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RECENT ADVANCES IN TOOL CONSTRUCTION.

By Col. Alex. Bertram.

(Read before the Mechanical Section, 2nd March, 1911.)

In this paper it is the author's intention to speak more particularly of the early history of machine tool building as it has come under his personal observation, from his schooldays until the present time.

In 1861 there was in operation in the town of Dundas, Ontario, a small jobbing shop conducted by Robert McKechnie, a young patternmaker, who graduated from the Dundas foundry of John Gartshore, and who had struck out for himself in a small way, to carve out an existence in the then growing Province of Ontario. In the following year (1862) he was joined by a young Scotchman in the person of John Bertram, who had received a thorough training as a machinist, and these two founded the Canada Tool Works, or what is now known as The John Bertram & Sons Co., and started as builders of wood machinery, at the same time doing a jobbing trade with the local mills and factories. During 1863 the late John Bertram designed and built in that small shop what was perhaps the first engine lathe ever made in Canada, and from that date the designing and building of machine tools has been continuously carried on at the same place, but, of course, in much better fitted shops than the first small wooden building of those days. This first and somewhat primitive lathe had a swing of 12″ over the shears, and, with a 6′ bed, weighed about 600 lbs. The difficulties under which the lathe was built were greater because of the fact that the small shops had nothing in the way of means of planing the bed. This difficulty, however, was overcome at the Gartshore Foundry, where, also, the leadscrew was cut. The planer in use in that shop was a Scotch-built machine, and, of course, had a table of sufficient length to plane this bed without a shift. This lathe was finished in about six months, and a large portion of the small turning was finished by hand tool turning, as at that time there were few self-acting lathes, and certainly none in this shop. All the gears had cast teeth made from wood patterns, and even the change gears for screw-cutting had cast teeth moulded up in the same manner. The castings for this lathe were made in the Gurney Foundry, Hamilton. From this small beginning the partners of that business were encouraged to develop their business, and others also embarked in the same line, with more or less success. Mr. John Bertram was a mechanic of advanced ideas, and was never satisfied unless the development of his designs and the organization of his shop were ever on the advance. He at once adopted standards for shop use, in the way of Whitworth standard threads for taps and dies, and also inaugurated male and female, or what are now known as plug and ring gauges, for sizing the bore of wheels and pulleys, and for the turning of shafts. He also saw the necessity of cutting gears, and finally designed and built a gear-cutter. This machine was of the most simple form, consisting of a bracket bolted to the shop wall, carrying a mandril and a dividing plate. A man was trained to feed the cutter slide up and down. During the operation he very often made a slip and spoiled the gear. In those early days Brown & Sharpe cutters were developed, and from that time until the present day B. & S. cutters have been in constant use there for gear-cutting. All key-ways at that time were cut by hand, and it was remarkable how well this was done, and the time taken for small keys was not as far away from present-day methods, when setting up and preparing a machine to do the work is considered. To duplicate the key-ways in change gears for screw-cutting, a broaching tool was used. After the keyway was roughed by hand, the broach was driven through, thus producing a standard finish, which served the purpose.

His next step was to design a milling machine, Fig. No. 1, for cutting keyseats in shafts. All the movements were by hand, and the machine and its cutters are herewith shown. Since this date, in the early sixties, many changes have taken place toward improving the turning lathe. Then it was considered satisfactory to furnish a 24" lathe with a flat shear bed, having single ribs connecting the ways together, a headstock having a four-step cone, with a 2½" belt and a gear ratio of about 5 to 1. The spindle front bearing, 1¾ inches diameter, running in cast-iron bearings, all the gearing having cast teeth; a carriage or saddle with no power cross-feed, and a front apron fitted with running gears of the most simple

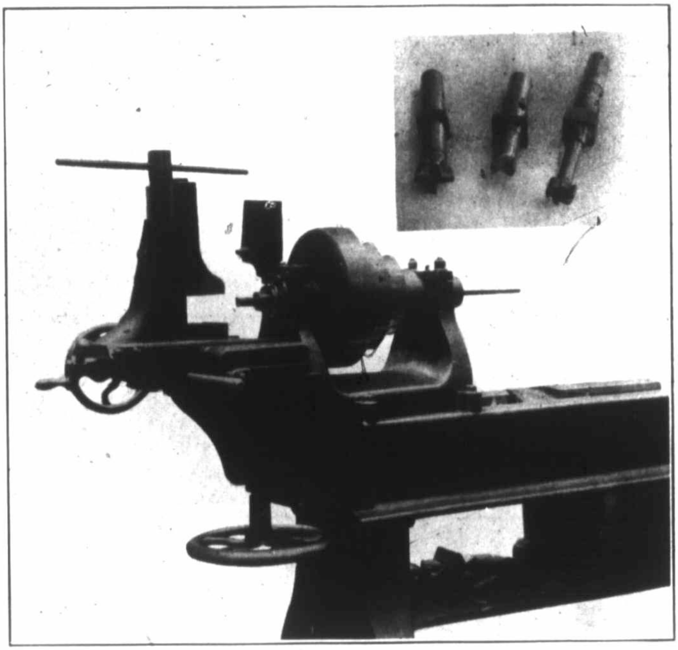
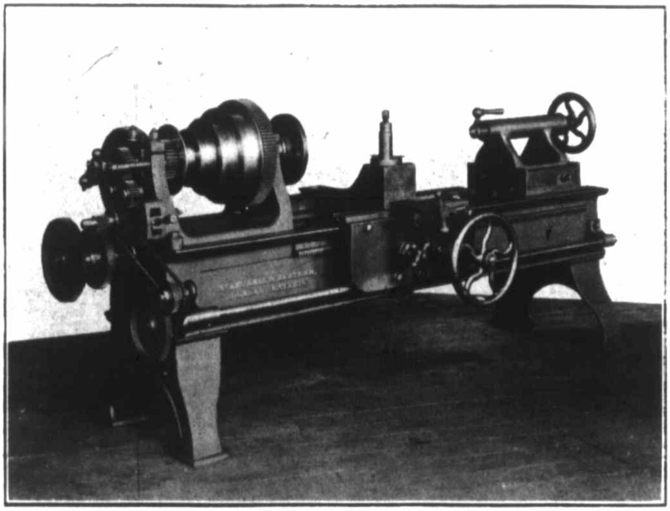


Fig. No. 1.



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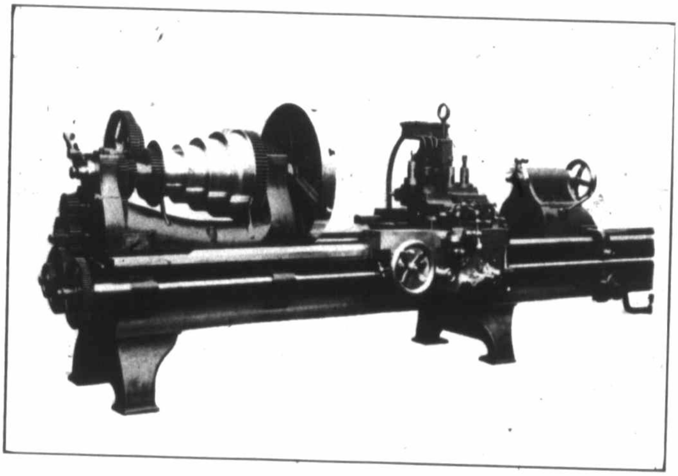

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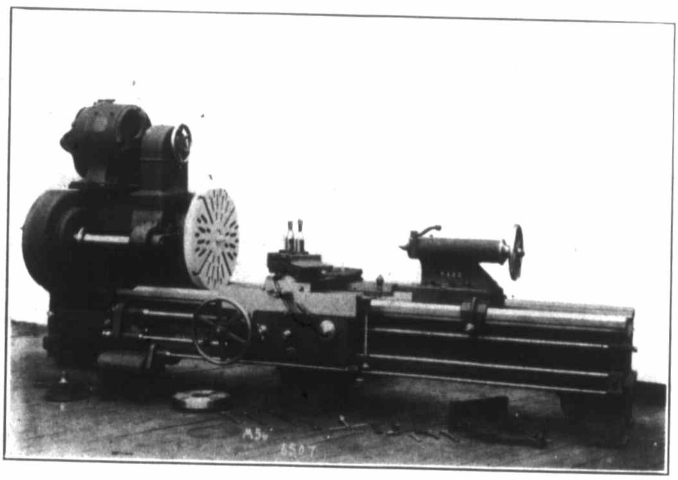

Fig. No. 4.

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type; a leadscrew nut of babbitt metal and tailstock fitted between the flat ways. Yet this was the condition under which the present high-speed machine was developed, and probably I am safe in stating that a greater improvement has been made in iron turning lathes than in any other machine tools in the large group of iron-working machinery.

In order to fully illustrate the changes, we shall show three designs of standard iron-turning lathes.

Fig. No. 2 shows the type of lathe built by this firm until 1885. This lathe is better known to the trade as the flat shear-engine lathe —that is to say, the top of the ways of the bed are a flat surface. The carriage or saddle carrying the tool block is gibbed at both front and rear to the ways of the bed, on which it has its bearing. These ways were planed to an angle of 55°. This lathe swings 24" in diameter, and it will be clearly seen how limited the cone and gear power was as compared with the powerful high-speed machine of the present day. Mr. Bertram having had his early training among Scotch and English machine tools, the designs followed were naturally more of that type.

In the early seventies two types of lathe head construction were freely discussed among mechanics in Canada. The one favoured largely by English practice, and termed the "conical" or "solid bearings," appealed to many by reason of its easy adjustment for wear. One element, however, seemed to have been overlooked, and that was the expansion and contraction of the spindle with varying temperatures. This difficulty soon decided the fate of the conical bearings as at that time constructed, for although some English makers hardened and ground both the spindle and bearing, this could not remedy its seizing qualities, and, therefore, the present parallel front and back bearing in lathe head construction has been adopted by nearly all builders.

Fig. No. 3 illustrates a standard engine lathe as manufactured by one of the American builders. In this design it will be noted that the saddle and tailstock have separate bearings on inverted "V's." This construction is favored for lathes of small size, but many leading American builders favour a flat bearing for the tailstock, which, when provided with proper adjustment for maintaining its alignment, is much more easily kept clear of cuttings.

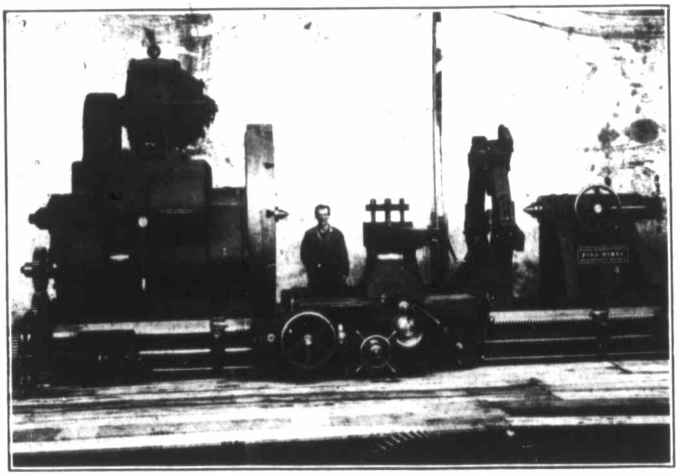
Fig. No. 4 illustrates one size of motor-driven lathe as built by the Bertram Company to-day. In order to economize in the manufacture of this machine, the construction is such that any stock machines may be converted from belt to motor, or *vice versa*, as required, and for that reason it is termed the "convertible type." The gear and cone ratio is such as to permit of the use of standard motors of variable speed, as made by all the electric companies, and when so arranged with motor drive attached to the running gear, the lathe head loses all semblance to that of the original machine, but it is fast superseding the cone-driven lathe in many of the leading machine shops. This is particularly so in the sizes running from a 30" swing and up.

There are many strong arguments favouring the motor-driven lathe. Several of the minor advantages may be noticed. First, the use of the motor does away with the overhead line-shaft and its maintenance. From the fact that belting and the line-shaft have been done away with, the machine may be placed to greater advantage in a shop, and in this way space may be economized. The range of speeds which are obtained by the variable speed motor through the drum type controllers enables the operator to arrange the cutting speeds to suit the material being machined. This arrangement of speeds is made possible by the fact that the operator, by moving the handle shown at the right-hand of the carriage, instantly controls the spindle speeds. This, of course, is a decided advantage over changing the belt on the steps of the cone-driven lathe. Again, in this, as in all motor-driven machines, the cutting speeds and feeds are very much increased, as the power delivered at the cut by the motor is from 50 to 100% greater than the power obtainable in a belt-driven machine, and the absence of belt pull on the cone gives a greater degree of accuracy to the work produced from the same lathe. In consequence, with the use of high-speed cutting steel, the output of the motor-driven lathe has been increased from 30 to 50%. It may be remarked that the tremendous increase in power in the running head has necessitated the re-designing of the lathe, making all the parts throughout proportionately heavier than the same sized lathe of ten years ago.

Fig. No. 5 shows another form of motor-driven lathe known as the "all-geared" type, driven by constant-speed motor or single pulley drive by countershaft. In this machine all changes of speed are effected by clutches, and no changes of belt, as on a cone, are necessary. For lathes of very large size this construction will commend itself to the user, although there are arguments against the number of gears made necessary to give the desired changes. On all large lathes of this type, separate motor for quick traverse of the saddle along the bed is provided. Movement of the tailstock by the same means gives greater efficiency or quicker adjustment of the tools to the cut.

The foregoing covers in a general way the advance in construction of the engine lathe. Another type of lathe which in recent years has received considerable attention, namely, those for locomotive and coach wheel turning, will now be considered.

Fig. No. 6 shows this machine as originally designed by the Pond Tool Company, of Plainfield, N.J. As first built it was belt



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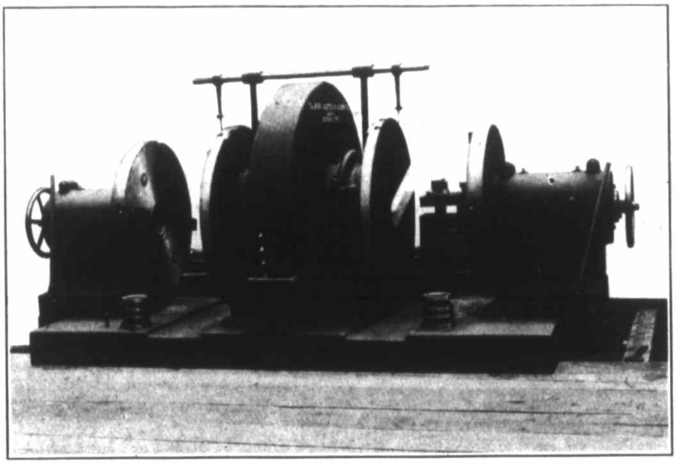

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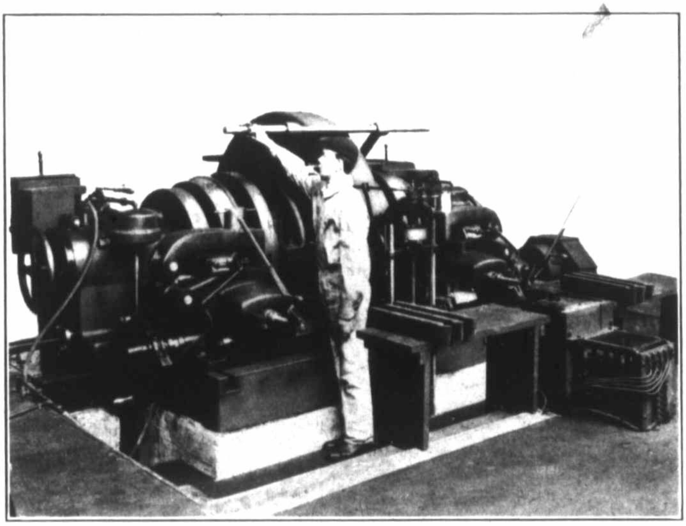

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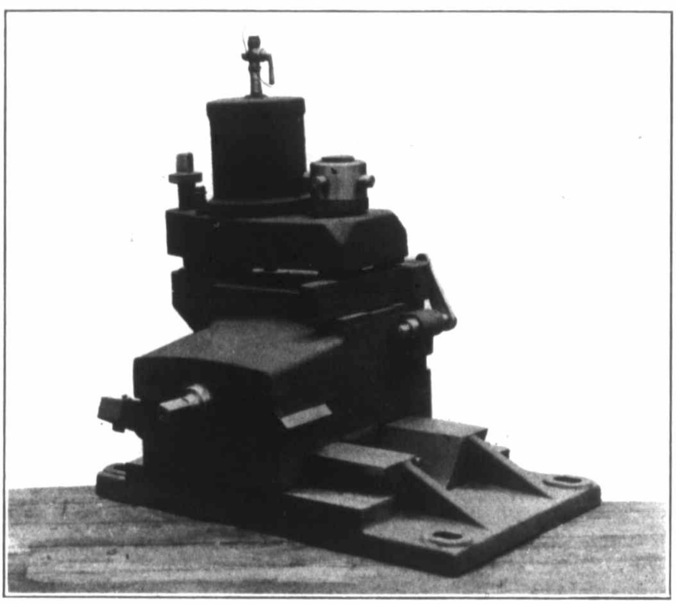

Fig. No. 8.

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driven, having about 9 horse power, and a capacity of from 4 to 6 pairs of wheels per day of 10 hours.

The special features of this machine are:

(1) The central drive. It is known as the worm drive. The power is transmitted direct from the cone shaft, or as the machine is built to-day, from the motor, to a worm and a worm wheel, which is mounted on the end of the driving shaft. The end of this main driving shaft is a worm which in turn engages a large worm wheel in the centre of the machine. Both worms and wheels run in oil tight cases, which ensures perfect lubrication. In this way the power reaches the machine midway between the wheels, and, in addition to securing uniform power, the central drive makes it possible to support the wheels on both sides. This is accomplished by means of self-centering chucks, which grasp, or grip the axle journals, and chuck jaws engage the tires.

(2) The compound rests, which carry the cutting tools, are mounted on the bed, and are held by four bolts in T-slots—in this way any springing tendency is prevented, and in consequence the heaviest cuts can be carried.

Fig. No. 7 shows the machine as built to-day by the John Bertram Company. The machine has undergone radical changes, these having been brought about by the introduction of high speed steel and the use, for driving power, of an electric motor directly attached. As already stated, the original machine was capable of turning from four to six pairs of tires per day, but upon the introduction of the motor, the power was thereby increased to 20 horse power, and the output increased from six to eight pairs of wheels per day, with one man as operator, and one man as helper to roll the wheels in and out of the machine. For a number of years this was considered a standard day's work, but soon the energetic shop managers of the leading railroad companies increased the horse power to thirty, with the result that the output was increased to from ten to twelve pairs of wheels per day, this necessitating an additional helper to roll the wheels in and out of the machine. Not content with this, however, the power was further increased to from thirty-five to forty horse power, the output thereupon averaging 14 pairs of wheels per day, with two operators and two helpers. This undoubtedly demonstrated the possibilities of the machine, but it also demonstrated to the manufacturers the fact that labour-saving devices must be added, since the output had reached the limit of human endurance.

The latest achievement is clearly illustrated by Fig. No. 8. It consists of a new design of tool block clamping device for holding the tool, and being operated by compressed air, facilitates the work of the operator. Power is also applied for both moving and clamping the heads on the bed.

In Fig. No. 9 there is illustrated the segment in the central driving gear, which opens, closes, and locks automatically as the wheels are rolled in and out, this requiring no attention whatever from the operator. These labour-saving devices have so perfected this machine that the output has steadily increased, until, under a recent test, 33 pairs of wheels were turned in nine hours and thirty-three minutes.

The Wheel Lathe specially designed for turning the tires of locomotive driving wheels as used up to a few years ago, is illustrated in Fig. No. 10.

Those familiar with the modern machine will readily see that the construction is light in all its parts, particularly in the head and face plates. The power is limited, owing to the narrow belt by which the machine was driven, and the output was consequently limited to 1½ to 2 pairs of wheels per day. The top of the bed was a flat surface, and in consequence the pedestal carrying the tool blocks had to of sufficient height to carry the tools to the center. Owing to their length in a lathe of 80 inches, this was an extremely weak feature, as is was scarcely practicable to make them of sufficient size and strength to prevent springing. This, together with the weakness of the driving plates and the primitive method of holding and driving the wheels, accounts very largely for the small output obtained.

The modern 90" driving wheel lathe is illustrated in Fig. No. 11. The machine has been designed throughout with a view to obtaining the greatest rigidity at the point where the greatest strain is imposed; this elevation also permits of the use of very short and stiff tool posts. The back web of the bed, not being subject to so great strain, is low; this facilitates the handling of wheels in and out. The tool blocks are equipped with a tool-holder, which renders easier the setting of the cutting tools. The operator is thus relieved of opening and closing four nuts each time the tools are set. The feeds are positive, being operated by connecting rods attached directly to the tool block feed shaft.

The head is equipped with a 50 horse-power motor; the power is transmitted through a train of gears and a 7" shaft to the internal gears on the face plates. As the internal gears form wide flanges on the face plates, the plates are given great rigidity, and by the use of improved drivers, Fig. No. 12, which hold the wheels perfectly rigid, the heaviest cuts can be carried with little or no vibration.

In order to fully realize the improvement in the machine, it need only be stated that while the output of the old machine was from 1½ to 2 pairs of wheels per day, the average output is now 6 pairs of wheels per day, while, under special test, 10 pairs of driving wheels were turned in 9 hours 6 minutes.

Fig. No. 13 shows a cut taken in the above test.

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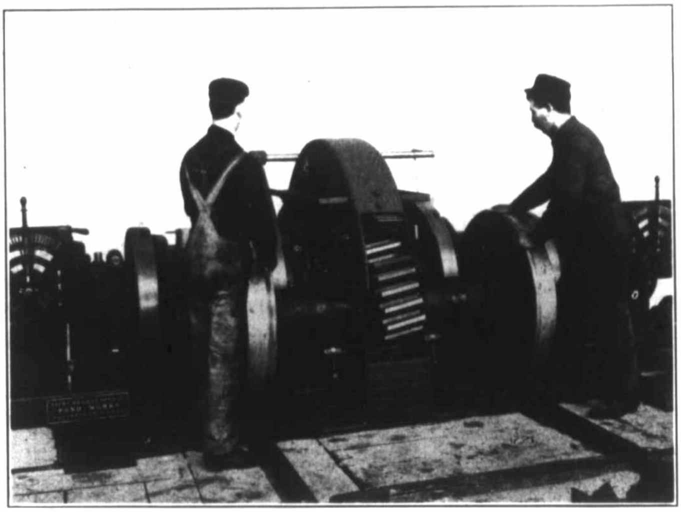

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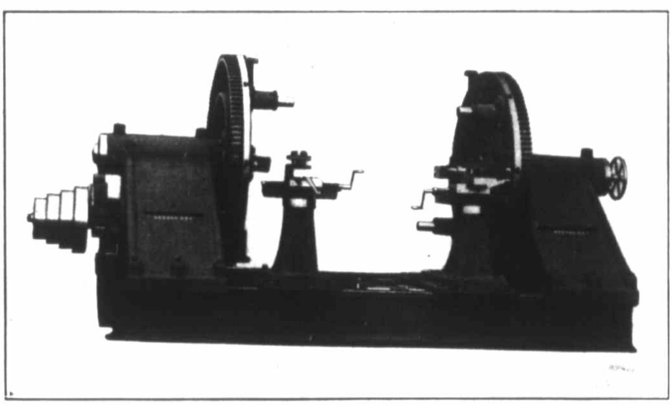

Fig. No. 10.

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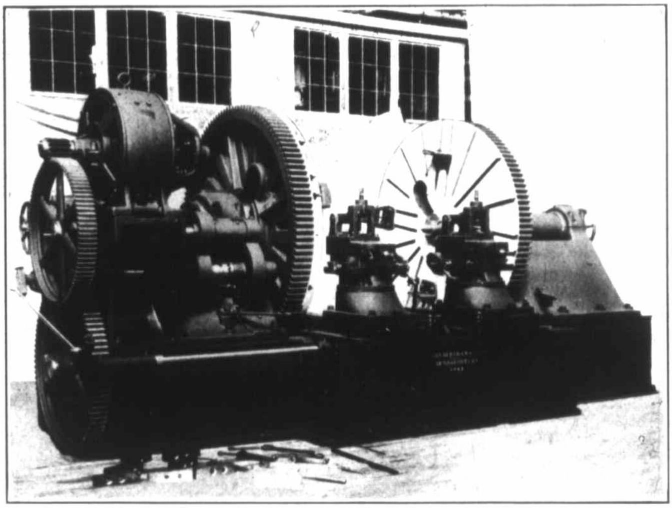

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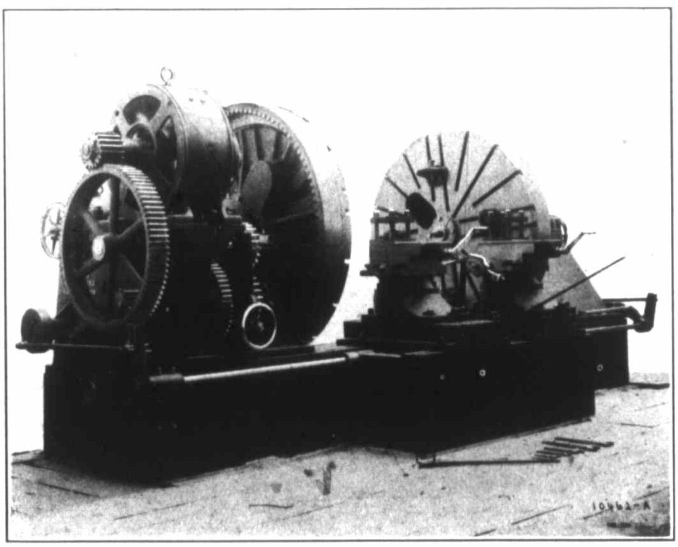

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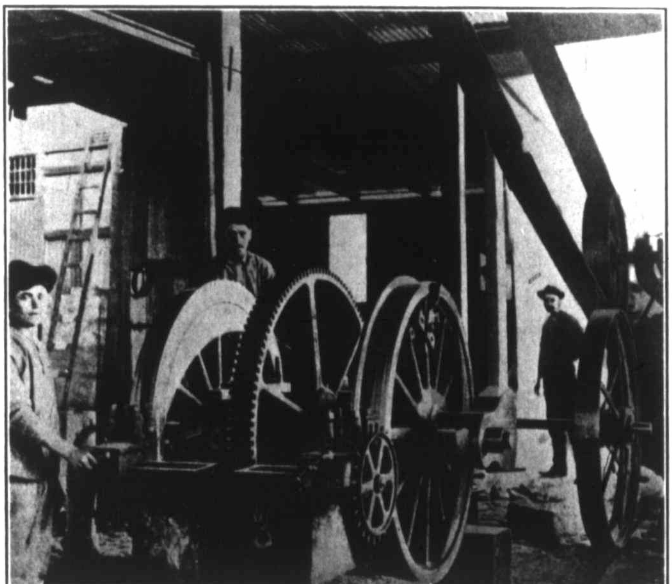

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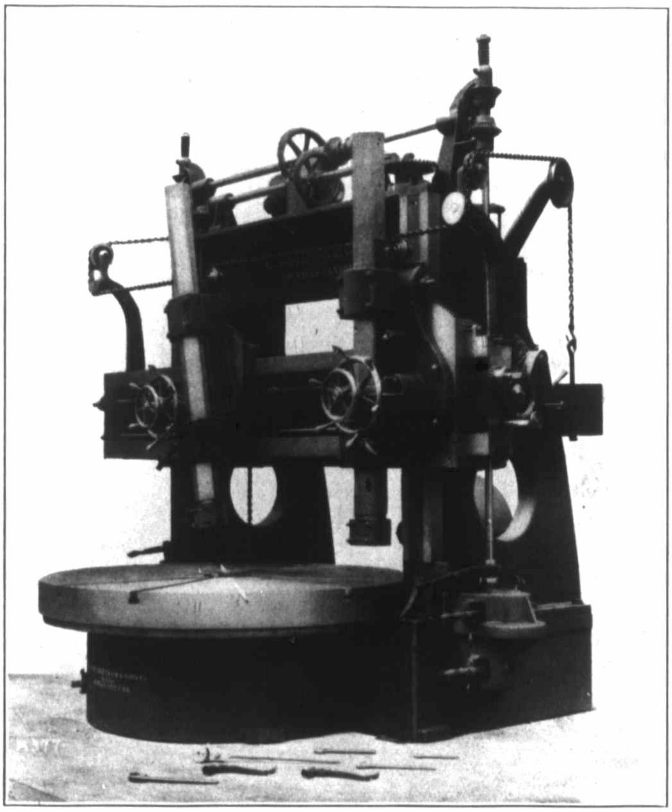

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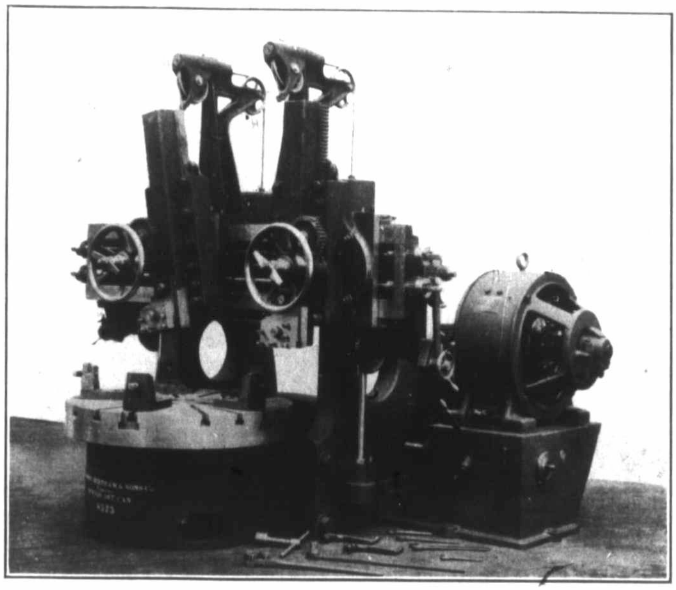

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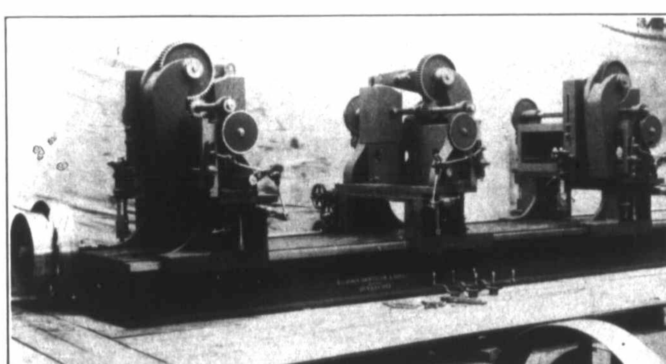

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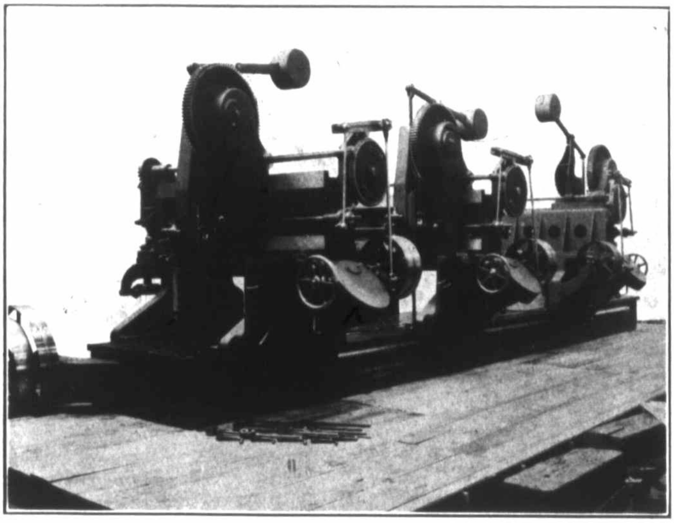

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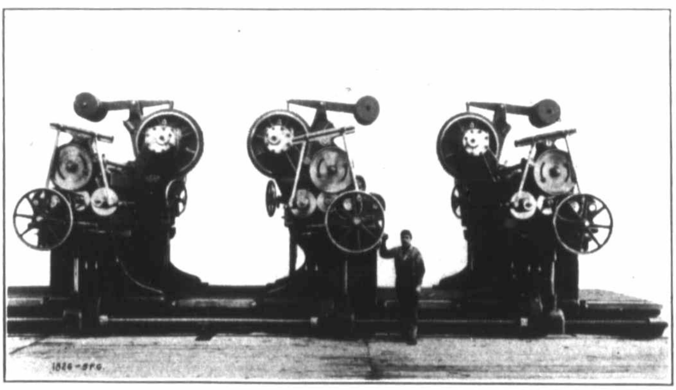


Fig. No. 19.

Fig. No. 14 illustrates a curiosity in wheel lathes from a photograph taken from a lathe in use on a branch railroad in Mexico. The bed consists of square timbers, a main gear in halves, which is clamped to the axle at its centre, while the wheels and axle run in their own journal. Claim is made that a pair of wheels were turned in one week, which would scarcely fill the requirements of our large Canadian roads.

The subject of lathes should not be dismissed without a word on the boring and turning mill, another form of lathe construction, so arranged as to permit of the easy chucking of articles to the face-plate. This machine has also been brought to the stage of quick adjustment of rail heads and bars, all the surplus power and energy of the man being developed to increase the number of hours actually at the cutting point of the tool.

Fig. No. 15 shows a standard boring mill, as built by the Bertram Company, for the Canadian market.

Fig. No. 16 shows a Bertram tire boring mill for coach wheel tires up to 42" diameter. The construction is especially for heavy duty.

Few machines which have to do with the production of the modern locomotive have undergone such changes in size, weight, and power as the frame slotting machine. This is due to the increased size and weight of the locomotive of to-day, as compared with that of a few years ago. This, of course, causes a corresponding increase in the size of the frame to be slotted.

Fig. No. 17 will show the slotting machine, as built by the Bertram Company, until about 1898. The opening in the yoke was 34" wide and 12" high, and the bed had a length of 36'. The machine was capable of slotting one pair of forged frames in sixty hours.

Fig. No. 18 illustrates the standard three-headed slotting machine, as in use in the Canadian Pacific Railway and other railroad shops. The opening in the yoke is 48" wide and 26" high, and the length of the bed is 40', giving the machine sufficient capacity to slot four of the largest sizes locomotives frames in from 32 to 34 hours.

In Fig. No. 19 is illustrated the largest type of triple head frame slotting machine which is known. It was installed in the Montreal Locomotive Works about three years ago, the dimensions of the machine being—opening in the yoke 61" x 34", and the bed is 50' long, maximum stroke of cutter bars 32". The machine is capable of slotting six locomotive frames simultaneously, and has the power and rigidity necessary to do the work at the minimum cost under modern manufacturing conditions.

In common with most of the other large machine tools, the method of drive in the slotter has been changed and improved by the introduction of the motor. As will be seen in this plate, each head is driven by a 20-horse power motor, from which the cutting bars are driven through powerful friction clutches, which permits the operators to have convenient control of the bars at all times. This improved method of drive has superseded the long shaft, which ran the entire length of the bed in the older machines, communicating the power to the cutting bars through a system of clutches.

These facts will show that the slotting machine of to-day has three times the capacity of the machine manufactured a few years ago. In consequence a very great saving has been effected in the cost of slotting frames, for, as has been shown, in the earliest machine it required 60 hours to slot one pair of frames, the machine as next improved slotted four frames in 32 hours, while the latest improved machine averages six frames in 40 hours.

In passing rather hurriedly through an outline of machine tool improvements, a few words should be said on the subject of the drilling machine. In common with nearly all classes of machinery the drilling machine has of late years received its share of attention. The following plates will serve to illustrate the development of this type of machine tool, and render unnecessary an explanation of the improvements in detail.

Fig. No. 20 shows the first ratchet and drill brace used in the shops some forty years ago. Fig. No. 21 is a very old illustration of an American-built drill. Fig. No. 22 illustrates a vertical drill, built in the Bertram Works about 1869. Fig. No. 23 illustrates the latest Bertram vertical drill. Fig. No. 24 shows a full universal radial drill. The first machine built from this pattern was exhibited at the Centennial Exposition at Philadelphia in 1876. Fig. No. 25 represents the latest production in full universal radial drills.

Time will not permit the discussion of present-day drilling records, or to compare them with those of early days. Many articles on high speed drilling have appeared from time to time in engineering publications, and the wide variations in results obtained might be an interesting point for discussion at a subsequent meeting. Some of those present might then be able to give valuable information regarding personal experiences.

This paper should not be concluded without giving some attention to one of the most important machines, namely, the iron planer, and in doing so it should not be necessary to go into its past history further than to state that since 1694 little was accomplished in its development until early in 1800.

As stated in the introductory remarks, there was a machine of this type in the Gartshore Foundry in 1863. This machine had a cutting speed of about 10′ per minute. The gearing was made

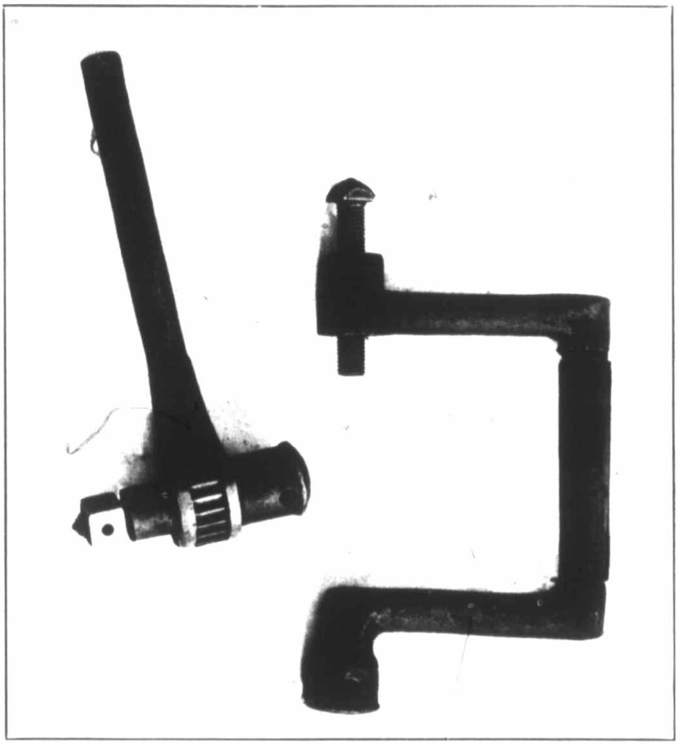
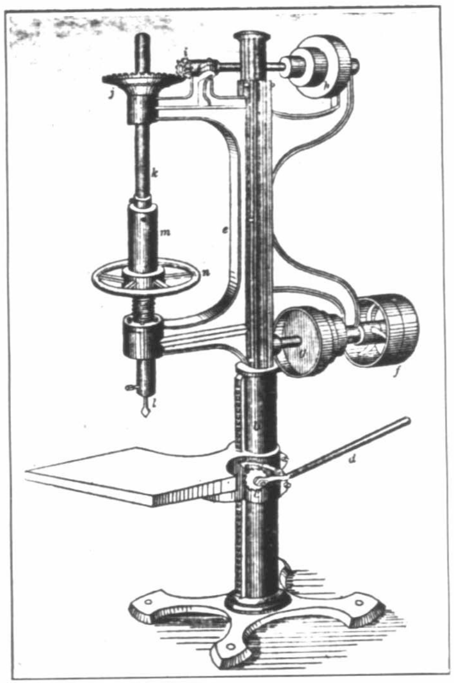


Fig. No. 20.



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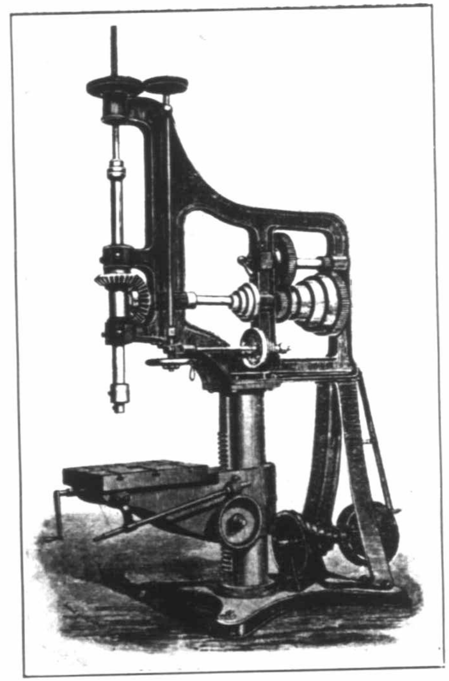

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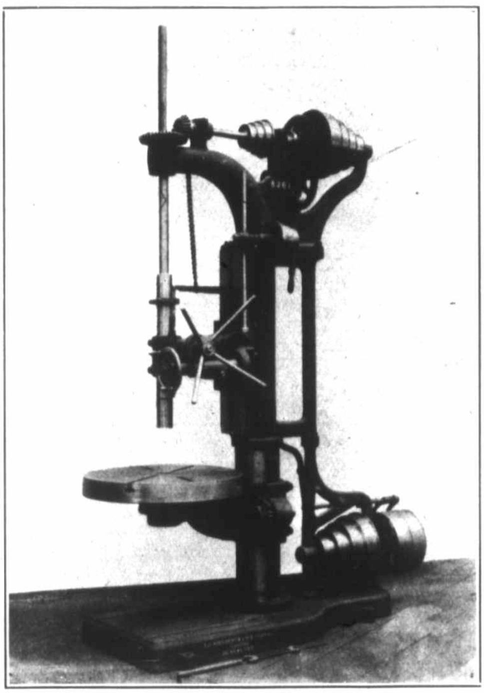

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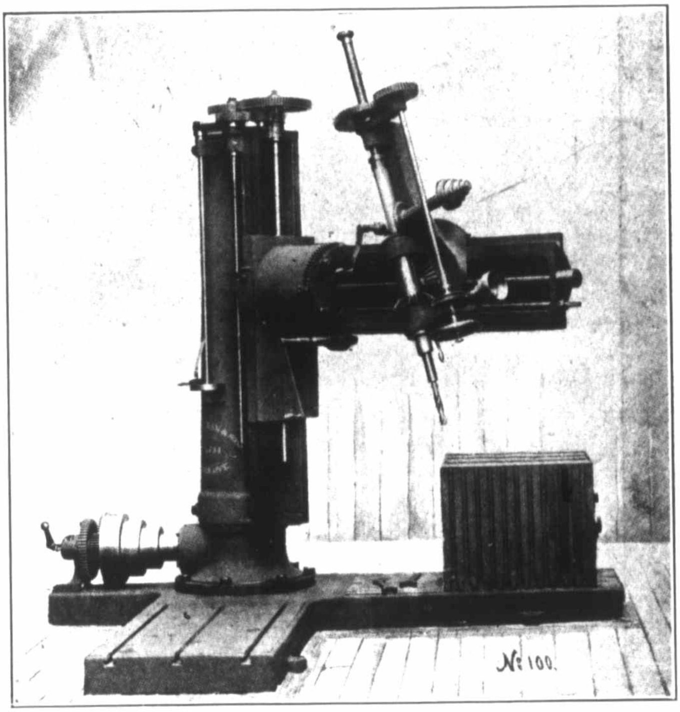

Fig. No. 24.

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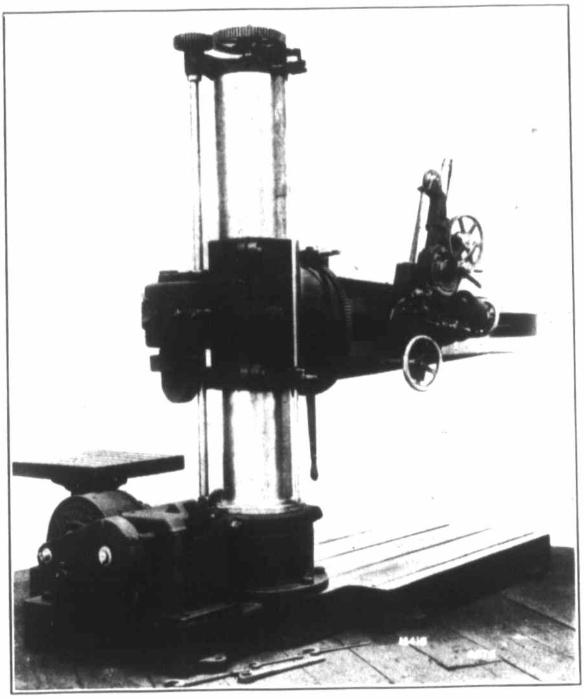

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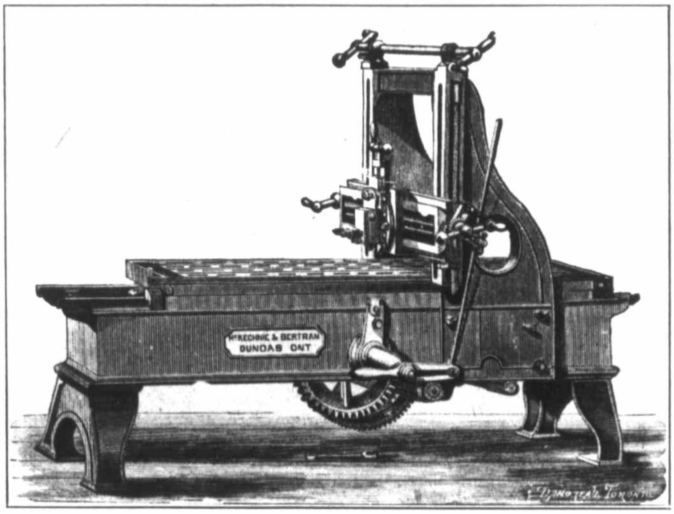

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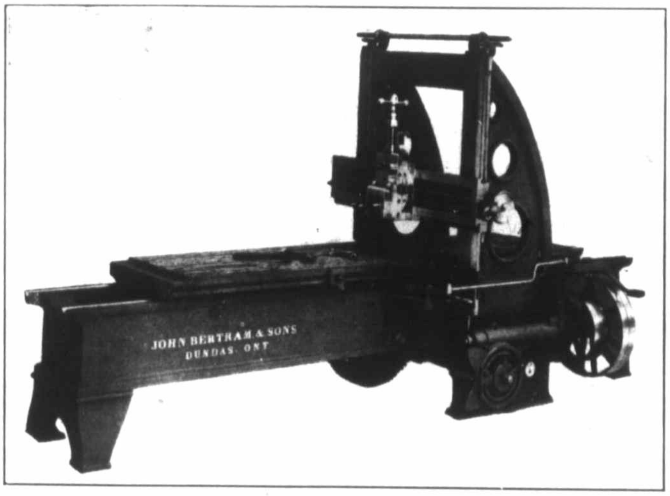

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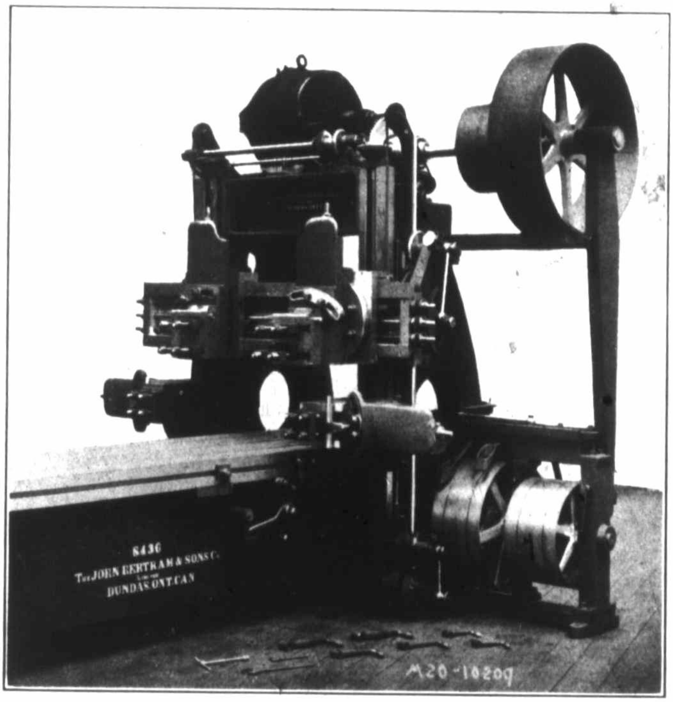

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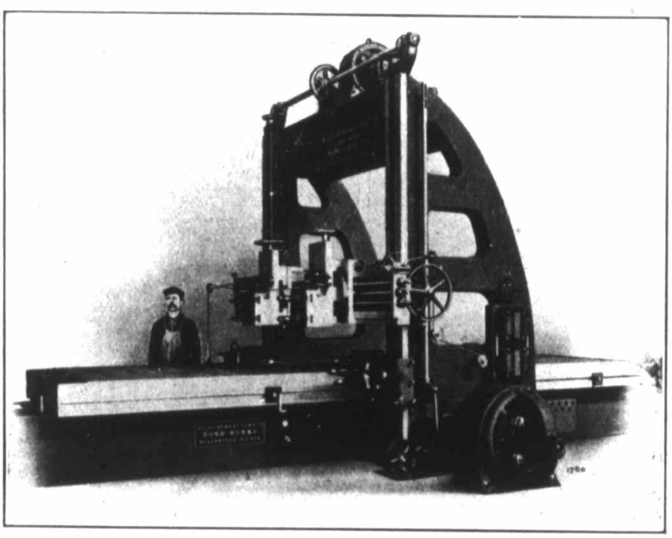

Fig. No. 29.

with cast teeth, and the rack had a double section having the teeth staggered to give a smooth and uniform motion to the table.

Fig. No. 26 illustrates one of the first machines built in the Bertram Works in 1867. The power is delivered to the table by a single 3" belt running at a velocity of 512' per minute, with a gear ratio of 6.25, giving an effective pull on the table of 3750 lbs., and a cutting speed of table 20' per minute.

Fig. No. 27 represents a 36" planer, driven by two 3" belts, one of them being used as a forward or cutting belt, and the other for the reverse motion. A belt velocity of 1,000' per minute and a gear ratio of 13.4 to 1 delivers an effective pull on the table of 8180 lbs., at a cutting speed of 20' per minute.

From the above some idea is given of the gradual development of iron planers. In recent years modern shop construction demanded economy in space and a more convenient shop layout. This led to the adoption of an individual drive made possible by the improvements in electrical machinery, and for the past eight or ten years the usual plan of mounting the motor on top of the planer housing has been followed. This plan is more or less faulty, due to a liability of the machine producing defective work by reason of the natural vibration caused by the motor being placed in that position. To obviate this danger the use of pneumatic clutches was introduced, and a motor drive placed at the base of the housings.

Fig. No. 28 represents a motor drive mounted upon the housings of the machine, power being transmitted by four belts, two for cutting and two for reverse. This drive was developed to give increased belt pull without excessive belt shifting velocity. The increased pull wide single belt for both forward and reverse motions would demand double the shifting speed to obtain as prompt and uniform a return of table as the original narrow belt required. This increase of shifting speed was practically impossible, hence the introduction of the four-belt drive. With two narrow belts for each motion the required increased pull is obtained, and the same facility of shifting remains as in the old two-belt drive without any increase in shifting velocity. In this construction by a gear ratio of 8.8 to 1, a belt velocity of 1,330' per minute, an effective pull on the table of 10,000 lbs. is obtained at a cutting speed of 36' per minute, at the same time maintaining a comparatively low belt speed and the use of a 5" belt for the cut and return.

We now reach the most modern drive applied to iron planers, and the following is quoted from a circular issued by the Pond Tool Works of the Niles-Bement-Pond Company at Plainfield, where the improvements were designed and carried out. Fig. No. 29 represents the machine in question.

"In the Pond reversing motor planer is offered an entirely new method of driving and reversing at variable speeds. This system is the result of years of experimenting in this line, and has proven itself absolutely reliable under the most severe and adverse working conditions. It overcomes all the undesirable features of belt and gear-box drives, and does away with clutches, either pneumatic or magnetic, and all shifting belts

"The reversing drive essentially consists of one motor, which acts as a generator at the instant of reversal. This result is accomplished automatically by a patent controller. On the controller are mounted two index scales or dials—one controls the range of cutting speeds and the other the return speeds. Each scale is provided with 13 graduations or divisions, by means of which an equivalent number of different motor speeds are obtainable by simply sliding the thumb piece on the scale. There are no dashpots in the system.

"The cutting speeds obtainable on the standard type of planers vary from 25′ to 40′ per minute, and the return speeds from 60′ to 100′. However, these speeds can be changed to suit individual requirements. The cutting and return speeds are entirely independent of each other, so that it is possible to use the slowest cutting speed and the highest return speed, or *vice versa*. The table is reversed by adjustable dogs, which throw the controller into the dynamic position, the current which is generated at this instant bringing the motor to a stop. The motor, being directly across the main circuit, has at all times full field strength to brake on, regardless of the speed at which it is running. These conditions account for the quick action of the planer at the instant of reversal, as well as for the perfect electrical action of the motor, there being absolutely no sparking or other electrical strain.

"At the instant of reversal, in which the motor is being brought to a stop, the controller automatically reverses the main circuit to motor, which gives the reverse direction of rotation. The dynamic feature of the controller is absolutely dependent upon speed of the motor, and automatically takes care of the various speeds of rotation. At the end of the stroke a table dog throws over the pilot switch. This is the only mechanical motion in the entire drive. The pilot switch is entirely enclosed, and is placed in the same position on the bed as the mechanical lever of an ordinary belt-driven machine. The pilot switch operates with such ease that it is not necessary to use a wrench to secure the reversing dogs, the latter being quickly adjusted to any desired stroke by means of hand clamps.

"The kinetic energy stored in the work, planer table, armature, and other moving parts of the machine is absorbed by the braking action of the operating torque of the fields on the rotation of the armature, which is accomplished without the least shock, jar, or hesitation. The current generated by this action passes into the starting resistance, and then off as heat, the result accomplished being exactly the same as if some form of mechanical brake had been applied to motor to bring planer to a stop, with the difference, however, that the action is perfectly smooth, has no wearing or frictional surface to contend with, and needs no adjustment. The over-load on the motor at the instant of reversal is never over 50%. The entire drive of the planer is on the floor, or near the floor, where it is accessible. Owing to the absence of the usual belts, clutches, etc., the variable speed planer occupies a minimum floor space.

"The larger machines can be equipped on special order with a pendant switch, usually suspended from the arch, but which can be placed and operated from any point on the planer. With this feature the table can be advanced, reversed, or stopped from a position convenient to the cutting tool with the same ease and assurance as with the pilot switch. The pendent switch may be used regardless of position of the reversing dogs.

"Speed changes are made so easily, positively, and instantaneously that the operator can, if desired, slow down at any part of the stroke, returning at once to normal or increased speed. If a hard spot is encountered at one portion of the stroke, or if there is an extra depth of cut at any point, the operator can slow down to meet conditions. The most economical speed for different metals, such as steel, iron, bronze, or brass, is instantly available.

"The reversing is accomplished so positively that a stroke of 4½" can be taken on a 96" machine."