mathematics, and was intended to be a *practical* mechanical engineer, in addition to his special every-day working experiences, he should attend evening classes, and thoroughly study mechanical drawing and applied mechanics, giving as much of his spare time as possible to improve his mathematical knowledge. The youth, who was to become a *theoretical* engineer, in addition to his work in whatever special branch he might be engaged, could not do better than make himself a thorough master of mathematics and chemistry. Each would then have the foundation laid, after which they would be able to use their own discretion, as to what other sciences was necessary for their special branch of either practical or theoretical engineering to enable them to take their respective places in the engineering world.

MR. WILLIAM SCHÖNHEYDER wrote that he fully appreciated the Paper, thoroughly agreed with nearly all the author had said, and believed it would be of great benefit to many engineers. But there were just two words in it to which he would take exception, as they not only did not express the meaning which they were intended to convey, but also already meant something different. One word was "chucking," which was evidently intended to mean some process of drilling or boring or turning in a lathe (either vertical or horizontal), with sundry tools, such as twist drills (short or long), reamers, &c., so as to produce first-class work. But chucking already meant the process of securing firmly and truly any piece of work to be operated

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upon, no matter whether it was to be roughly or finely finished, hence appliances as "scroll-chuck"; "three-jaw chuck," &c. The other word was "screw-machine"; this the writer would take to mean a machine for producing screws, and not, as was evidently meant, a "copying machine," that is, a machine for producing exact copies from either a turned article or a flat template. These two words had been, he understood, introduced from America, and were certainly not objectionable on that account; but while he was fully anxious to see as many as possible of the best American machine methods introduced and applied in this country, he did not therefore see either a necessity or an advantage in the introduction of the two words mentioned. Either "boring" (or "fine-boring") and "copying" seemed to the writer quite correct and sufficient expressions.

Fig. 4. *Built-up Formed Cutters for Circular Milling.*

Rope Pulleys.

Belt Pulleys.

Bevel Wheels.

Fig. 5. *Circular Milling Machine at work.*

Fig. 6. *Samples of Circular Milling work.*

Fig. 7. *Milling a Lathe Bed.*

Fig. 8. *Template used in planing a Lathe Bed.*

Fig. 11. *Vertical Chucking Machine.*

Fig. 12. *Horizontal Chucking Machine.*

Fig. 14. *Jig, with tools and work.*

1. Jig.
2. Part to be jigged.
3. Boring Tool, with stop collars in place in jig.
4. Boring Tool and two Guide Bushes.
5. Double Reamer for finishing two holes of different diameters.
6. Extra hardened and ground Guide Bushes.
7. Facing Tools, with adjustable stop collars for regulating depth of cut.

Shop Features.

Fig. 17. *Tool Stand.*

Fig. 18. *Fitter's Bench.*

Fig. 19. *Bolt Rack.*

Fig. 20. *Shop Flooring.*

Fig. 21.
School for Apprentices.

Fig. 22.
Lockers and Washstands.

Machine Shop.
Fig. 23. *Heating Apparatus.*

Fig. 24. *Ceiling arranged for easily putting up Main Shaft and Counter Shafts.*

Fig. 25. *Drilling Machine for testing the hardness of iron, and record card to go with same.*

*Samples of Gauges, Boring Tools, and Circular Milling
exhibited at Meeting.*

Fig. 26.
*Limit and
Caliper Gauges.*

Fig. 27. *Boring and Drilling Tools with Fig.*

Fig. 28. *Circular-Milled Work.*

Samples of Grinding Work exhibited at Meeting.

Fig. 29. *Steel Spindles, etc.*

Fig. 30. *Steel Spindles, Cast-Iron and Gun-metal Parts.*

Fig. 31. *Shafts, Corliss Valve, and Axle.*