(See Appendix.)

PRACTICAL HINTS

ON

MILL BUILDING.

BY

R. JAMES ABERNATHEY.

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PREFACE.

My primary object in preparing this book was to place before the milling public a distinctively flour-milling and mill-building work. This, I have thought, was needed; and in its preparation have constantly endeavored to make it plain, simple and entirely practical; and if to any extent I have, in the estimation of the reader, failed in carrying out the design, I hope that such failure will be charged up to my good intentions only, allowing one to balance the other, leaving the book free to stand on its merits exclusively, giving it credit for whatever of value it does contain.

The tables on gearing, belting and shafting I have carefully prepared for this work; but much of the other general matter of a mechanical nature has been copied from good authorities, prominent among them being CHAS. H. HASWELL. I have preferred to give, in the main, the productions entire of these authorities, with credit, to rewriting, recompiling and putting them in as original, as they could not have been very much improved, if at all, and could not have been considered original or any more valuable than in their present shape.

R. JAMES ABERNATHEY.

MOLINE, ILLINOIS.

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PART FIRST.

ARTICLE I.

SOMETHING ABOUT HOW IT USED TO BE DONE.

It is not, perhaps, necessary in a work intended to be strictly practical in character to say much about the origin and progress of flour making. It is more the province of the historian to enter into details of that kind; and, yet, no work exclusively devoted to the art of mill building and milling can be considered complete without a brief mention of its progress during the present century at least, as in that time all, or nearly all, of the great improvements now visible have been made. It is unnecessary to say much about the condition of the art previous to the advent of the nineteenth century. For many generations it had apparently remained about the same, with little or no progress or improvement of any kind. Oliver Evans was probably the first man to awaken any great amount of interest in the matter. To him belongs all, or nearly all, the credit for arousing the slumbering energies that had lain dormant for so many centuries, and for quickening into life a progressive movement that has continued in operation to the present time, with favorable indications that the end is not yet. It is true, the progress for many years was slow—almost a standstill in the condition left by Evans; but improvement has been going on all the time, (slow it may have been, but very sure,) up to a period dating one decade back; since which time progress has been very rapid. Although the principles upon which Evans' system was founded are still in vogue, and his plans, to some extent, carried out in detail, modified by the improvements in construction, still, a mill built after Evans' most approved plan and just as he would have built it in his time, would be considered very crude when compared with one of our more modern mills of to-day. Many of the improvements now used in milling were unknown to Evans; but the difference would not be so apparent as to the number and difference of improvements, as it would in the manner of construction.

The millwright, in those days, was supreme master of the situation. He did not depend much on mill furnishers and machinists; he was his own furnisher, largely, and as for machinists, the nearest country blacksmith filled the bill admirably. Almost everything was made of wood, and the millwright made it. Those were palmy days for millwrights; they were just what their name implies: literally, mill-builders. If a shaft was needed it was not necessary to go to town to hunt up a machine shop and await the humor of the proprietor in getting one. If there were any saw-mills convenient, a shaft would soon be forthcoming; or, if there were no saw-mills convenient, an adjacent woods or piece of timber would answer the purpose just as well. The millwright of those days would swing his axe over his shoulder, strike for the timber, select his tree, fell it, cut it off the length required, have it hauled to the mill, where he would proceed to form it into a shaft; after which he would go to his machinist (the blacksmith) and have his gudgeons made. Spike gudgeons for small shafts were mostly used in those days. These were driven into auger holes bored in the ends of the shaft and afterwards "trued" up and wedged fast. The shaft would not be round, but six, eight or twelve-square, just as we now sometimes make reel and conveyor shafts. If it was necessary to put a pulley, or a wheel of any other kind on the shaft, it was procured in much the same way as the shaft; at least they were made by the millwright. The pulley would be made solid of heavy plank, circled and dressed round with a chisel. Then a huge mortise, the shape of the shaft, would be cut through the center of it, and large enough to slip very loosely on and allow for "hanging," which meant to fix it on the shaft so that it would run true. This was done with a series of wooden keys, one or more for each square of the shaft, and driven from each side of the pulley alternately. By this means a wheel could or can be hung very exactly; the plan being to first fix a rest or guide at the periphery, but independent of the wheel, so that the turning of the wheel would not interfere with the fixed position of the rest. As the wheel would probably have to be made true both ways at the same operation, the rest would have to be fixed so as to guide both the face and the side of the wheel. It did not matter in this operation how many squares there might be to the shaft, or how many sets of keys; four sets only could be used to advantage in "hanging" a wheel. The rest fixed, and the keys all out of the way but the four sets needed, the operator (millwright) would give it a general "trueing" up all around, tighten up the keys a little, and then proceed to do it exactly. Every man who pretended to be a mechanic was not entrusted to hang a wheel: only the experts or best of the crew were given so important a task; and they, no doubt, felt the importance of the position of trust just as men now do who are entrusted with important missions. It was not always an easy task for the most expert to hang a wheel exactly true; and, under the most favorable circumstances, it required time and patience, and no little care in loosening and tightening keys, to bring the point worked upon to the required place exactly. If on trial, after having nearly placed the wheel in its proper position, it is found to be right in three places and wrong or out only in one, then, of course, the wheel cannot be true itself, and it would be useless to try further with the keys. If three points of the side of the wheel touched and were right and the fourth off, it would indicate that the wheel had not been well made, or else it had twisted or warped; but if the face of the wheel was to show the same discrepancy, it would be evident that the wheel had not been made true, and nothing more could be done with it but recircle and redress, or turn it off on the shaft when it could be done. But this kind of trouble did not often occur. Millwrights, as a rule, were fairly good mechanics, better than now; for the reason that they went at the trade when young as apprentices, and remained at it; now, anybody, if he ever swung a buck saw a few times, makes a good fair millwright, or at least he not unfrequently passes for such to the great detriment and loss of his employer, more especially the mill owner. But hanging a wheel is what we are talking about; and, as was just intimated, it was most generally found that at the first trial the keys, some of them, would have to be loosened to bring the wheel over at one point a little nearer the rest, or possibly a little further away from it; and, it may be that the same point on the face of the wheel might want to be moved a little in or out. If this was the case, a general backing and tightening of keys all around would be the order. If, however, the wheel wanted moving sideways, it was only necessary to back the key on the side that had to be moved, in the direction the wheel was to move, and tighten the key from or on the opposite side. This done, the wheel would have to be turned around again to observe the effect. It was, and is, among the possibilities, under similar circumstances, to get a wheel right after two or three operations. But, if the wheel was very large, it rarely ever occurred. It generally required repeated efforts, a long time and a great deal of caution and patience to bring about the desired result.

The operation is quite different now. The millwright does not make his own shaft, he simply puts it up; nor does he make his wheel; all are furnished from the machine shop ready to go up. The millwright gets his bearings ready, slips the wheels on the shaft, slips it into place, and the thing is done. It does not follow that everything is just right, though it not unfrequently happens that the machinist has done a poor job. The eye in the wheel is too small and has to be filed out before it can be got on the shaft; or, it is too large and has to be bushed; or, it may not be bored true, and consequently will not hang true on the shaft. For all these drawbacks the millwright is irresponsible, but he knows who is; and, while the machinist is rarely held accountable, he is many times anathamatized and brought to judgment before the righteous tribunal of the weary, patient, and oftimes profane millwright. Bad fitting iron work is something that did not disturb the serenity of our forefather millwrights; but probably other things did that were just as annoying. Making the shafts and the pulleys was not all the millwrights had to do in those days; they had to make the cog wheels, little and big, and make the cogs to fill them with; no sending off to a manufacturing establishment to buy them already made. The wheels had to be made in much the same way as the pulleys, and mortised for the cogs, and then hung on the shaft in a similar manner as described. The cogs driven, laid out and dressed much the same as now, only we use iron wheels instead of wooden. The wheels and cogs are furnished by the mill-furnisher, and all the millwright has to do is to fit, drive and dress them. All of the styles of wheels were, of course, quite different from what they now are; but one style in particular would be considered quite odd now to those who had never seen them. The body of these wheels was made like a solid wooden pulley, and banded with iron; a pitch line would be struck on the side near the periphery, which would be spaced off the same as any other wheel, according to the number of cogs and pitch, and then auger holes bored through to receive the cogs, which were merely round pins turned true, with a round-turned shank just the size to suit the auger hole. These were the bevel wheels of those days and used to connect shafts running at right angles with each other, the same as our bevel wheels do now. When this kind of wheel was intended to do a great deal of work, as for instance, connecting the main upright shaft with the main gearing in the pit; or, in connecting the spindle with the driving power, it was made with a double head, with the round pins or cogs running through both heads, while the cogs of the master or counter wheel gearing into it would come between the two heads. This double trussed head prevented the round cogs from springing as they probably otherwise would have done. All of the wheels intended to take the place, or rather that answered the purpose at that day of the bevel wheels of to-day, were not made in that way exactly. Large wheels for heavy work were framed together with a heavy rim, which was mortised through on the side instead of being simply bored. Into these mortises cogs were fitted very much the same as we now fit them in an iron bevel wheel.

It was then, as we have seen, more in the mode of construction than in general principles, that a mill of those times differed from a mill of the present time.

Everything that could be made of wood was made by the millwright at the mill; he built the water-wheel (iron turbines were unknown then); made his own penstock; made his pulleys, wheels and shafts. The main upright shaft was made of wood, ponderous in size; all of the other uprights and all the laying shafts were the same, and greater or less in size, according to the amount of work they had to do. Not only, as has been noted, were the shafts made of wood but almost everything else. But little iron was used, none for any purpose where wood could be used as well. Belts were a rare luxury, very few being used for any purpose.

The following extracts from Oliver Evans' *Millwrights' Guide* will better illustrate the methods of his time:

DIRECTIONS FOR MAKING WALLOWERS AND TRUNDLES.

By example 43, in the table, the wallower is to have 26 rounds 4½ pitch: the diameter of its pitch circle is 3 feet 1¼ inch, and 3 feet 4¼ inches from outside. Its head should be 3½ inches thick, doweled truly together, or made with double plank, crossing each other. Make the bands 3 inches wide, $\frac{1}{6}$ of an inch thick, evenly drawn; the heads must be made to suit the bands, by setting the compasses so that they will step round the inside of the band in 6 steps; with this distance sweep the head, allowing about $\frac{1}{8}$ of an inch outside, in dressing, to make such a large band tight. Make them hot alike all around with a chip fire, which swells the iron; put them on the head while hot, and cool them with water, to keep them from burning the wood too much, but not too fast, lest they snap; the same mode serves for hooping all kinds of heads.

Dress the head fair after banding, and strike the pitch circle and divide it by the same pitch with the cogs; bore the holes for the rounds with an auger of at least 1½ inch; make the rounds of the best wood, 2⅝ inches diameter, and 11 inches between the shoulders, the tenons 4 inches, to fit the holes loosely, until within one-inch of the shoulder, then drive it tight. Make the mortises for the shaft in the heads, with notches, for the keys to hang it by. When the rounds are all driven into the shoulders, observe whether they stand straight; if not, they may be set fair by putting the wedges nearest to one side of the tenon, so that the strongest part may incline to draw them straight: this should be done with both heads.

OF MAKING BOLTING WHEELS.

Make the spur-wheel for the first upright, with a 4½ inch plank; the pitch of the cogs, the same as the cog-wheel, into which it is to work; put two bands ¾ of an inch wide, one on each side of the cogs, and a rivet between each cog, to keep the wheel from splitting.

To proportion the cogs in the wheels, to give the bolts the right motion, the common way is—

Hang the spur-wheel, and set the stones to grind with a proper motion, and count the revolutions of the upright shaft in a minute; compare its revolutions with the revolutions that a bolt should have, which is about 36 revolutions in a minute. If the upright go $\frac{1}{6}$ more, put $\frac{1}{6}$ less in the first driving wheel than in the leader, suppose 15 in the driver, then 18 in the leader: but if their difference be more, (say one-half,) there must be a difference in the next two wheels; observing that if the motion of the upright shaft be greater than that of the bolt should be, the driving wheel must be proportionately less than the leader; but if it be slower, then the driver must be greater in proportion. The common size of bolting wheels is from 14 to 20 cogs; if less than 14, the head-blocks will be too near the shafts.

Common bolting wheels should be made of plank, at least 3 inches thick, well seasoned; and they are best when as wide as the diameter of the wheel, and banded with bands nearly as wide as the thickness of the wheel, the bands may be made of rolled iron. about $\frac{1}{8}$ of an inch thick. Some make the wheels of 2 inch plank, crossed, and no bands; but this proves no saving, as they are apt to go to pieces in a few years. The wheels, if banded, are generally 2 inches more in diameter than the pitch circle; but if not, they should be larger. The pitch or distances of the cogs are different; if to turn 1 or 2 bolts, $2\frac{1}{2}$ inches; but, if more, $2\frac{3}{4}$; if they are to do much heavy work, they should not be less than 3 inches. Their cogs, in thickness, are half the pitch; the shank must drive tightly in an inch auger hole.

When the mortises are made for the shafts in the head, and notches for the keys to hang them, drive the cogs in and pin their shank at the back side, and cut them off half an inch from the wheel.

Hang the wheels on the shafts so that they will gear a proper depth, about $\frac{2}{3}$ the thickness of the cogs; dress all the cogs to equal distances by a gauge; then put the shafts in their places, the wheels gearing properly, and the head blocks all secure; set them in motion by water. Bolting reels should turn so as to drop the meal on the back side of the chest, as it will then hold more, and will not cast out the meal when the door is opened.

ARTICLE II.

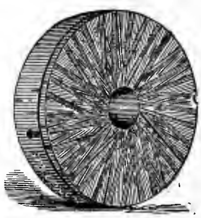
PRIMARY LESSONS FOR THE APPRENTICE.

In making this work thoroughly practical, as it is intended to be, it is or at least it seems necessary to begin at the bottom: begin with the apprentice in his first effort to make a square cut with the saw, or dress a piece of timber square with the plane. These are trifling matters with the advanced mechanic or even with the senior apprentice; but, with the junior, the lad who has just taken hold for the first time to become acquainted with the arts and mysteries of the mill-building trade, it is a somewhat different matter. His saw seems always determined to run either on one side or the other of the line, all of his efforts to the contrary notwithstanding; and, while, of course, he does not then know it, his efforts to prevent it are oftentimes the cause of his discomfiture. If a saw is sharp, true and evenly dressed, as it always should be when placed in the hands of a learner, for the purpose of making good cuts and true, it is best for the boy to give it a fair start, keep it moving and let it take care of itself. It is far more liable to run true than if a constant effort is made to force it a little first to one and then to the other side of the line. A good eye, a steady hand and plenty of nerve, is all that is needed to make a success in squaring off the ends of timbers with the saw. It is true, if a saw is in bad condition, with more set on one side than the other, or with one side of the teeth longer than the other, then it is simply impossible for a boy or even the most skillful workman to make a square cut. Such a saw should never be furnished an apprentice. Masters and others do not like to furnish their best saws to new apprentices for fear of getting them bent or buckled, and it is not necessary that they should do so; but it is necessary that they should put their old saws in the best shape by making them sharp, even and true; with such a saw the apprentice with care will soon learn to make a very creditable cut. One thing he must remember from the start and that is the line must be left on the body of the stick, or the part that is intended for use. The saw should never be started right on the line nor on the inside of it, but always on the outside, and as close to it as can be without cutting on it. By being thus careful, if the cut is not true it can be made so with a plane, having the lines to go by. The same thing could be done with the aid of a square, provided the stick was straight and square; but the proper way is to have the lines left on as a guide not only for trueing-up by, but to make certain the stick is the full length designed. It is not always necessary that the end of a stick should be sawed off exactly true and square, but the learner should cut off all with equal care. A careful habit in handling the saw ought to be formed. Even if it is not necessary to have a nice, square cut, it can do no harm if such a cut is made, but on the contrary, will do much good in forming a careful habit. This is not only true in handling the saw, but is equally true with regard to the use of other tools and in doing other kinds of work.

An apprentice ought to learn as soon as possible how to dress his own saw; ought to know when it is out of order and just how to put it in proper order; besides making him skillful it also makes him self-reliant. Right along with the use of the hand-saw, among the first lessons to be learned by the apprentice is how to dress-up stuff. Dressing up stuff sometimes means very plain, unskillful and very hard work; this is more particularly so in surface-planing rough boards. This, however, is not so much done as formerly, as there are now but few localities where dressed lumber cannot be readily obtained. The use of machinery-dressed lumber has taken off a great deal of the hardest kind of work in mill-building, a good share of which used to fall on the unfortunate apprentice. Dressing rough lumber was and is a job that adapts itself to the capacity of the ordinary apprentice, as he can work at that day after day without requiring much watching or many instructions. But when it is necessary to dress timber for any purpose, straight, out of wind, and square all around, it requires a little more skill. When instructed to dress up a piece or any number of pieces in this way, the learner must first determine which he will use for the face, side and edge, or two face sides. The best looking sides of the piece must be selected for the faces. By glancing along it with the eye it can be determined whether it be much in wind, or warped, or not; if not much it can be planed in shape by the use of the eye as a guide; but if very much in wind, then it will be necessary to plane a straight or level spot crosswise on one end of the stick. On this spot and across the stick must be laid a parallel strip, that is, a strip of pine board say two or two and one-half feet long and from two to three inches wide, dressed of an exact equal width from end to end; or, in the absence of such a strip, or two of them, as there must always be two just alike, the iron square can be used instead. The strip or square being placed at the end as directed, the same operation must be performed at the other end; the plane must be used on the stick crosswise as before, and the other strip or another square laid across it; by sighting across these two strips or squares it can be determined whether or not the two planed spots are out of wind with each other. If the strips show no wind, if they cover each other exactly every way, then the spots may be considered right; but if they do not, the planing must be resumed and continued until it is right, using the strips at each time of trial as proof. After the spots have been made correct, the stick must be turned over first on one side and then on the other, and a chalk line or a straight-edge, and pencil or scribe-awl, as the case may be, must be used to get a line from end to end of stick. To do this right the line or straight-edge must be placed just even with the planed spots on the ends of the stick. If there should happen to be a piece split off the corner, or it should be an imperfect corner for any other reason, so that it could not be told by the eye when the straight-edge was in just the right place, one of the wind strips or a square should be held against the planed spots, and the line or straight-edge set to that. In work of this kind a good straight-edge is preferable to a line when it can be made available, because a much finer line can be made with a pencil or scribe-awl than can be with a chalk line; and when the job is very particular the scribe-awl should be used in preference to everything else, as the line will be not only fine, but cannot be rubbed out as might be the case with either chalk or a lead-pencil. After the lines have been made the stick is ready for plane, axe or adze, as the party doing the work may think best. If the stick is crooked and badly warped, it is best to hew it down with either an axe or an adze, as it can be done quicker and much easier in that way. After the hewing has been done the plane must be used for smoothing and straightening up. The face side of a bad stick once dressed up nicely the greatest difficulty is over. It is most likely the other sides of the stick will have to be spotted at the ends in the same manner as the first, but the wind strips will be no longer needed, as the square can be used from the face side already dressed, for that purpose. After the spots have been made, lines the entire length of the stick will also have to be made in the same manner as on the face in the first place, and the same mode of dressing will probably have to be adopted; although it may not, as it will depend on the quantity that has to be dressed off; if not very much the plane will answer without other aids. The two face sides being dressed square, the other two will have to be dressed and squared from them in the same manner as the second face side was squared from the first. If a frame of any kind is to be made of lumber dressed square on all sides, there is but little difficulty in laying it off or marking out the mortises and tenons; but it is not so easy when timber has to be framed in the same shape that it comes from the saw-mills. It must be remarked that the apprentice is not, as a rule, troubled much with the laying out of frame work; but it is his business, if he expects to become master of his calling, to watch closely to see how it is done, in order that when the time does come, as it is sure to, if he is studious and industrious, he will be fully prepared to do it and do it well. Hence the reason for being so particular in this work in calling attention to the minutest details of the first part of an apprentice's work. It is necessary that he should know something about the principles controlling everything he undertakes, and he must understand that a frame made of rough-sawed timber badly twisted and warped, would also be badly twisted and in wind if it were framed in that condition. A great deal of outside heavy framing, in water mills especially, has to be done with the stuff in its rough state, as it does not pay for that purpose to dress it all over by hand or by mill either, unless everything for the purpose is very convenient, which is not often the case where this kind of framing is to be done. The timber that is to be framed in the rough must be taken out of wind by spotting the ends in the same manner as before described on the first face side, and corresponding spots on the other side made in the same way and square with the first; this done, the iron square on which are marked the inches, must be laid across the planed spots just as though it was the intention to see whether it was square or not, and then with a scribe-awl mark the stick on both sides and at both ends, just two inches from the corner; then the square must be moved over and the other two sides marked in the same way. These marks are the guides for striking chalk lines; one line on each side of the stick. Of course any other number of inches would answer the purpose. It is not necessary to be confined to just two inches from the edge for striking the chalk line; but that sized space is generally the handiest, for the reason that for timber 6x6 in size, a great deal of which is used, there is always allowed two-inch face and two-inch mortise and tenon. By having a 6x6 stick lined off in this way, the two-inch blade of the iron square can be laid along the line right over where the mortise or tenon is to be, and the same marked off on both sides without moving the square. Where the timber is larger or smaller than 6x6, this mode is not so likely to work, as the mortises and tenons are liable to be larger or smaller also, as the case may be. It may be understood that for all purposes the square will have to be applied along the lines instead of along the edges of the piece, as would be the case were it dressed true all around. In laying out tenons the square must be kept to the lines in scribing around for the shoulder, otherwise the cross lines will not meet; this rule must be observed if the ends have to be cut off square. After the mortises and tenons are made, it will be found that the frame will not be liable to come together well without some additional work. It will be found on examination that the chalk lines that have been laid on the stick, while just two inches from the corner or edge at the spot where it has been planed, on the other side of that spot it is probably more. To overcome that difficulty the two-inch blade of the iron square will have to be laid along on the outside of the chalk line, but touching it as in laying out the mortise; and along the outer edge of the square a heavy scribe line must be made; the opposite side of the stick must be treated in the same way. After this is done the stick must be sawed across the face even with the heads of the mortises, and down to the lines just made, after which that portion of the stick must be cut out down to the line on both sides and dressed evenly across. This operation must be performed with every mortise in the stick. It will then be found that the faces of all the mortises are parallel to each other and they are also ready to bore for the pins. For two inch mortises an inch and a half is generally allowed from the edge of the face of mortise to center of hole, and one-inch holes are the common size. With larger and smaller mortises greater or less space is allowed, also larger or smaller pin holes, and more of them if the frame is heavy.

It will probably be found after the mortises are all ready that the tenons cannot be got in and to their place, on account of the body of the post being too large to go down in the boxes made over the mortises; the remedy for that will suggest itself when the difficulty is discovered, but it is not proper to await a trial before getting the tenon ready. The post must be treated in the same manner as cap and sill or mortised piece; the square must be laid along the line in the same way, and the outer edge marked with a scribe-awl to which the operator is to work in dressing off the surplus wood. This can be done to any distance from the shoulder to assure its not striking on the sill or cap, as it may do in getting the frame together. If such a frame is to be planked up on the inside as a forebay or penstock, the cutting on the post must be done on the outside, but if the reverse is true; if the planking goes on the outside, then the cutting away of parts to meet the boxing on the mortise must be done on the inside. After the tenons have been made ready in every other way, the pin-holes or "draw-bores" must be made. It must be remembered in boring pin-holes in tenon that the center of the hole must come nearer the shoulder than did the center of the hole to the edge of mortise face; the reason is obvious, as by that means the driving in of the pin draws the shoulder of tenon and face of mortise close together. The difference should be about an eighth of an inch in hard wood frames; if the distance from face of mortise to center of pin-hole be one and a half inches, then the distance from tenon shoulder to center of hole should be about one and three-eighths of an inch. There are no special instructions to give for making mortises and tenons, except that for all millwright work great care should be exercised to have them fit snug. When an apprentice has got far enough along to make a neat and true mortise he is almost ready to receive journeymen's wages; and if there is any one thing more than another, that an apprentice should take pride in, it is in making a good mortise. There is but one or two things to observe to succeed:

bore carefully and not bore under the line; then block out just as carefully, after which use a paring chisel with the same care, and there need be no failure in making a good mortise.



ARTICLE III.

PRIMARY LESSONS FOR THE APPRENTICE, CONTINUED.

There is another kind of lumber dressing that was at one time a very common pastime for the learning mechanic, and that was the dressing up of staves for circular vats or tubs. This has never been so common in flour mill work as in some other kinds: paper mills notably. Still there is more or less of it to do in all branches of the trade yet. Wooden lagging for pulleys is got out in the same way, though in a general way but little attention is paid to any specific rule or mode of getting out stuff for lagging pulleys, unless they be large and wide on the face, then it is important to get it out with care; the inside must be nicely hollowed out to suit the circle of pulley and the edges properly beveled. It is a common practice when the pieces are irregular in width to bevel them first, using the pattern from the back or outside of the stave or lag. It must be remembered that the bevel is not the same on every piece; if the pieces vary any in width, there is a constant variation of bevel with every variation in width. In order then to get the bevel on each piece right, it is necessary to make a bevel pattern. This is done by taking, say, a half-inch board and striking a circle arc on it corresponding with the outside circle of pulley drum or tub; then mark a line running directly from the center to the circumference of circle. The sweep by which the arc is struck answers for this purpose, provided it is dressed at the outer end part way, so that one edge runs to the center. Along this edge of the sweep after the arc of circle has been struck, a line must be drawn for the bevels; the piece must then be cut out carefully to the lines that

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have been made. This pattern should be made about sixteen inches long and sufficiently wide to be convenient, with the beveled shoulder long or deep enough to suit the thickness of stuff to be dressed. By the use of this little device the proper bevel to any width piece can be obtained. As already said it must be worked from the back; and after the edges have been jointed and beveled, the back can be rounded off to suit the circle of pattern.

For ordinary lagging, however, the back does not need to be rounded off, as the whole will be turned off after pulley is completed; but for vat or tub work of any kind, and sometimes for the soling of water wheels it is necessary to round off the back neatly. After this is all done the inside must be dressed or hollowed out. The same pattern will answer for this also, by striking an arc on the outside corresponding with the inside circle of cylinder. In cases where the pieces to be so dressed are to be of a uniform width, the common bevel can be used if it suits best, as the bevel is the same on all; but a pattern for rounding and hollowing must be used the same as in the first case. It must not be forgotten that whether the pieces be of uniform width or not, each piece must be parallel, otherwise there will be a varying bevel on the edges: the wide end of a piece will have more of a bevel than the narrow end. This is particularly so when the pattern is used for beveling; if the pieces are of a uniform width and a fixed bevel used, then there will be no difference in the bevel on the piece, whether it be of equal width from end to end or not; but if a set of staves for instance were taken to set up a tub of any kind, which were not parallel, it would be found impossible to get them in position in a circular or any other regular form. As a matter of course, tapering tubs or vats must have the staves wider at one end than the other, but the difference must be provided for and made uniform throughout, otherwise a failure in setting up would be the result. All staves of this kind ought to be of a uniform thickness, gauged to that; and to get at that properly, the edges should be first beveled, then hollowed out on the inside, after which a gauge set to the required thickness should be run along the edges from the inside, allowing the surplus, if any, to be dressed off the back, as it is much easier to do. A stave dressed in this way is presumed to be out of wind, and certainly is, if there be no twist or warp of any kind in the stuff before dressing.

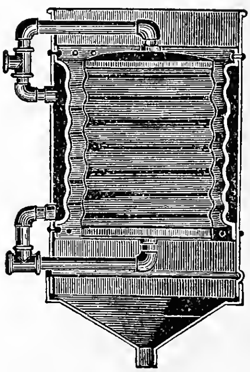
Dressing up a piece having more than four sides, as a conveyor, reel or other shaft, requires a little more practice and skill than any of the foregoing, but frequently falls to the lot of the beginner quite early. If a piece of timber already planed and squared is to be dressed with eight squares as a conveyor shaft, it is quite an easy task both to lay out and dress. With such a piece not exceeding two feet square, all that is necessary is to take the two feet blade of the common iron square and lay it across the face of the stick; if the stick be just two feet square, then the iron square (or two-foot rule either will do) will have to lay square across the stick; but if the stick be less than two feet square the rule will lay at an angle across it. When lying at an angle it will be important to see that the corners of the rule —two of them on the side used, or in the case of the iron square the two outer corners, must be placed even or flush with the two sides or corners of the stick; then with the scribe-awl a point must be made either at figure 7 or 17, or both if desired; one only is necessary; after which a gauge must be set to meet the points made; with this gauge the stick must be lined on each square or side, two lines for each; the corners of the stick must be dressed down to these lines, when a very perfect eight-square stick or shaft will be obtained. This mode of making a conveyor-shaft requires as a rule too much time, and should not be adopted unless the piece of timber is already very straight and square, more especially if the planing has to be done by hand, as is the case with most mill jobs away from the large towns. The ordinary and less troublesome way of making a conveyor or other shafts of this kind is to first cut off the ends square, leaving the stick about the length required or a little longer, so that the ends can be finally squared and finished, after which the shape of shaft must be laid off on the ends in this way: first ascertain the center; this must be determined somewhat by the shape of the stick; if it be fairly straight the center of the stick in the rough will answer for the center of shaft when dressed; in fact, it must, for unless the stick is much larger than needed, an indicated center very far from the real center would be likely to leave the shaft deficient on one side. But if, on the contrary, it be sprung and crooked, the indicated center must tend to the full side of the stick, otherwise a deficiency would occur on one side of the shaft when finished. When the center has been fixed to suit the stick, a circle may be struck on each end the size necessary to lay off the eight squares required. To do this we will say, for instance, the shaft requires to be six inches diameter across the squares; to ascertain the diameter of circle necessary we multiply the six by thirteen, and divide by twelve, the product will be the diameter required or a circle in this case of exactly six and one-half inches in diameter. It is important to be quite accurate in setting dividers so as to have the circle exact. After the ends have been circled to suit the shape of the stick, a starting point or line must be drawn across each end exactly parallel with each other. To do this either of two modes can be adopted. It must be understood that these lines, as well as other lines afterward to be made, indicate the position of the squares; each line runs from corner to corner opposite each other across the end of the stick. To determine the position of the first line it will be best to draw a light temporary line with a lead-pencil across the end from two opposite corners. This line would be supposed to be the center of two opposite squares. At one end of this line and on the circle must be measured a distance equal to one-half the width the square is intended to be; the judgment may be depended on for that, if not, a little further on will be found a rule for ascertaining the width of the square in advance. From the point thus ascertained a line must be drawn across the end exactly through the center of the circle. This establishes the first line. In order to get a corresponding parallel line on the opposite end, the piece may be so adjusted as to bring the line exactly level by a true spirit-level; the level can then be taken to the other end, held to the center and adjusted until just right, then draw a line under it; or, a strip can be fastened on the lined end, nicely adjusted to the line and a similar strip used at the opposite end in much the same manner as the level, except that it must be adjusted with the eye until parallel with the other. A mechanic with a good, reliable eye, can make it very accurate in this way. These strips should be about two feet long, or long enough to project a reasonable distance from the piece. These lines fixed, the squares must be laid off. To do this, the size or width of squares must be first ascertained; this may be done by multiplying the diameter the shaft is intended to be across the square by five and dividing by six. Thus a shaft intended to be six inches across the squares would have a net width of square of two and one-half inches; the width of square determined, the dividers must be brought into requisition; and in setting them it is necessary to have them space exactly 2½ inches, otherwise in running around the circle they will either run behind or run beyond the starting point; in either case a new adjustment would be necessary. After the dividers have been set correctly, begin at the point where the line already made crosses the circle, (either end of the line), and step around the circle carefully. If the dividers are right, they will be found to come out even, the last step of the dividers will land where the first started. Lines can then be drawn from point to point through the center in the same manner as the first line was drawn, thus dividing the ends into eight equal parts corresponding with the eight squares which the shaft is to have.

The face lines of the squares are then made in this way: A small straight-edge or strip of any kind, a square, or anything available and suitable, is laid on the end of the piece in such a manner as to take in any two points intended to form one of the squares; a line must then be drawn with a knife or scribe-awl, along the edge of the strip and through the center of each point to the outside of the piece. The strip must then be moved around one point only, and a similar line drawn. This must be repeated until all the squares at both ends have been marked, then the piece must be lined from end to end to dress by. To do this, the piece, if not straight, should be supported on the corner in such a manner as to bring the face line of square about perpendicular. A chalk line can then be stretched along the piece, using the terminals of the face lines as points to work from. After the line is stretched, it must be raised as nearly perpendicular as possible for striking; because, if allowed to vary a great deal from a perpendicular direction, it would be liable to make a curved line on the piece, which would prevent the face of the square from being straight when dressed. After all the squares have been lined in this way, the four corners of the piece can be dressed off first with an axe or adze, then planed nicely to the lines. This will form four of the eight sides or square; for the other four the same mode of lining will have to be adopted, although with less trouble, as the half-finished shaft can rest solidly on one of the newly-dressed sides, while the lines are being struck on the opposite one for the other four. It is not necessary to use a chalk line in this case if a long straight-edge is available, as it can be laid to the place and a fine pencil or awl line can be made along it, either of which is better than a chalk line. The reason this mode of lining would not answer in the first place is, because owing to the crooked and rough condition of the stick, a good and true line could not be made. These last lines made, and the other four squares dressed, a complete eight-square shaft is the result.

In getting out a six-square shaft much the same method is adopted as in the eight-square just described. Some millwrights use six-square shafts for reels, but they make a very awkward shaft. A twelve-square shaft is much the best for reels. Twelve-square shafts are to be dressed in much the same manner as the others. The rule for obtaining the width of squares on an eight-square shaft will not hold good for determining width of squares on a twelve-square shaft. In making what would be called a seven-inch reel shaft, it is best to strike a seven-inch circle and divide it into twelve equal parts, and allow it to be whatever it will make across the squares when dressed.

Water-wheel (wooden) shafts are usually dressed with sixteen sides or squares; and while there are not so many shafts of this kind used now, it is probably well enough to give the operation of getting out a water-wheel shaft a passing notice. The stick for the purpose is best selected standing, and in felling great care must be taken not to split or otherwise damage it. After the tree from which the shaft is to be taken is cut down, the shaft piece is cut out of the butt end, or near to it, with the ends cut off about square, and a circle of the size required struck on them. The first lines are then drawn across the ends in the same manner as on the conveyor shaft, and the circle divided into sixteen equal parts to correspond with the sixteen sides. The faces of the squares are marked off in the same way, and a chalk line is struck, one at a time only. The stick is adjusted so that the face line on the end of the stick will stand exactly plumb with the chalk line on upper side. The workmen then get up on top of the log with heavy chopping axes to do the "scoring." They chip in and split off nearly to the line. This operation is followed by a heavy broad-axe in the hands of a skillful workman. The work is tested every few moments with a plumb line to see that it is right. When the first side is finished in this way, the log is turned so as to bring the next square in position, and which is dressed in the same manner as the first; then comes the next, and so on, until the stick has been dressed all around. This operation does not finish the shaft. As must be remembered it has been roughly dressed; larger than intended to be when finished. There should be at least one-half inch left all around to finish to the proper size. Before it is counter-hewed it is customary to haul it to the place where it is to be used, there to be finished.

It of course does not follow necessarily that the mill-wright should always go to the forest or woods to cut down and dress the shaft. It may not always be convenient to do so. It may be more convenient to bring it to the mill rough; but in either case the mode of dressing would be the same.



ARTICLE IV.

PUTTING GUDGEONS INTO WOODEN SHAFT. MAKING CONVEYORS.

Wooden shafts, either for conveyor or reel, or for any other purpose, should be dressed as straight as possible, not only because it is necessary to make them run easy and true, but it also greatly lessens the difficulty of putting in the gudgeon. It is next to impossible to put a gudgeon straight in a crooked shaft, more especially wing gudgeons, which have been mostly used in the past. It is sometimes a troublesome job to get a winged gudgeon in true when the shaft is as straight and true as it can be made; and it is much worse when the shaft is not straight and true.

The mode of proceeding is something like this: First cut the shaft to the length desired, leaving the ends square. The best plan for marking a shaft square for cutting off is to fasten two strips of board together at right angles with each other, each about five inches wide. They can be fastened together either with nails or screws, the latter are best. Then one end must be cut perfectly square—just as true as the iron or any other square used by the mechanic. If in cutting off the end of the angle the saw should run either one way or the other, then the plane must be used to make it square. The angle finished, one of the sides can be laid on the uppermost square of the shaft as it lays on the trestles or elsewhere, while the other side can be pressed against the second square below, or the one at right angles with the top, in the same manner as an ordinary square is held when squaring other kinds of lumber. Then along the end of the top angle, the same as along a square, a line may be drawn. This marks the second square. The angle can then be moved to the next square, when it can be marked in the same way, making sure that the two lines meet each other; then the next square can be marked and so on all the way around. If the shaft is then cut off and dressed neatly to this line the end will be as near square with the body of the stick as it is possible to make it.

It will be noticed that the wings of the gudgeons are thicker at the butt than at the other end, that is, the wings are wedge-shape. The thickness of the butt of the wings must be taken into account in mortising out the shaft to receive them, as the butts want to fit snugly, while there should be a gradual widening of the mortise outward to the end to allow for wedging. The imprint of mortises or slots must be made on the ends of the shaft. These slots cross each other at right angles or ought to; however, the shape of the gudgeon determines the shape of the slots. After they have been marked on the ends and carried back on the shaft the length of the wings, a good rip-saw can be used to advantage in cutting them out, after which the butts can be bored through with a small bit or auger. A chisel must then be used for finishing the slots. There will probably be considerable cutting out around the center to receive the body of the gudgeon, all of which will suggest itself to the workman. When the slots are finished so as to allow the gudgeon to slip readily in place (it must not bind), a curf must be cut on each side of each slot and about one-quarter of an inch away. These curfs are to receive the wedges. As should have been previously stated, in laying out the end of the shaft a circle of the diameter of the outer end of the wings should have been struck. It is common enough to strike both circles, that is, a circle for each end of gudgeon, the butt end being larger than the other. The last named circle, however, is not necessary; the necessity of the other will be discovered a little further on in the operation. After all the preparations have been made, the gudgeon is put in place and temporary wedges used to secure it while it is being trued. Any convenient mode of trueing and centering may be adopted; but the best probably is to procure a strip of board, which must be made straight on one edge, and about five or six feet long or longer, according to the length of the shaft. In one end of this strip, down through the edge, bore a small auger hole about three-eighths of an inch. Into this fit a pin neatly, but loose enough to move easily. One end of the pin must be dressed to a fine point. This ready, the straightened edge of the strip can be laid on the shaft with the end containing the pin overhanging the gudgeon. The pointed end of the pin must then be pressed down until it touches the gudgeon, say at the extreme end. The strip must then be moved backward on the shaft, keeping the pin exactly over the center of the gudgeon. If, after moving the strip the length of the gudgeon, it is found the pin does not touch, it is an evidence that the extreme end is too high. This trial should be made on a square containing one of the wings. All the trials should be made on wing-squares of the shaft. What is necessary to do when the outer or extreme end of the gudgeon is too high, is to back the lower wedges on the other two wings, that is, the two running at right angles with the one the strip is resting on, and tighten the upper wedges, after which another trial must be made. It may be found just right the second time; but it is not likely to be. It may have been lowered too much the first time, and, if so, it must be brought up by loosening the upper wedges and tightening the lower. When exactly true one way, the other must be tried and treated in the same way, until right.

The gudgeon can be made true and straight by working from two sides, but cannot be centered in that way. For centering, the proof strip must be used on four sides; and the centering and truing ought to both be done at the same time, for the reason that if, after it had been trued up and was on trial found to be not in center, it would have to be loosened again, thus necessitating double work, as it would take just as long to true it the second time as it did the first.

After the truing and centering is completed, the end of the shaft must be dressed down to the wings ready for the bands. The first operation is to saw around the shaft at the butt of the wings so as to allow it to be dressed even with them; then, by the use of a draw-knife or other tool, the end of the shaft can be shaved down, the circle on the end already provided being a guide between the wings. This done, the bands must be driven on—two or three, as may be required. There are generally two for conveyor shafts, and three for reel shafts, the gudgeons for reels being longer than for conveyors. The bands on snug and tight, the temporary wedges must be removed, permanent ones put in their place and driven in very hard. The permanent wedges should be from about nine to fourteen inches in length, according to length of gudgeon and not more than one-quarter to five-sixteenths of an inch thick at the butt. They should be made of hard wood, and of a width to suit the size of gudgeon.

Large gudgeons, as for water-wheel shafts, are put in the same way as described, except when the bands are driven on they should be heated very hot. Smaller bands are sometimes heated; but for ordinary reel and conveyor shafts this is not necessary, as they can be forced on tight enough when cold.

The winged gudgeon is one of the oldest kind now in use, and one of the most troublesome to get in and adjust. A much more convenient pattern is now sometimes used. It consists simply of a flanged disk with the journal attached; both cast solidly together. The outside diameter of disk is a little less than the diameter of the shaft. The flange should be about three-fourths of an inch in depth, and about three-sixteenths in thickness, while the body of the disk should be about five-sixteenths of an inch thick. The inside of flange and inside face of disk should be turned out true from the same centers by which the journal is turned off. Through the body of disk and as near the periphery as convenient, there should be three bolt holes at equal distances apart. Sometimes one bolt hole only is used, and that right through the center of journal. This, however, is not so good a plan as the other, as three bolts will hold better than one; and, besides, if one of the three gets loose, the other two will hold the gudgeon in place until the third is tightened; whereas, with but one, if the bolt gets loose the whole gudgeon is loose.

The mode of putting in this kind of a gudgeon is to first make the end of shaft exactly square in the same manner as previously described; then strike a circle on the end in size corresponding with the inside diameter of flange. To this circle the shaft must be neatly dressed back to the depth of the flange. If convenient to use a lathe, a much better job can be made; but if not, it can be done very neatly with a chisel. When this is done the gudgeon will slip to its place, and when there, will be exactly true. To fasten it, joint bolts must be used. They may be seven to nine inches in length. This style of gudgeon can be put on in less time than a winged gudgeon, and can be made, if anything, truer and better every way. While I have no knowledge of gudgeons of this kind being used on very large shafts, such as water-wheel shafts, I have no doubt they could be used for that purpose just as well or better than the old-fashioned wing gudgeon. More bolts, and stronger, would have to be used to make it firm.

It has not been very long since nothing but wooden conveyors were used in this country, but in the past few years other styles have been adopted. Part wood and part iron have been for a long time in use. The wooden shafts are turned round, and iron spiral flights put on, forming a regular screw or worm; and occasionally the ordinary flight is made of iron instead of wood. The best style of conveyor now in use is made with a continuous spiral of heavy sheet-iron, and fastened to a gas pipe for a shaft. This style of conveyor is very light, very durable, and very effective, and is no doubt the best for all purposes that can be obtained. The different styles of iron conveyors are made by the patentees or manufacturers, and cannot very well be made by millwrights as a general thing, and need not, therefore, any description of the mode of making. But as the wooden conveyor is likely to be to a greater or less extent in vogue for many years to come, and as they have to be made by the millwright wherever he may happen to be doing a job of work, it is necessary that some attention should be paid to such in this connection.

The mode of making a flight would be too tedious and could not be described intelligibly; and, besides, flights already finished and ready to drive can be bought from the various manufacturers much cheaper than they can be made by hand. As simple a plan as can be adopted for marking off a shaft for the flights, is to procure a strip the width of one square of the shaft, and about ten inches in length. One end of this should be cut bevelling to correspond with the run of the conveyor, or, if liked better, the wooden angle used in squaring or in marking the end of shaft square, can be used by cutting one end of one of the sides of it to the required bevel. A good average run for a conveyor for ordinary purposes is about nine inches, although, if more work or less speed is required, or both, the run can be made longer —to sixteen inches, if desired. In the case of a nine-inch run, the bevel would be one inch and one-eighth to the square. To get at this correctly the strip must be first made the exact width of a square, then two square lines must be drawn across it near the end, exactly one and one-eighth of an inch apart. From the extreme of one of these lines to the opposite extreme of the other, a line must be drawn. This line should be made with the point of a knife deep and distinct. To the line thus made the end of strip should be cut off and dressed exactly. It can then be laid on one of the squares and a pencil line drawn across the square along the prepared beveled end. It can then be moved to the next square and adjusted so as to meet the line last made, and another lead-pencil line drawn. The strip must be again moved to the next square, and so on until the shaft has been marked from end to end. After this has been done, center lines should be made along each square with a chalk line, or by any other means. The last named line indicates the center of the holes that have to be bored for driving the flights. These should be bored just back of the angling pencil mark so that the face of the flight may be flush with the mark, which acts as a guide for driving the flight, and enables the workman to get a more perfect worm.

There are, of course, other modes of laying out a conveyor for driving the flights, but none better. A pair of dividers are sometimes used, set at nine inches for a nine-inch run, the starting point to be made where the first flight is to be driven, and that square of the shaft divided into nine-inch spaces. On the next square the starting point will be one and one-eighth of an inch forward of the first, and each successive square will have just that much the start of the last until all are divided off, when the shaft will be ready for boring and for driving the flights as before. This method may be a little quicker than the other, and with a skilled workman is probably good. It will be found just as important in dressing flight not to have the auger holes too small, as it is not to have them too large; for while in a pine shaft, the wood being soft, a hard wood flight may be forced into a hole much too small, it is not near so liable to remain tight as though it were driven reasonably tight at first. It is necessary only that the corners of the flight shall have a firm hold in the mortise. It will be secured much better than if the whole body of the flight tenon forced its passage into the shaft.

ARTICLE V.

THE BUILDING OF HUSK-FRAMES. SETTING AND ADJUSTING BED-STONE. TAKING IT OUT OF WIND. MAKING CURBS.

There are many forms of husk-frames, both of wood and iron; and to attempt to describe the mode of making all would be a useless task, and unnecessary for the reason that the millwright so far advanced as to be able to construct any good form of a husk-frame, would be also able to adapt himself to circumstance, and make whatever changes and modifications that might be needed in any case, or make entirely new models if necessary or thought expedient.

One of the chief points to be considered is, to have the frame as open and free as possible. There should be no more posts than are really necessary to insure strength and rigidity. I have noticed a very convenient form of husk, on which were four run of stone in a nest, that had but eight posts. There were four main corner posts, and four additional for supporting the bridge-trees, two of which were framed into the four corner posts and ran entirely through the husk; the other two were in turn framed into the first two bridge-trees in such a manner as to form a square. On each of the four sides of the square thus formed were placed a tram-pot and step for sustaining the spindle. The ends of the two principle bridge-trees in this kind of a frame, as well as being double-tenoned, should be well boxed into the posts, as they have to sustain all the weight, including the spindles and burrs. This plan of husk-frame is very convenient on account of its being so open and accessible. Little or no trouble is experienced in getting into the gearing, which is most favorable for filling the crown wheel, a job that has to be done quite often.

The more substantial plan is to have a pair of posts to each bridge-tree or for each run of stone, especially when the burrs are in a single line; but when in nests this, of course, cannot be done. The time is, though, probably coming when no more frames will be built in that way. It is so much better in every way to have the burrs all in a single line, that ere long it will be generally adopted. Few new mills are now built in any other way. It is true, spur gearing cannot be used to good advantage; and it is just as well not, because, if gearing be used at all, bevel gearing answers the purpose as well or better. The most popular and undoubtedly the best mode of driving the burrs is by means of belts; but whether by bevel gear or belt, the frame so constructed as to have a pair of posts for each run of stone, is equally well adapted to either, as the belt can be so adjusted either open or reel as to run around the post.

The framing in a husk-frame ought to be very carefully done, and the tenons made to fit the mortises very snug and tight. No pins should be used, but, instead, long bolts or rods with a nut on both ends. These should run through from cap to sill, and crosswise from cap to cap at top (at the ends of the frame), and from sill to sill at bottom. With these rods the frame can be drawn together very tight, and kept so by being careful to tighten up as the lumber shrinks.

Iron husk-frames, as a matter of course, are built by the general mill-furnisher and manufacturers, and according to different plans. The base of an iron frame or a combination of them, as is the case where two or more run are put on one frame, rests upon a separate and independent pedestal, while the tops are all joined together either with iron or wood. The latter mode is preferable, because in a long frame all joined together, iron to iron, the constant contraction and expansion incident to the changes of temperature keeps the spindles most of the time out of tram. When joined together with wooden string pieces this cannot occur—to any appreciable extent, at least. Parties who are getting mills built should bear this fact in mind; and when contracting for a mill to be furnished with an iron husk-frame, they should see that the frame is so constructed as to prevent the difficulties spoken of.

The size of timbers to be used in wooden frames must depend on the size of frame and the number of run it is to contain or support, and the manner in which it is built. This matter should be left to the judgment of the millwright. Doubtless the best plan of finishing the top of the husk-frame is to have the timbers all flush. For each run of stone there should be two main bearers running across the top of frame, and tenoned into the main cap. The distance apart of these bearers must be determined by the size of the burrs. Between the main bearers must be fixed two short cross-trees in such a manner as to form a square, the center of which will be the center of the spindle. On this square the bed-stone must be set; or, if liked best, it can be let down say six inches in the frame, which then answers both for a bearer and a binder. But if this plan is not liked, a separate binding frame can be made, and laid on and fastened to the main frame.

It is an old-fashioned practice, and a very good one, to bind the stone with wooden keys driven between the stone and the frame. A key-seat should be cut in each of the four sides of the frame, and four keys fitted snugly in these seats and against the stone. After the stone has been placed and centered, these four keys must be driven at once or in such a manner as not to displace the stone. After they have been made securely tight, they must be cut off even with the frame so that the stone can be faced or curbed around.

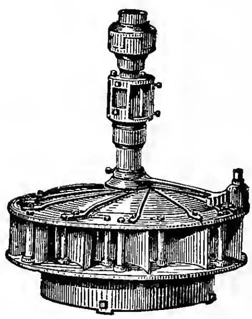
The best and most convenient plan for fastening or binding the bed-stone is to use set-bolts, four of them to each run, having broad, heavy nuts. These nuts to be fastened into the timbers inside the frame, one in each of the four sides; the bolts run through from the outside of the frame, each of them pointing to the center of the stone. When the stone has been placed, these four bolts are to be tightened up in the same manner as the keys, or for the same purpose, and in such a way as not to move the stone out of place. If, however, the stone should be displaced, it is quite easy to readjust it by gradually loosening on one side and tightening on the other. To operate these bolts after everything has been closed up, hand-holes should be left in the floor of the husk, neatly closed by hatches snugly fitted into the opening.

For leveling the stone a similar device must be used. Three set-bolts running up from below through the bearers, with broad, heavy nuts set in above, will answer the purpose. There should be fixed in the plaster on the back or under side of the stone, at the points where it rests on the bolts, small iron plates, or metal plates of any kind, to receive the points of the bolts. Thus, with bolts to level and bolts to adjust centrally, it becomes a very easy task to fix a bed-stone in good shape, and when fixed it can be firmly held in place. By fixing a center in the eye of the bed-stone after it has been centered and fastened, and suspending a center plumb to the bridge-tree below, the tram-pot can be centered exactly and fastened, after which the spindle can be put in place and trammed. It may not prove, if on trial the spindle shows out of tram, that it is all in the spindle; on the contrary, if great care has been exercised in centering the tram-pot, it would go to prove that the face of the stone was out; but if the face of the stone proves, on a test with a perfectly true spirit-level, to be right, it is best not to move it, but to adjust the spindle to it. There should, however, be no doubt about the face of the stone being level.

The common mode of tramming is to attach a strip of board, one end of it mortised to suit the spindle, to the square part of the neck of the spindle. The strip must be long enough to reach to the skirt of the stone. To the outer end of strip, by means of a gimlet-hole, a quill piece of steel wire, or some similar substance, must be fastened. This must be adjusted so as to touch the highest part of the stone. The spindle must then be turned until the tram-strip or arm indicates the opposite side of the stone. The difference must then be noted, and the foot of the spindle moved to suit as near as can be judged. The spindle must again be turned around, and the quill adjusted to strike the high place again. Then the foot of spindle must be moved to suit, as before, and again it must be tried by turning the spindle around. This mode of working, trying first the face of the stone and then adjusting the face of spindle to suit, must be continued until it is right, which it will be when the quill touches lightly all around.

This result cannot, of course, be accomplished unless the stone is entirely out of wind and in good face. A bed-stone can be taken out of wind mainly by the use of the tram as a guide, if sufficient care is exercised. A narrow strip of the face next the skirt must be dressed all the way around exactly to the point of the quill. Afterward the center of the stone can be dressed to the line thus made by the use of the red staff. A good circular proof and red staff are, however, much better adapted to the purpose; and the stone ought to be dressed out of wind before putting down, so as to avoid any trouble of that kind in tramming. It is assumed that the husk has been floored over before the stones have been placed; and here it would be well enough to say that the top of husk-frame should be raised above the level of the main floor—how much must be determined by the taste of the parties interested. There should be an elevation of at least six inches; ten or twelve inches are not out of the way. Many frames are raised even higher, but it is best not to be extreme in the matter. After the bed-stone has been placed and secured, it must be faced around with, say, about one and one-quarter inch plank, cut in circle segments to suit the size of stone. These should be about six inches deep, and should be fitted closely to the stone so as to prevent the meal from leaking through and being wasted; also the butt joints should be fitted closely together. To this facing the bottom of the curb has to be fitted, consequently it should have an even surface on top. The face of the stone should stand above the wooden facing about an inch when first put down.

Curbs are now chiefly made of staves. The staves are dressed out two and one-half to three inches inside. Generally they alternate, pine and walnut, and are bound top and bottom with walnut strips. This makes a very durable as well as a very fancy curb. The most convenient way of constructing a stave curb is to first make the top in the ordinary way, and fasten to the under side of it a circle of wood in diameter equal to the inside of curb. To this circle the staves can be fastened as they are fitted. A light iron hoop can be driven on the other end of staves to hold the curb in place until bound around and finished. Care should be taken in dressing out the staves to have them of such width as will fill the circle even, so as not to have to close with a narrow or wide stave; it spoils the looks of the curb. To make a "sprung" curb, a perfectly clear pine board that will dress an inch in thickness must be selected. This should be evenly planed to a gauge both in width and thickness. Then a gauge line should be run on both edges, three-sixteenths scant or a strong eighth, from what is intended to be the outside of the curb. The inside of the board must then be marked off in regular spaces for curfing. The number of spaces must be determined by the width of saw curf. Ordinarily it requires about ninety-six cuts; if the saw is very coarse, less will be required; if unusually fine, more will have to be made. The curf lines must be drawn square across the board, and square lines must be made on the edges from the curf lines to the gauge lines. After all is ready it must be sawed down very carefully on the lines made, and down to the gauge lines, but not over them; when this is done, the board must be laid on the floor or bench, curfed side down, and covered over with shavings, on which a reasonable quantity of hot water must be poured for the purpose of steaming and toughening the fibres of the board, to prevent it from breaking while springing into shape. When, in the judgment of the workman, the board is sufficiently toughened, it must be bent in shape by two persons taking hold of it, one at each end. When the ends are forced together, they must be held so until fastened, which is done by lapping with a solid piece circled out to suit, or a short curfed piece similar to the body of the curb. A curb made in this way must be bound around top and bottom the same as the stave curb; this is necessary to brace and stiffen it. Walnut or pine, according to taste, may be used.



ARTICLE VI.

DRAFT OF FURROWS — DRESSING — PUTTING IN THE IRONS — BALANCING.

There is, perhaps, no way as yet to determine the exact draft the furrows of a mill-stone should have; and it is also true that there is no positive or arbitrary line or rule of action. There is no doubt that the draft could vary very materially in two different run, both in the same mill, and the fact go unnoticed by the most expert miller if he had no other evidence than the kind of work each was doing. All other things being equal, there would be no appreciable difference. The common rule is to allow one inch draft to each foot of diameter: thus, a three-foot burr would have three inches draft, and a four-foot burr, four inches. The draft measured from the shoulder, or back edge of furrow. As to the number of furrows to the quarter, there may be some ground for dispute. One thing is quite clear: if the draft for the leading furrow just indicated approximates very closely to what it ought to be, the third furrow in a three-quarter dress gets a long way from it. Therefore, if there be any value in a uniformity of draft, the fewer furrows there are to the quarter the better; and hence it would seem reasonable that a two-quarter dress would be better than three. The number of quarters is determined by the size of the stone. Land and furrow space should be about equal. In some cases there should be less land than furrow space; but that part of the subject will be referred to further on in the work. For a pair of burrs to run with the sun, the furrows should run to the right of the center, and the inner end of the leading furrow four inches from the center in a four-foot stone, allowing one inch draft to the foot. To run against the sun, the furrows should run to the left side of the center. The furrows in both upper and lower burr run in the same direction.

There is a great deal more importance to be attached to dressing the furrows than to the draft; for on the kind of dress depends largely the kind of work the burrs will do. If the dress is bad, it generally follows that the work will be bad, also. The bottom of furrow should be dressed very even and very smooth, and drawn out to a firm, feather-edge. There should not be even the semblance of a shoulder on the feather-edge of a furrow; no obstruction of any kind; nothing but a smooth, gradual incline up to the land. A reasonable depth only at the eye should be allowed, say, a scant quarter of an inch, gradually lessening as it approaches the skirt, where an eighth of an inch is deep enough ordinarily. As to whether the furrow should be of equal width from end to end is a matter of no great importance, except that to have the bottom of furrow out of wind, it is necessary to have the inner end a little wider than the outer on account of its being deeper. There is no reason why the inner end should be the deepest, except to accommodate the greater volume of material to be ground in proportion to the surface. As the material approaches the outer edge of the burrs the volume becomes relatively less, and less depth is needed because it is then divided between furrow and land, while at the eye it is chiefly all furrow.

The stone should be lower around the eye than at the skirt. If it were possible to make it so, the burr should have a gradually inclined surface from the eye to the periphery, or at least very near the periphery. It would, perhaps, be best to have three or four inches of the outside surfaces parallel. The balance of the face to the eye should be a graduated bosom. The face, as well as the furrows, should be comparatively smooth; if cracked at all, very light. The natural grit of a good stone, if in perfect face, is all that is needed for granulating.

Putting the irons in the burrs sometimes falls to the lot of the millwright even now; although, as a general thing, the stones are furnished complete by the manufacturer or mill-furnisher. It is no difficult matter to get the bush in the bed-stone, as the opening is usually large enough to admit it. All that is necessary to do is to place it in a true position, about an inch below the face of the stone, fasten it temporarily with small wooden wedges or other appliances; after which prepared calcined plaster can be mixed with water to the consistency of a stiff paste, and run around the bush. This sets very quick and makes a good, permanent fastening.

To put in the balance-rynd is quite a different and more difficult task. In the first place the stone must be mortised for the lugs. This is done with diamond-pointed tools in the shape of cold-chisels. These mortises should be deep enough to allow the rim of the rynd to drop below the face at least one inch. After the rynd has been fitted to its place, and before fastening, the spindle, with driver, should be placed in it and the tram applied. The driving sides of the driver should be forced to a bearing on the lugs of the rynd by little iron wedges, or anything else suitable; and then, instead of adjusting the driver, it should remain fixed, and the rynd moved to suit the requirements of the case, or until the spindle shows in tram. The rynd is then temporarily fastened with iron wedges, until molten lead or brimstone can be prepared for running around it. Brimstone is preferable to lead, chiefly for the reason that it is not poisonous. There can no harm result from lead unless particles of it should become detached and be ground with the wheat. It would then poison the flour.

After the stones have been ironed properly, set and adjusted, and everything else connected with them in good shape, the balancing of the runner has to be attended to. The standing balance of a burr is easily enough obtained, but how to get a running balance puzzles the brain of many a man who supposes he has a pretty thorough knowledge of the business. This arises from the fact that in the past much less attention was given to running balances than now. Before milling was reduced to so fine an art as it now is, a good standing balance was all that was considered necessary; but in these days of even granulation and scientific milling, generally a stone must have not only a good standing balance, but a good running balance as well; and the miller or millwright who cannot put a stone in good standing and running balance is considered "off." The standing balance is necessary in order to have the stone and machinery connected with it to run smoothly. The running balance is necessary in order to have the stone grind or granulate evenly. A stone out of running balance runs with one side high, and the opposite lower, and hence the cause of uneven granulation. The great reason that getting a stone in running balance is, and has been, so little understood, is, because millers and millwrights pay so little attention to the principles controlling the operation; nor can the operation be made intelligible without understanding why it is that, after a stone has been put in complete standing balance, it should run with one side high when put in motion.

There is no doubt that the same result has been observed many times in other ways without knowing the cause, or, at least, without discovering the relation. Almost every man, when a school boy, has made an indention in the center of his slate, and tried to suspend it on the point of his pencil. This he could rarely do when in a state of rest; but soon discovered that by whirling it, it would remain suspended, and nearly on a level plane while the motion was rapid enough; but as soon as the motion would cease it would drop off. The same thing has been noticed by attaching a weight to the end of a cord, and giving it a rapid, whirling motion. The weight will at once come up almost on a plane with the hand holding the cord; when the motion ceases it drops back. And, again, when the governor of a steam engine is in a state of rest the balls seem inclined to get as close to each other as possible; but when the engine is put in motion they apparently repel each other, and endeavor to climb up to the plane of suspension. The same cause that impels these bodies upward, impels upward the side of the burr that runs high. This is called centrifugal force, or a tendency to fly outward from the center. It is the opposite of the attraction of gravitation. There is no positive force at work in raising these bodies upward: it may be considered rather as a negative force. The tendency is outward; and when tied, as by a cord or otherwise, the greatest distance outward can be attained only by climbing upwards; and up it will climb, if the motion be rapid enough, until the plane of suspension is reached, but never above it. These laws of motion control the workings of the mill-stone when in motion. All mill-stones (runners) measure sixteen inches and upward through. The point of suspension is at least half the distance from the face, usually more. It ought to be three-fifths of the thickness of the stone from the face to the cock-eye. In consequence of this mode of suspension, there is a great deal of weight both above and below the point; and while the burr may have been very evenly balanced standing, it may be that in one block much of the weight is concentrated, instead of being generally distributed. In that case, as soon as the burr be put in rapid motion, the heavy point will tend upward, and, of course, throw the opposite side down. The tendency of the weight is to get as far as possible from the perpendicular center of motion; and to do that it must go up. It can not go down, because by so doing it approaches nearer the center. If the heavy weight should be above the point of suspension, or near the back of the stone, the opposite effect would be the result of putting the stone in motion. The tendency would be down instead of up; and for the same reason, by inclining upward, the center of motion is approached; by dropping down the distance is increased.

There is a great liability to concentrate too much weight in one point in giving the stone a standing balance, particularly if the stone be much out. Sometimes ten to twenty pounds of lead are put in one spot to get a standing balance. This is sure to make the stone run "out." It will be understood by what has been said that, when a burr is too heavy below, it will run up at the heavy point; and if too heavy above, it will run down at that point. This fact understood, and the reasons therefor, the practical part of putting a burr in running balance ought to be readily comprehended with a little instruction. The first part of the operation is to dress out some strips, about one-quarter inch thick and two inches wide. They must be dressed to an exact thickness, and laid across the face of the bed-stone, three of them, in the form of a triangle, with the ends fastened to the facing around the bed-stone to hold them in place. The runner must then be put in position and let down on the strips; after which a suitable rest must be fixed over the back of the runner for the purpose of turning it off. The strips are used to hold the stone steady. If left free it would oscillate to such an extent that it could not be turned true; and if let hard down on the bed-stone it would burn and damage both. By rubbing on the wooden strips it is held in place and no harm done. The mode of securing rest and turning off will suggest itself. After the back has been finished perfectly ture, as it ought to be, the strips can be removed and the stone lowered a little. It will then be ready for a trial. The eye will tell whether it is in running balance or not as soon as it is put in motion; but it cannot without aid locate the exact high or low spot. To do this a finely pointed lead-pencil can be used. It must be held carefully against the rest, in the same manner as the chisel in turning off. Whenever the pencil touches the stone, it must be removed, and the stone stopped. An inspection will then show the high point, as it will be marked. By remembering the principle involved, it will be known there is one of two things certain: either the point that is marked by the pencil is too heavy below the point of suspension, or the opposite point is too heavy above.

It is assumed the stone has been put in standing balance before trying the running balance; and it is also assumed that the stone is provided with balance-pockets, as they are all now made in this country; and it is further assumed that the common mode of balancing has been adopted, that is, with circular lead weights, a little less in diameter than the pockets, so that they can be put in and taken our freely. These weights are prepared by cutting moulds of different depths in a pine, or other soft wood plank, into which molten lead is poured to form the weights. Now, it may be that the pencil mark may be right over a pocket, in the bottom of which a number of these lead weights have been put in getting a standing balance. If that be true it will be evidence that the weight is too low, thus causing the stone to run high at that point. To get the weight up nearer the back of the stone, a few circular pine blocks must be made, the lead lifted out of the pocket, and the blocks put in place of it. The lead must be then put back. The blocks will not affect the standing balance, being very light, but they serve to raise the lead and may thereby secure a running balance. It may be found, after putting the stone in motion again, that it still runs too high at the point; if so, it will probably be necessary to use more lead. A given amount for trial must be put in the top of the pocket already loaded, and an equal amount in the bottom of the opposite pocket. Or, instead of running high, it might be found on trial that the high point ran low, and the opposite ran high. In that case it would be evident that the weight had been raised too high. To remedy that, some of the wooden blocks must be taken out and the weight let down, and the stone again put in motion to observe the result. If it now be discovered that this point again runs high, it will be proof that the weight was dropped too low and must be raised again by the addition of one or more blocks; but if it still runs low, the weight must be dropped lower down by taking out one or more blocks. But, to go back again, if after the weight has all been raised to or near the top, and the burr still runs high at that point, as has been stated, more lead must be added to the loaded pocket, and a precisely equal amount placed in the bottom of the opposite pocket; and if the same point still runs too high, more lead must be added, an equal amount to each pocket. But if, on the contrary, the previous high point should run too low, then an equal amount of lead must be taken out of each pocket. It must be remembered to keep the standing balance in view all the time; and hence the necessity for adding to, or taking from, equal amounts each time when working in two opposite pockets.

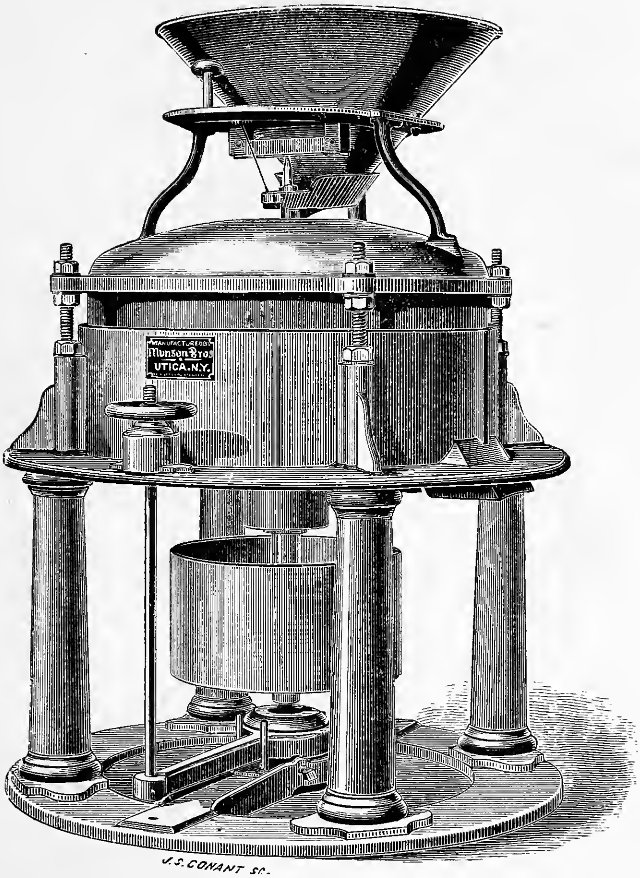
It is not often that a running balance can be obtained until after many trials; nor is it often that it can be got by working from two points alone. If often happens that two pockets have to be weighted in getting a standing balance; and when so, four will probably have to be used in getting the running balance. But whether two or four, it must not be forgotten that when taking weight from, or adding to, opposite points, the amounts must always be equal. To make a high point run low, the weight must be raised; and to make a low point run high, the weight must be lowered. Whenever one point runs too high and the opposite too low, as a matter of course to equalize it, the weight must be placed near the top or back of the stone at the high side, and near the bottom or face on the low side; that is, if it cannot be fixed by raising or lowering in the one pocket.

There are patented devices or attachments that work in these pockets which raise and lower the weights with a screw, and act substantially as the mode just described. The same rules govern the raising and lowering of the weights in both cases. It sometimes occurs that, owing to the heavy and irregular parts of the stone coming between the pockets, it is impossible to get a good balance, standing or running. In such a case a standing balance can be obtained by making an opening in the plaster on the back of the stone, and pouring in melted lead; and there are still burrs in operation that have never been provided with balance pockets. In either case some other mode besides the one described by the pockets will have to be devised. A very simple, though homely method, is to procure two light hoop-iron bands to go loosely around the stone. It would be better to have the band made open, with small lugs at either end, and a bolt to tighten it up. One of these bands must be placed near the top of the stone and the other near the bottom. Little wooden wedges can be forced in between the stone and band at intervals around the stone, and the bolt tightened sufficiently to hold it; or, if there should be no bolt, the wedges must be forced in tight enough to hold it. These bands are now supposed to be far enough away from the stone to allow small bars of lead to pass between, double over, and hang on the band. To utilize these bands for getting a running balance, the same rules must be observed as in the other case. At that point running high the lead bars must be attached to the upper band, while on the opposite side it must be fixed to the lower band; and if it still runs high at the same point more lead must be added, to both places equal amounts; but if, on the contrary, the order is changed, and it runs high where it had previously run low, then an equal amount of lead must be taken from each place. One advantage this arrangement possesses is, that no matter where the pencil touches, or where the stone runs high, that precise point can be reached with the weight, and it is, therefore, much less trouble to get an exact running balance in this way than by the other. This mode is here introduced merely to show how it can be done. The operator can invent any other method that may suit him better.

ARTICLE VII.

RIGID OR LOOSE DRIVERS — MOTION — PORTABLE MILLS — SPEED OF BURRS.

Many millers and millwrights are now advocating rigid drivers for mill-stones; that is to say, the stone should be fastened rigidly to the spindle. There is probably, no doubt, when in a state of perfection, but that a rigid driving attachment answers the purpose well; better, possibly, than the ordinary method; but the difficulty is to secure and keep perfection. It is quite evident that if, in order to do even granulating, it be necessary to have the faces of the stones exactly parallel to each other, the moment the face of the runner gets the least out, or at an angle, be it ever so slight, with the face of the bed-stone, that moment even granulation ceases if the runner be rigidly fastened to the spindle. It is well-known that, owing to the strain on the spindle caused by the pressure of the driving apparatus, either belt or gear, and for other reasons, it is next to impossible to keep the spindle constantly in tram. This being the fact, it will be readily enough understood how difficult it will be to keep the faces of the stones parallel with each other when the runner is fastened rigidly to the spindle, because whenever the perpendicular of the spindle is disturbed, so also will the parallel of the face be disturbed; and the longer the stone runs without tramming, the worse it will get. It is, perhaps, not absolutely necessary that the stones should be adjusted to each other to a hair's breadth; but it is necessary that the adjustment should be practical and kept so, in order to obtain the best results. With a rigidly hung runner this cannot be done unless the spindle



MUNSON'S PORTABLE MILL.

Made by MUNSON BROS. Utica, N. Y.

(See Appendix.)

can be kept constantly in tram. It is not argued that it is impossible to do this; but it is maintained that it is very difficult to do so, even under the most favorable circumstances. The same obstacles present themselves to some extent where the runner is attached loosely to the spindle. The spindle is just as liable to get out of tram, but it does not have quite the same effect on the face of the stone. It is true that the nearer the spindle is in tram in either case, the better the work performed; but the face of the loosely hung runner does not obey the behest of the spindle so promptly and so inevitably as does the rigidly hung runner. If properly adjusted and well balanced, the loosely hung runner will preserve its line of motion unless the spindle is too much out of tram.

It would, from this mode of reasoning, seem to follow that in practice the well-attached and well-balanced loosely hung runner is to be preferred to the rigidly hung, at least until some better method of adjusting and permanently fixing the rigid combination than is now known be discovered.

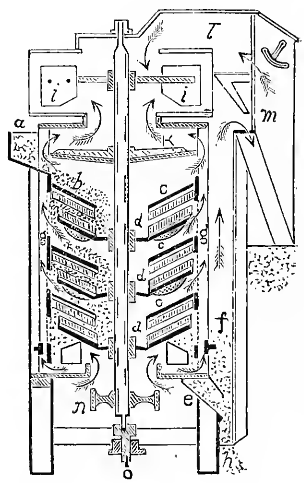
That even granulation is necessary to the best results in flour making requires no proof, as it is universally admitted: therefore, any method of hanging or attaching the runner to the spindle that will insure the most perfect relation between the faces of the two burrs when in operation, because on that depends even granulation, is the best. It cannot be done with the rigidly hung runner unless the spindle can be kept constantly in tram. It can be with the loosely hung runner, all other things being right and equal, whether the spindle be exactly in tram or not. It would follow, therefore, that until the rigid arrangement has been so far perfected that the spindle will neither spring, nor in any other way get out of tram when at work, the other is the best method, and may be the best under any circumstances. In attaching the driving apparatus to the stone it is necessary that both sides of the driver should bear with about equal force, otherwise the stone will be forced out of its proper position, causing one side to run high and the other low. The fact that drivers so often work badly (having a bearing on but one side and causing the stone to tip,) is one of the strongest arguments in favor of the rigid fastening; for when the stone is fastened to the spindle no other driver is needed, nor can there be any tipping on account of a bad working driver. But with a reasonable amount of care there is no occasion for having a faulty or bad working driver, as the most obstinate unadjustable driver can be made to work right; or, if it can not, then some good adjustable driver can be put in its place. Adjustable drivers are very numerous and some of them very good.

The plan for putting a driver into a bail already in the stone, is to place the spindle in position, the same as described when setting the balance rynd; tram it to the face of the stone; then fit the driver with cold chisel and file until it bears equally on both driving lugs. It sometimes requires a great deal of patience and skill to make a good fit in putting a new driver into an old burr with the irons already in, but it should not be abandoned until right. Another essential in even granulation is in having a steady, regular motion to the stone. There is far more importance attached to this one point than is generally supposed. This is especially so in old mills, when the husk frame is in bad order, and the gearing generally badly worn. Under conditions of that kind it is impossible to get the steady motion needed for good results without some way of regulating the motion. This is best done by a spring of some kind. The value of a spring is not confined to old, rickety mills alone, but also adds materially to the result in the best constructed new mills, be it driven either with belt or gear. The main line driving the burrs should have attached to it a strong spring, and on each of the spindles should be another. A reciprocating steam engine cannot be constrncted to give a positively uniform motion. It must lose while passing the center, and gain immediately after; and while this loss is not perceptible to the eye, or sensible to the touch, yet it can be readily detected when the proper means are applied for the purpose. There may not be the same difference with water wheels as motors; but there is, no doubt, sufficient to warrant the use of springs on the spindles at least. Steam engines of short stroke and quick motion should always be used for driving flour mills, as the variation in motion cannot be so great as with long-stroke, slow-moving engines.

Portable mills are now, and have been much in vogue in this country for many purposes; and some of them are most excellent. Where mills have already been completed with a full complement of burrs on the husk frame, it is very convenient to add one or more portable mills, as the case may be, for the purpose of grinding middlings; or, in grist mill, if unprovided for in the start, a portable mill comes handy for grinding feed. For this purpose the runner may be attached rigidly to the spindle, as rapid work is of far more importance than even granulation. A rigid under runner portable mill is much the best for grinding feed, as it can be kept hard up to the work. It is, perhaps, not so important whether the runner is upper or lower. So long as it is rigid, it can be kept hard to the work in either case. One among the best arrangements for portable mills is to have the under stone hung on a cock-head, the same as the upper runner. Ordinarily by this means, with well-balanced stones, just as even granulation can be done as in the other way, with the advantage of greater grinding capacity if required. A small mill built on this plan will do the work just as well, and a great deal more of it, than can be done on an equal sized stone on the other plan, that is, with the upper stone for the runner.

It is probably impossible to fix a uniform speed for burrs under all circumstances; but, the following table of minimum speeds will come near enough for good results. In varying, the speeds should be made rarely, if ever, above the tabled speed:

Stone.	Soft Varieties. (Winter.)	Hard Varieties. (Spring.)
48 inches in diameter....	150 revolutions.	120 revolutions.
42 " "	172 "	138 "
36 " "	200 "	160 "
30 " "	240 "	192 "
24 " "	300 "	240 "
20 " "	360 "	288 "
16 " "	450 "	360 "
12 " "	600 "	480 "
8 " "	900 "	720 "
6 " "	1200 "	960 "



ARTICLE VIII.

CLEANING WHEAT — MACHINES AND THEIR LOCATION.

Cleaning the wheat properly before grinding is a matter that receives far less attention than it deserves. Wheat for grinding cannot be too well cleaned, so long as the coating is preserved. No process of cleaning that mars or breaks the covering of the berry can be considered good. No attempt should be made to break the berry for the purpose of removing chit, germ, or anything else. These can be separated from the flour after the wheat has been ground. All that should ever be attempted by a scouring process is to remove all of the dirty, fuzzy foreign substances that adhere to the berry. Any means or process that will make the berry clean without breaking it is good, and can be safely used. Any means or process that does in any way break the berry, no matter what is claimed for it, is essentially bad, and for this reason: if a kernel of wheat should be broken sufficiently to expose the flour, as is always liable to be the case in any hard scouring process, it becomes a prey to the dust and dirt already scoured off, which is very apt to adhere tenaciously to the flour exposed portions, be ground down with it, and become so intimately mingled with the flour that it is impossible to separate them, and the consequence is bad colored flour. There is but little doubt that flour is spoiled in color, to a greater or less extent, in this way, without those interested knowing the cause. This may not be considered a very serious evil, and probably is not; but it is nevertheless one of the evils and drawbacks to making good flour: one that can be easily remedied, and should be, by always selecting machines or modes of scouring that will in no way break the bran. If that is done, there can be no trouble from that cause.

By far the most important part to be performed in cleaning wheat successfully is to separate it thoroughly. This by many millers is, unfortunately, considered of but trifling importance; and yet a much greater mistake in reference to the matter could hardly be made. There are some seasons, in some localities possibly every season, that not more than one-half the wheat is fit for a high grade of flour; and unless this half can be separated from the balance and ground alone, no high grade of flour can be made. This is often the experience of millers in various sections of this country, and probably other countries as well.

Most of the leading flour-makers work up a reputation for one or more brands of good flour during a time when wheat is of good quality; but when the poor quality season comes around, as it is sure to do, they then find it impossible to keep up the grade, simply for the reason that they continue to separate, clean and mill in other respects just as they did when the wheat was all of good quality. They grind all the wheat together under the wild delusion that good and bad wheat mixed ought to make good flour. Instead of doing this, the separating facilities at least should be largely increased, and every grain of wheat unfit for the higher grades of flour removed. The good that is left (there is always some good,) can be safely risked to make the high grades; while the remainder can be ground into grades about equal in market (probably not quite equal in value,) to that made by grinding it all together.

The true way is to arrange for cleaning and separating properly the worst crop; and then when wheat is good enough in quality not to need so much cleaning and separating, a portion of the machinery can stand idle until needed again. It is not to be expected that as good results generally can be obtained, or as much money made by making flour out of a bad crop as can be done when the wheat is all, or nearly all, good; but it is far better to maintain the reputation of good brands of flour, even if it is done at a slight loss, because a reputation and trade once lost is not so easily regained in these days of close and sharp competition.

The first cleaning operation is through what may be styled a receiving machine. This is designed for removing weeds, sticks, straws, and other rough matter not belonging to the wheat. This machine may be built in the mill, or, what is better, it may be bought from the manufacturer, as such machines are made by manufacturers that are complete and ready for operation when leaving the shop, and are first-class in every respect, and do excellent work. During the off seasons, when wheat is very bad, more than one operation of this kind is essential. It is a very good plan to have a weigh-hopper follow this machine, especially in country mills where wheat is delivered by farmers direct. Farmers are generally very careless about cleaning their wheat, in fact do not clean it at all in many instances, but haul it to the mill right from the threshing machine. It is probable that if their wheat were run through a receiving separator before being weighed, and they made to stand the loss in weight, they would soon learn to be a little more particular in cleaning, and thus save the miller a great deal of loss and trouble.

After the wheat has passed through a receiving separator, it passes either to a bin or to another separator of a similar kind, but constructed to do closer and better work. This may be considered the second process, whether it follows the receiver immediately or not. By this second process the oats, small weeds, and a portion of the cockle is removed; and if one operation does not remove all, it is best to have two, or as many as is necessary to make the work complete. After this again comes the grader. In grading, there should be as many operations as is necessary to absolutely separate the perfect from the imperfect wheat. It is not necessary that the separations or screenings should be an entire loss; on the contrary they should be re-cleaned and made into lower grades of flour, either alone or by mixing with good wheat. It is only for making the best grade of flour that the best of the wheat must be used; and for that purpose only is it necessary to make such a close and positive separation as has been recommended. The quality and reputation of best grade of flour should be kept up, and this can only be done by separating the good from the bad wheat before grinding. For lower grades the imperfect wheat can be ground alone or re-mixed with good, as occasion may require.

Following the grader comes the smutter. In the past few years there has been serious questions raised as to the value of a smutter as generally constructed. It is maintained in some localities that a smutter is too severe on the wheat, and ought not, therefore, be used. This theory, however, finds its advocates chiefly in localities where the wheat grows very perfectly, and free from smut and other impurities. Under such circumstances the smutter can be dispensed with and milder methods of scouring only resorted to. In all other cases, however, and they are by far the more numerous, a mild scouring iron or other smutter should be used.

After the smutting process the wheat should undergo a polishing operation. What are called brush machines are chiefly used for this purpose. There probably cannot be too much polishing or brushing done, provided the machines are as they should be, and do not in any manner break or damage the wheat berry. The wheat should be rubbed or polished until it is clean, for the reason that the kind of material taken off by this process is just such that, if ground down with the wheat and into the flour, remains with the flour ever afterward. Bolting will not separate it. It may be removed to some extent from the middlings by purifying, but never from the flour.

The order of arrangement for cleaning machinery would be: first, to have the receiving separator in any convenient locality where it can be got at easily to keep it free from sticks, straws, and other rubbish that is liable to clog the screens and chambers. This should be done in a building separate and apart from the mill, when possible. In fact, all of the cleaning is now frequently done, in the best mills, either in a separate building or in a part of the mill building fitted up and provided for the purpose. When the rough material has been removed from the wheat by receiving separator, the location of the succeeding finer grade separator is not so arbitrarily fixed as is the case where there is but one separator used in a mill, and that a fine one. It should be set on the stone floor, where it can be seen at all times, and where the sieves can be kept free without extra trouble. This of course can only be done with suction machines; blast machines make too much dust and dirt. But, as stated, when the wheat has been put in good shape with a receiving separator, the second machine can, and ought to be, placed in the top story of the mill, and immediately under it the grader, so that the stream of wheat may pass from one to the other. Under the grader should be the smutter, and under the smutter the brush machine. This arrangement allows the wheat to pass in one continuous stream from one machine to the other without re-elevating. Of course but one of each kind of machine is here included; but if more than one of each kind be needed, it is obvious that the same order can be followed, only it may require two runs; in which case the wheat will have to be once re-elevated; oftener if the necessities of the case and the number of machines require it. After the wheat has passed through all the machines and finished, it is again elevated to the top of mill, or high enough to deposit it in the stock-hoppers over the burrs, ready for grinding.

When it is designed to make two or more distinct grades of wheat by one cleaning operation, there must be a grader for that purpose, through which the wheat must pass after having passed through all the other machines. This should be over the stock-hoppers, if possible, so that the different grades can be run into different hoppers by spouting.

ARTICLE IX.

BOLTING—HOW TO CLOTHE THE REELS.

As has been already strongly impressed upon the mind of the reader, bad and imperfect wheat will not make good flour no matter how ground or how afterwards treated. Also, it must not be forgotten, that good wheat may be spoiled in grinding to such an extent that no after treatment will save it. But allowing the best of wheat to be used, and that ground in the best possible manner, it is still possible to spoil the flour and reduce its market value. Bolting the flour is a delicate operation, and requires skill and care; and unless the system of bolting be in harmony with the mode of grinding, and both good, the best results cannot be obtained. Handling the stones while grinding requires a manipulation which only long practice can insure. A good grinder can be made by actual experience alone. The leading principles to be observed is not to grind too fast nor too low; a moderate speed and moderately slow feed, and the stone high enough at all times to prevent crushing into a fine powder or pulverizing the wheat. It matters not whether the system of milling be a high or a low system, it must be borne in mind that granulation is the mode of reducing that produces the best results. This subject has been referred to before, and will probably be referred to again in this work, as the author thinks it should be forcibly impressed upon the mind of every miller, or others engaged in the art.

It is now generally conceded, by those who are in a position to know, that the first operation in bolting is to remove the bran. The chop meal as it leaves the stones is run through a reel, provided for the purpose, covered with a coarse cloth, say, from No. 1 to 000, according to the mode of milling: the higher the grinding the coarser the cloth must be. This operation is intended to remove nothing but the coarse bran, which passes off at the tail of the reel, while the flour, middlings, and fine bran, or shorts, sifts through the cloth and is conveyed to the head of the first flour reel. To simplify the matter, and get as clear a knowledge as possible of the operation, we will, in imagination, perform the work after scalping on two reels, and consider the various combinations of cloth that may be used for the purpose.

We will suppose a half chest of two reels, eighteen feet in length. On the first half of the upper reel will be put No. 9 cloth; on the left half No. 10. On the lower reel, first half, No. 10, then six feet of No. 6, and the remainder, No. 1. This may be considered a fair outfit for a grist mill, or a mill where no special effort is made to do merchant work, or make a high grade of flour. It is assumed that while the reel has a full feed, the No. 9 cloth on the first reel will bolt clear enough, therefore, the product of the 9 cloth can be run off into the flour chest; but as the chop nears the tail, and the volume becomes less, finer cloth is needed to make it bolt clear, and hence the No. 10. When this fails to bolt clear enough, owing to the decreasing volume of material, the product is cut off, and instead of running into the flour chest, is sent to the head of the lower reel; so is, also, the entire tail product of the upper reel. All that passes through the 10 cloth on the lower reel is sent back to the head of the upper reel and bolted over, while that which passes through the No. 6 cloth is called middlings, and is sent to its proper place. The product of the No. 1 cloth, in grist mill work, which we are now considering, is called ship-stuff or shorts, and is used only for feed; the tailings of the lower reel go to the bran bin. Each reel should have under it two conveyors, one under the other, the upper having cut off slides every few inches, as it may sometimes occur that only a part of the No. 9 cloth can be used for flour, owing to unfavorable conditions. In such cases as much of it as will not do for flour must be cut off, and run off with the return. And, again, there may be times when all the No. 9, and all, or nearly all, the No. 10 in the upper reel will make flour, in which case the slides must be closed to that point. The object in so arranging with double conveyors and slides is to enable the miller to handle the flour to suit circumstances and conditions; and in this the miller, if he be not expert in his business and a man of good judgment, may often fail. It is better to have the returns too rich, than to have the flour too poor; so that in watching the returns, watch also the flour, as the intention is to get it all in flour ultimately; and it is, consequently, better to keep the flour rich and pure by returning heavily when needed to keep the reels full.

There is also another point to be watched. In keeping the reels too full it is possible not to get all the flour out until it passes entirely over the No. 10 and on to the No. 6. This must not be allowed, as it is so much of a virtual waste. In large mills, or mills large or small where merchant work is the object, when the latter difficulty occurs it is best to add more cloth.

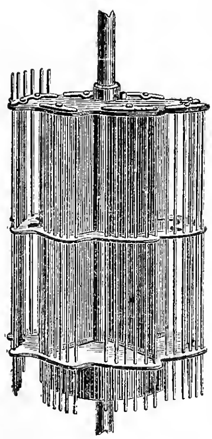
Just as good and probably a better plan to clothe a custom bolting chest, is to cover the upper part entirely with No. 9 cloth, and the lower reel as before stated. This is certainly better when the quantity of cloth is gauged closely to the grinding capacity of the stones. Grist mill or custom flour does not require to have so high a color, but ought to retain all the strength, and will, consequently, bake fairly white. And then, too, in custom mills preparation is not made for handling and re-handling stuff, consequently it must be ground and bolted so as to get the great bulk of the flour out the first time; although the middlings product should be purified and re-ground, as will be again described in this work. This is the chief reason why so much coarser cloth is recommended. Of course, when all the cloth on the upper reel is No. 9, the cut-offs must be managed, as previously described, to suit the condition of things while grinding, all the points being watched at the same time.

In order to make one move forward, assuming the facilities to be the same, the cloth on reels should be changed to No. 10 at the head of upper, one-half of its length, and No. 11 extra for the other half; No. 12 one-half length of the lower reel, five feet No. 6, two feet No. 2, and the remainder No. 00. This combination of cloth reduces the bolting capacity of the reels, but greatly enhances the value. The cut-offs and returns are worked substantially as before, and if all other things are equal, a very fine quality of flour can thus be made. The products of the Nos. 6 and 2 are middlings, and may be run together, provided means are not at hand to purify them separately; if so, they should be kept separate until after being purified, for the reason that a somewhat different operation is needed for coarser middlings. They need coarser cloth and stronger air currents. But under the head of new process the whole operation of purifying middlings will be treated.

In order to obtain still better results, the best probably that can be obtained except where thorough arrangements have been made for the highest order of milling, is to clothe the upper reel, first third with No. 11, double extra; second third, No. 12, double extra; last third, No. 13, extra, and first half of lower reel with No. 14, extra; the remainder of the lower reel to be as last directed. This last combination of cloth will make the flour as clear and as pure as will be required under any system of milling here being described. It must be remembered, though, that the two reels as last clothed will have but little more than half the bolting capacity of the first. The two reels have been adhered to in order to more simply illustrate the methods. When greater capacity is required, more reels must be added; and while the numbers of cloth may be adhered to, the quantity of each may be varied to suit the changes.

In large mills where many reels have to be used, two, four, six, or more reels, as the case may be, are used for flour and returns alone. For instance, in using six reels for the purpose, the four upper may be clothed just alike, or all like the single upper that has been described. Into these four reels the stream of meal is evenly divided. These four reels may all discharge in one conveyor, if so liked, as the product is all alike or ought to be. It simplifies the matter to have one conveyor for all. This conveyor is provided with slides or cut-offs as in the previous case, and they are regulated in the same way. Following these four first reels, there must be two others for returns. These can be clothed their entire length with the No. 14, extra, named for the lower reel in the other case, unless it be deemed advisable to put a number finer near the tail. The entire sifted product of the two last mentioned reels goes back to the heads of the first four, while the tailings go to a bran reel, if the bran has not been taken out in the first operation as previously described; the bran reel to be covered with coarse cloth, same as the scalping reel first mentioned. But whether the bran has been taken out or not, the product should go to a coarse reel, not finer than No. 1 cloth; coarser, possibly. This will separate the fine bran and shorts from the middlings, which must then go to a dusting reel; said reel to be clothed the entire length with cloth of the same fineness as the finest used on the return reel. More than one dusting reel may be needed, but all must be clothed alike, and the stream divided on them. The dustings can be used in some of the lower grades of flour. After the middlings have been thoroughly dusted they can be purified; or, if a high order of milling is practiced, they should be graded or sized before being purified. This is done by passing them through a reel having a number of different grades of coarse cloth suited to the size of the middlings. Ordinarily, by this mode of milling, a reel clothed with Nos. 6, 4 and 1 would be about right for grading the middlings. After grading, the different kinds should be purified on different machines, otherwise there would be no value in grading. The system of bolting here described, while it does not embody all of the more modern methods, will achieve good results; and when a straight brand of flour only is aimed at, will do almost as well as the most improved methods.

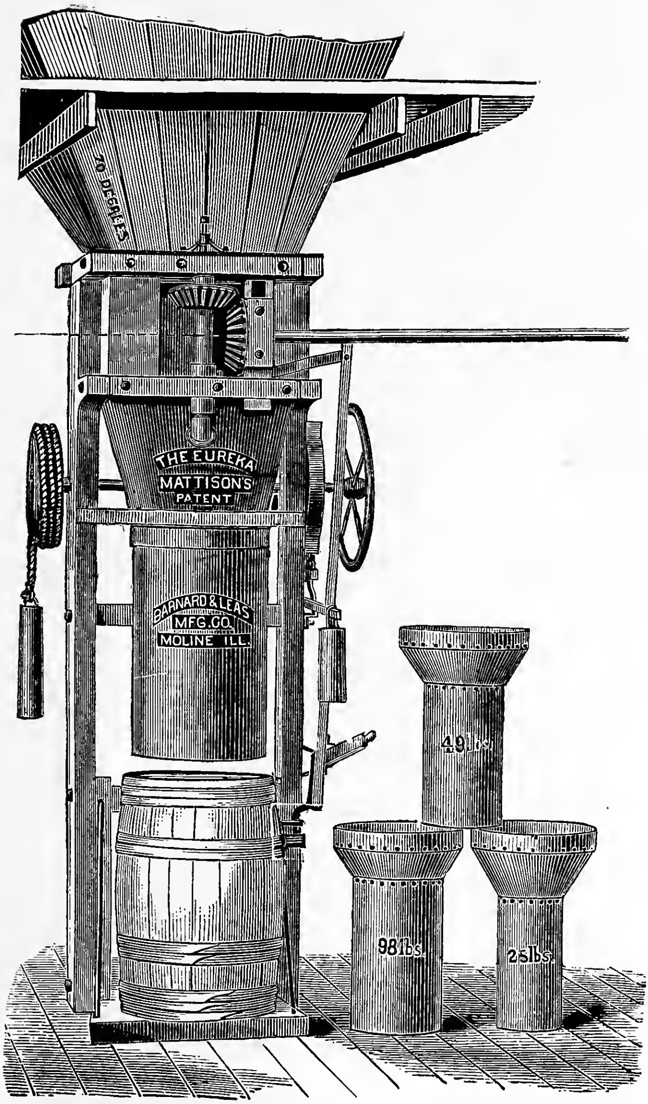
This method is more universally in use at the present time, has been for many years, and likely to be for many years to come, to some extent possibly as long as flour is made. It may not be the best, and the writer thinks it is not the best, but it is simple, easily adopted, and may be safely enough used when it is not convenient or expedient to fit up for the more advanced methods.



ARTICLE X.

SPECKY FLOUR—HOW REMEDIED BY PERFECT CONSTRUCTION OF REELS AND BOLTING CHESTS.

There are many things that ought to be looked after in the construction of a bolting chest that are too frequently entirely ignored. The chief aim in building bolting-chests, and making other preparation for manufacturing flour, is to be able to make the flour as pure, white, and clear as possible. The habits and tastes of the people require this; and while it may be, as is often claimed, that unbolted or partially bolted flour is healthier and better in every way for human food than that which is so thoroughly bolted, still it is no part of the miller's business to take that matter into consideration; he is not necessarily a sanitarian, and the miller who attempts to run his mill on such supposed sanitary principle will, ere long, find himself without customers and without a trade. It is true there are always some customers who must have, or who think they must have, bran flour for their use. The wants of such can of course be supplied from the most approved mill that may or can be fitted up. If a mill be only half arranged for making good flour, it would be an easy matter of course to supply the few comparatively who want partially bolted flour; but it would be impossible to meet the demand and requirements of the great mass who must have pure flour. Few flour-makers entirely ignore this fact. They all recognize the importance of making good flour; but many fail to appreciate the still greater importance of aiming to make the best. It is frequently argued by careless millers that, while their flour may be a little dark and specky, it is, nevertheless, strong, and will bake



EUREKA FLOUR PACKER.

Made by BARNARD & LEAS MFG. COMPANY, Moline, Illinois.

(See Appendix.)

up white, and, therefore, it is just as good as anybody's flour. This is a mistake; but such men rarely ever see it. They continue to run on year after year, blindly laboring under this fatal delusion, wondering now and then how it is that some neighboring miller gets along so well and makes so much money, while he barely keeps even, and don't always do that. He, of course, attributes it to luck, or to most anything except the real cause, which is nothing more or less than that the lucky neighbor keeps up with the times, makes his flour just as pure, white, and clear, as the people demand; and if the people should demand a still better flour, he loses no time in trying to make it better. Such a flour-maker will always have a ready market for his flour, at profitable prices.

It is not sufficient to say that flour is good enough, because it is generally white and clear. If specks are allowed to remain in it the market value is to that extent spoiled. It might take a long search with a powerful microscope to find a speck in the bread, but it is easily detected in the flour, and should, therefore, be kept out. This is one of the points that ought to be attended to. In the construction of a chest every precaution should be taken to prevent the flour from becoming specked in passing through and out of the chest after it has been bolted.

A very easy method of overcoming the difficulty, is to make the head of the reel thoroughly round and hang or attach it to the ribs, true; or if it cannot be attached truly, it can afterwards be dressed true by swinging the reel on a pair of trestles and striking a true circle with a scribe awl. A nicely adjusted and keen-cutting plane can be used for dressing it off to the circle. This method of doing it is not perfect as could be done by a lathe, but in the absence of a lathe (and they are generally absent in cases of this kind), this is the best mode that can be adopted. After the head has been trued up, a circular opening corresponding with it must be cut from an exact center, out of the inner head lining, and just large enough for the reel-head to revolve in without rubbing. The opening in the reel-head should also be made in a true circle, ten or twelve inches in diameter. A round tin tube must then be prepared to suit this opening, and long enough to reach the outer heading into the reel, far enough to insure it to feed well. This tube is fastened securely to the outside heading by a flange about an inch deep running all around the tube. A flanged opening on top of the tube when in position admits the flour, and to this a feed spout is attached. Three or four flights in the form of a conveyor must be driven in the reel shaft to assist in feeding.

This device will, probably, be found sufficiently effective; but if greater security is desired, a circle half an inch thick and about two inches wide can be fitted around the reel head and fastened to the lining. The head must then be closed up entirely, by fastening a solid circle of wood three-fourths of an inch thick to the open circle already attached. It is thrown out half an inch from the main heading, to make sure of clearing the revolving reel-head. To this false lining a round tin tube must be fastened, as above described, and allowed to run two or three inches into the reel, at the same time fitting the circle in the reel-head closely. This tube must be about fourteen inches in diameter. Through this tube and through the false lining, back to the outside heading, must be nicely fitted another tube, or a square box will do as well by putting corner strips in the bottom like a conveyor-box. This tube must be fitted closely to the outer heading, closing in the false lining, and tight every way, with a feed opening on top similar to the one first mentioned. If this arrangement is made complete, it is scarcely possible for specks to escape.

Another drawback may seriously interfere with making the flour as pure and clear as it ought to be when every preparation has been made for making the best, and that is carelessness in constructing or arranging for the slides under the conveyors. The openings in the bottom of conveyor are usually made in the center, and only about three or four inches square, as the case may be. This should not be done, because there is a great liability to carry past the point where the meal is intended to be discharged, and if the conveyor runs very full it is almost sure to do it. Thus, for instance, the upper conveyor is supposed to carry everything in the direction of the head. The miller finding his flour too poor beyond a given point draws a slide to drop it in the return conveyor below; but, instead of it all discharging here, as is intended, a portion of it is carried over and becomes mixed with the flour and deteriorating it to that extent. The discharge openings in a conveyor should be either cut entirely across or else on the carrying side, running back to the opposite corner strip. The slides should be made to draw away from the carrying side, lest they might not at all times be drawn far enough, in which case the flour would carry over on the end of slides.

Another annoyance is frequently experienced in working with a bolting chest. It often occurs that the hoppering is made too flat, and, as a consequence, the flour sticks and adheres to such an extent as to keep the miller constantly pounding to get the flour down into the conveyor. This matter should be well provided for by making the hoppering boards very smooth, as smooth as can possibly be made, and then by getting them in at such an angle as to make it impossible for the flour to stick to any great extent. The hoppering in a flour bolting chest should never have less than an angle of sixty degrees, and it should have more when it can be obtained.

It is a frequent practice, in small mills especially, to drop the returns from the upper reels through the conveyor down on the lower reel. This should not be done. Instead, a slide should be made above the reel to guide it over to one side or the other of the reel. It should be run to the back side in half chests, or to the center between the reels in whole chests. All the reels in any sized chest should run in the same direction, that is, all pitch one way. It is much easier to keep out the specks in that way.

ARTICLE XI.

THE ELEVATOR—HOW IT DISCHARGES—MODE OF CONSTRUCTION—SPOUTS—SOME INSTRUCTIONS FOR PUTTING THEM UP.

Years ago, in the early history of the present epoch in milling, and down even to a comparatively recent period, it was customary in building a stand of elevators, to plant the foot, or boot, at one side of the mill-building in the basement, and land the head on the opposite side in the top of mill. Or, no matter in what direction run, about that much slant or pitch was deemed necessary, in order to have it discharge properly; and no doubt it was, owing to the slow motion given them. The slow motion, however, did not determine the pitch, but rather the pitch determined the speed. In the absence of positive knowledge in reference to the matter, it now seems fair to assume that, under all circumstances and at any speed, the millwrights of those days believed a stand of elevators must have a given amount of pitch forward in order to discharge. When a stand of elevators pitch forward to any great extent, the belt drags heavily in the up leg; hence the importance of running slow to save wear and tear on the belt. So many feet per minute was evidently the way it was reckoned, and the number of feet was made as few as possible to save the belt; and hence the antiquated idea still in vogue among many millwrights, that the way to reckon the speed of an elevator is by the number of feet the belt should travel per minute. There was some logic in the method of our forefather millwrights reckoning by the number of feet traveled, because their elevators would discharge fairly well at any reasonable speed, from ten revolutions up;

and so long as the elevator had capacity, the slower it ran the better for the belt. But elevators as now generally put up, that is, perpendicularly, will not discharge at any speed, nor is there any material wear on the belt by reason of friction or rubbing on the legs of the elevator.

A more illogical method of determining the speed of an elevator as now constructed could not well be devised than by the number of feet the belt should travel per minute. If it were logical and mechanical, there should be some uniformity in the matter; but there is none. The millwright who confines himself to ordinary mill work only, and uses pulleys ranging from twenty to twenty-four inches in diameter, fixes his speed at from about two hundred to two hundred and twenty-five feet per minute, which gives a speed to the elevator pulley of from thirty-five to forty revolutions, according to the variations in the number of feet. Some will insist on a few more feet, and some a few less; but the speed obtained, thirty-five to forty, is very good, and about what it should be. But the millwright who builds large grain elevators, and uses pulleys four and five feet in diameter, has a different speed for his belt. He runs his belt about twice as fast as the mill-builder, and, consequently, gives his pulley about the same speed as the other, and, of course, is about right. Both give their pulleys about the same number of revolutions, but vary widely in the number of feet their belts travel.

To illustrate the beauty of this mode of reckoning the speed of elevation, we will suppose a young millwright, not very well posted about speeds, who is about to put up a stand of elevators, using a twenty-inch pulley. He goes to one of those millwrights, accustomed to use large pulleys only in his business, for advice about the number of feet the belt ought to travel. Of course, he will give him the speed to which he is accustomed, say, four hundred and fifty feet. The young man bases his calculations on that speed, and runs his pulley about eighty-five revolutions. Well, if he were elevating hard grain, wheat or corn for instance, he might get along at that speed, but would probably have to line his elevator head with sheet iron to keep it from cutting out too rapidly, as it would have to constantly undergo a terrible threshing from the very forcibly discharged grain. If, on the contrary, he were elevating chops from the burrs, or some similar substance, he probably would find the most of it going down the elevator again, unless the cups were well constructed with the view of a rapid discharge; and even then much of it would be likely to go back. So much for the beauty of reckoning the speed of elevators by the number of feet the belt should travel.

But for one well-known mechanical force, a perpendicular elevator could not be made to discharge. All elevators would have to be built slanting, or with a strong pitch forward, as was done years ago, before the true method was recognized and put in practice. By centrifugal force only can a perpendicular stand of elevators be made to discharge; and in determining the speed of elevators the laws controling the discharging force must be recognized. The first law says that the centrifugal force generated by different sizes of pulleys, all making the same number of revolutions per minute, is in proportion to the size of the pulleys. Thus, a four foot pulley revolving thirty-five times per minute, would generate twice the force of a twenty-four inch pulley, making the same number of revolutions; and it would need just twice the force, as it would have twice the distance to throw its load; and hence the reason why all classes of millwrights have their pulleys making about the same number of revolutions, although differing widely in the number of feet they run their belts. They recognize and obey the behests of the law without knowing it. The law says that whatever number of revolutions is necessary to make a twenty-inch pulley discharge properly, the same is necessary for a sixty-inch pulley; and they all give their pulleys about the same speed, but they arrive at it by reckoning from the number of feet the belt should travel per minute; rather a roundabout way, to say the least.

The second law says that the centrifugal force generated by a given sized pulley running at different speeds, is in proportion to the square of its velocity. Thus, a twenty-inch pulley making seventy revolutions would have four times the force of the same sized pulley, making thirty-five revolutions; and hence the reason of the difficulty the young man would get into by making his elevator run eighty-five; it would have six times the force, nearly, that it would if he ran it but thirty-five; and hence, also, the difficulty that would be experienced by running the elevator too slow. If a twenty-inch pulley were to run one-half the speed last named, or seventeen and one-half revolutions per minute, it would have but one-fourth the force of a pulley making thirty-five, which would be insufficient to discharge it; instead, it would roll over with the pulley, and back down the leg.

The third law, which is merely confirmatory of the others, says the forces generated by different sizes of pulleys making different revolutions, are to each other as the number of revolutions multiplied by the diameterof the pulley. We find by taking the number of feet to the minute theory, that a belt traveling two hundred feet will make a sixty-inch pulley revolve twelve and three-fourths times, nearly, (12.7326), while it will make a twenty-inch pulley revolve a little more than thirty-eight and nineteen-hundredths times, (38.197), which makes the centrifugal force of the two just equal, as will be found by multiplying each speed by its own pulley. This would give the sixty-inch pulley exactly the same force, and no more than the twenty-inch pulley, with about three times the distance to discharge. This is manifestly insufficient, and needs no additional argument to refute it. The material would necessarily fall back down the elevator, as the action of gravitation would overcome the centrifugal force, and pull it downward long before it reached the point designed, or the discharge spout.

In elevators running from thirty-five to forty revolutions, material leaves the pulley on a tangent, about forty-five degrees from the top center; and would, of course, keep on in a straight line, (not a horizontal line), except for the action of gravitation, which disturbs its course, curves it downward, and lands it in the discharge spout as intended. The pulley can run slower than thirty-five revolutions, and there would be no perceptible difference in the result unless very much slower, when, of course, it would not work well, or not at all. But for grain especially, a much greater speed than forty can be worked very successfully. The writer once put up three stands of elevators, and ran them seventy revolutions, using a twenty-four inch pulley. It was done rather more from necessity, or expediency, than choice. An eleven-inch cup was used, and the quantity raised was fifteen hundred bushels per hour, which taxed them to their utmost capacity. The grain began to leave the cups immediately after passing the top center, and with such force that it would probably have gone a distance of ten or twelve feet if there had been no obstacle; but owing to the buckets being so full it scattered greatly, and a great deal of it dropped back down the leg. They, however, did their work, and are still doing it at this writing.

While under the same circumstance I would do the same thing again, still I would not advise any such speed. Forty-five revolutions should not be much exceeded for any purpose; not that a greater speed can not be made to work; but the force, and consequent wear and tear is unnecessarily great. The from thirty-five to forty rate of speed should be adhered to, ordinarily. Meal, or other material of less specific gravity than grain, will not stand as high a rate of speed, as it cannot get out of the way quick enough, and is liable to be carried back down; hence, for such, the standard speeds should be adhered to more closely. Sharp, purified middlings may be considered an exception. They are very heavy, and can be handled almost as easily as wheat.

The one chief lesson this chapter is intended to convey, and the one to be remembered is, that the speed of an elevator has nothing to do with the travel of the belt in feet per minute. A good speed for all elevators, with any size of pulley, is from thirty-five to forty revolutions per minute; but there may be a moderate variation from these figures either way, with good results.

It is true in these calculations no account is taken of the space between pulley and mouth of discharge spout, that is, the width of the leg; consequently, if in a case of necessity, a very small (say a six-inch) pulley would have to be used, greater speed would be necessary to throw over the mouth of elevator leg, as it would probably be nearly as great as that of an eighteen-inch pulley elevator. A much higher rate of speed in so small a pulley would not be objectionable, as the force would not be great enough to do any harm; but in no case where it is possible to avoid it should extremely small pulleys be used.

There is nothing mysterious in the mode of constructing a stand of elevators; on the contrary, the whole operation is rather simple. The boot is usually made independent of the balance. A good plan for making a boot is to make the lower half octagonal in form inside, two of the squares to be formed by slides that draw entirely out, thus opening the boot through and through in case of a choke or other difficulty when necessary to get inside. Just above the slides running across the boot come the bridge-trees. These must be of hard wood, sugar maple or something similar. These pieces should be about three inches deep and two to two and one-half inches wide. These bridge-trees, as well as the side-boards forming the two sides of the boot, must be notched or grooved into the piece that forms the outside board, front and back, of the legs of the elevator. This groove should be about a quarter-inch deep, and in width to correspond with thickness of stuff used. Corresponding grooves must be cut for the slides spoken of. The end boards, those mentioned as forming the front and back of elevator legs, should be dressed out the full width of the upper half of boot, out to out; then the thickness of the sides, measuring where they are grooved, must be cut out of the end pieces below the top of boot. For instance, the boards forming the upper half of the boot are seven-eighths of an inch thick; one-quarter taken out for grooves leaves five-eighths. Then commencing six or eight inches below the upper end of end-boards, (that amount ought to extend above the body of boot to attach the legs to) and cut or rip three-eighths of an inch off of both edges, shouldering neatly where the cut stops, as the operator will, by intuition, commence to rip at the extreme end, and end at the point we have mentioned for commencing. The sides of lower half of boot should be heavier than the upper, that is, when but seven-eighths stuff is used for the upper, the lower half should then be at least one and a quarter inches in thickness. The side pieces, including bridge-trees, should extend over about two inches at each, or four inches longer than the body of the boot. The boards can be fastened by common screws; the bridge-trees should be bolted through outside and against the end pieces. The width of boot in the clear should be a half inch greater than the pulley. A short shaft should be fitted in the pulley with length between shoulder one-half inch more than width of pulley, and journals, turned on both ends, long enough to suit the width of bridge-trees, and not less than one and a half inches in diameter; larger with larger elevators. Great care must be taken in adjusting bridge-trees and bearings to have the pulley hang true and its sides parallel with sides of boot.

The boards forming the sides of the elevator legs go between the front and back pieces, and are, or ought to be, fastened together with screws. All the butt joints should be made to fit together snugly; and when the elevators are large, tongue pieces made of hoop iron, can be used in connecting the butts. This prevents the ends from warping and getting out of place. This mode of closing in the top will suggest itself. The back board of back leg should run to the extreme height, while the front piece can run a few inches above the bottom of pulley. The side-boards can be fastened to these projections, which will make the head the thickness of the stuff wider than the balance of elevation. The front end of head should extend far enough to allow of a free discharge, say six to eight inches in the clear beyond the leg of elevator, for the ordinary sized elevators, such as are mostly used in mills.

Some millwrights make octagonal-shaped portable heads in two halves. When these are used, the legs are cut off square below the pulley, far enough to give sufficient clearance, and a table piece fastened to them. On this table the portable head is set, and cleated around to hold it in position. The head is divided in the center perpendicularly. This is a very good plan, and somewhat less troublesome than the other.

The legs of elevator should be in the clear three-fourths of an inch wider than the belt, and the belt should be three-fourths of an inch wider than the buckets. The other way there should be from one to one and a half inches clearance.

Ordinary elevators using from three to six-inch cups can vary in the size of pulley from sixteen to twenty-two inches in diameter, according to notion and convenience. Pulleys too small are objectionable; so also are pulleys too large. The top pulley must be the driving pulley.

The point of discharge is a matter that often has to be determined by circumstances. Ordinarily, the discharge spout is supposed to start at or near the bottom of the pulley. This is the safest, but it sometimes happens that owing to a lack of fall, the point has to be raised up nearer the center; and with properly made cups, and all other things favorable, an elevator can be made to discharge a few inches below the horizontal center, say, from four to six inches, according to size of pulley. But too near an approach to the center should not be attempted except when it can not be avoided.

Spouting is one of the most difficult jobs attempted by the inexperienced hand; nor can there much be here told that will help him in the matter. Skill and speed in putting up spouts can only be obtained by practice, and not always then. A few general directions, however, may materially assist.

Great care should be taken not to get the spout too "flat;" and, too, for hard grain it should not be made too "steep." Spouts for chops, fine flour, dustings, and such like, should have an angle at no time less than forty-five; always more when it can be obtained, and with the bottoms very smooth. Purified middlings do not need any more than forty-five, and will run very readily at thirty-five; any angle between thirty-five and forty-five will answer for middlings. Hard grain, or grain of almost any kind, does not need more than twenty-two and a half, and will run readily at sixteen and a half. Whenever necessary to run a spout very "flat," and there is any uncertainty about it working, it is best to fix a board at the greatest angle that can be obtained, and try some of the material intended to be spouted. If it refuses to run it will be useless to put up the spout. A change of some kind will have to be made so as to get a greater angle. All flat-bottomed, wooden spouts should be level crosswise, so that the meal, or whatever else, will spread evenly over the surface, and not run down in a corner. In a spout running through from floor to floor, with the direction changing on each floor, no attempt should be made to run the bottoms even with each other; on the contrary each section should be run independent of the other, with the bottoms level across. Where the sections are connected together, there should be a table-like division, consisting of a piece of board eight, ten, or twelve inches square, according to the size of spout. In the center of this piece a round hole should be cut, equal in area to size of spout in clear. This piece should be fastened by screws to the lower end of the section of spout already up. To this table the next section can be fitted and fastened. This method of connecting spouts changing direction is simple, effective, and saves lots of time and trouble. The table should be at least an inch larger all around than the spout; more may at times be necessary. A spout running continuously in the same direction, whether all the sections have the same angle or not, need not be so connected. They can be easily and nicely fitted together without any intervening table or connecting joint of any kind.

Spouts should never be made too small. Plenty of room is what is needed for stuff which moves sluggishly: it is not so liable to clog and stick. This should be remembered, especially if the spout runs "flat." Where there is plenty of fall it does not matter so much.

Round or round-bottomed spouts work freer than flat spouts; and sometimes a round tin spout can be made to work where flat-bottomed spouts fail; but whether round or flat, the bottom surface should be made as smooth as possible. All very flat wooden spouts should be lined either with tin, smooth sheet iron, or something else equally smooth and durable. Spouts intended for grain should be lined with heavy sheet-iron to prevent the wear. The moving grain wears wood very rapidly, and the faster it moves, the more rapid the wear; hence the reason why grain spouts should not have too much pitch or too great an angle.

By paying a little attention to the foregoing observations, and working carefully, little difficulty need be apprehended in getting spouts of any kind and for every purpose in well, and working well.

ARTICLE XII.

SHAFTING—HOW IT SHOULD BE PUT UP.

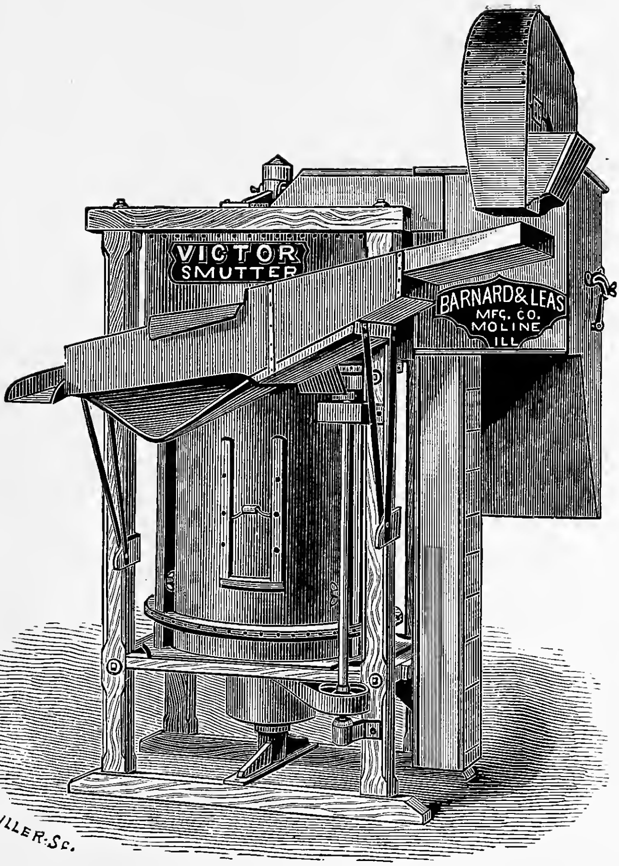
Badly put up shafting is one of the evils not only of flour mills, but of all other kinds of mills. Shafting should be very straight and true in every way; exactly level and in perfect line; and unless it is so it will run badly, while at the same time consuming more or less of unnecessary power. Heavy shafts, like the main line in a flour mill, or crank shafts leading directly from the engine, should be well and strongly supported. If a very long line, or whether very long or not, the best supports are stone piers surmounted by heavy iron pedestals or journal boxes; but stout wooden posts, or frames made of two posts and bridge-tree, answer the purpose well. Such shafts must run in brass or babbit-metal boxes. It is not unfrequently the custom in belt-geared mills to run the main driving shaft in this manner; and it is really the best when quick-motion engines are used, which, we are glad to say, is becoming quite common now. (A short stroke and quick motion is always best for flour mill purposes.) The center of the main line should be a reasonable distance from the centers of spindles, not much less than twelve feet. A reel belt, such as has to be used in this case, needs a greater distance between centers than an open belt; though in neither case should the centers be too close together. The greater the distance, within reason, between the centers of two shafts connected by belt, the better. The belt will not require to be so taut, and, consequently, produces less strain on the machinery.

When the main line runs through the husk-frame, as is the case when the burrs are run by bevel gear, the husk-frame, or foundation supports for the same, are all that is needed to support the shaft. The same is true when spur gear is used, when the burrs are all in a single line. If there be more than two pairs of burrs, so must there be more than one main upright, as it requires a large master-wheel and an upright for each two pairs of stone. The most common practice in the past has been, where spur gearing was used to drive the burrs, to place them in a nest around the master-wheel, driving four or five, or even more, with one wheel. This practice, however, is rapidly growing out of favor, and will, we think, soon be entirely unknown in this country, as we are not now aware of any new mills being built on that plan.

What is generally known as the main upright in the mill, or the upright shaft that runs from basement to garret, requires to be looked carefully after in order to get it exactly plumb, or perpendicular, in every way. Unless it is so, it is an abominable nuisance; and is in reality a great nuisance anyhow, in the opinion of the writer. The main upright, running as it usually does, quite slow, may run either in wood or metal bearings, according to the taste or notion of those interested. A close-grained wood, not too hard, as soft maple, makes a very good journal-box. When a metal box is desired, and it is either not convenient, or considered too expensive to procure iron journal boxes, wooden boxes can be made in the usual way, and afterwards cut out about a quarter of an inch in depth all around the shaft. There should be about the same amount of margin left at both edges of both cap and box; that is, there should be about a quarter of an inch left untouched that fits the shaft at both sides of the box. This will assist in holding the metal in place, both while pouring and after. There should also be a few shallow, small auger-holes bored at intervals around the box, where it has been cut out for the metal; these need not be more than one-quarter of an inch in depth. After all is ready, the box should be laid down on the floor, or other convenient place, and a section of the shaft laid in it. A little moist clay, or other similar substance, should be plastered around the shaft and against the wood as a precautionary measure to prevent the possibility of any of the melted metal leaking out. When all is completed the metal can be poured from the top; after which the cap can be treated in the same way, and so, also, can as many others as will be required. There are many shafts in a mill that can be accommodated with such boxes to a good advantage.

In preparing to put up a line of shafting, the extreme points most be established. The starting point must be leveled from in order to get the level of the other extreme. The leveling must be done with great care. Then a strong, fine line must be stretched from extreme to extreme, tight enought to prevent any swagging. To this line must be adjusted all the journal boxes, after which the shaft can be placed in position ready to run. But in no case should a line of shafting, or any part of it, be placed in the bearings until they are all right, as it is a very difficult task to either level or line a shaft correctly after placing it in position. The same rule of conduct for putting up a horizontal shaft must be observed in placing an upright. The extreme points must be established by plumbing, and then a fine taut line must be stretched to which the bearings are to be adjusted.

All main lines of horizontal shafting are supposed to be parallel with the building. All counter lines running in the same direction must be parallel with the main line. When building new mills it is best to lay the center lines of shafting off on the floors. This can readily be done before other machinery is placed and the extremes preserved even after the other machinery has been permanently located. Shafts running in any direction can be marked on the floor. To establish a counter line, running at right angles with the main line, it is best to ascertain the center of the counter, and mark it on the main line; then space off on either side of it a distance of two, three, or more feet, according to circumstances. A strip or sweep, ten feet or so in length, can



VICTOR SMUTTER AND SEPARATOR COMBINED.

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(See Appendix.)

then be used by boring a hole in each end with a small gimlet. One end of the sweep must then be fastened at one of the points made on the main line. This is done by boring the gimlet into the floor, leaving the sweep to swing freely, the gimlet acting as a pivot. In the other end of the sweep a scribe-awl must be inserted with which an arc of a circle must be described. The gimlet must then be taken out of the floor and that end of the sweep carried over to the other point on the main line and secured with the gimlet as before. Then, by using the sweep as in the first case, it will be found that the first arc will be bisected. This is the object sought for. A straight-edge may then be used by laying so that its edge will strike the center point first made on the main line, and at the point where the two arcs bisect each other. A line drawn along this straight-edge thus arranged will be exactly at right angles with the main line. A much shorter method is to use the common iron square, but is not so sure. The blades are too short to make it certain.

After counter right-angle lines have been established in the manner described, others running in the same direction, and convenient to the first, may be made by measuring instead of by the process given. It can be done with less trouble and will be just as correct.

There are many points in connection with putting up shafting that should not be overlooked. In a new mill especially, shafting cannot long be expected to remain where it is put. The seasoning and consequent shrinkage of the timbers of the mill displaces the shafting in a short time. It is sure to get out of level if not out of line.

It would, perhaps, be well to here remind all builders of new mills that it is not only well, but very important that every floor in the mill should be made crowning or full in the center, the bulge or crown increasing as you go up. In doing this the judgment of the millwright, or whoever else has charge of constructing the building, must be consulted to determine what height to run the crown. It will be quite evident if the timber used is just out of the river, or it is being used green from the woods, extreme shrinkage will have to be provided for, but if on the contrary the timber is already half seasoned, there will be proportionately less shrinkage.

The object to be obtained in making the calculation, is that after all the shrinkage has taken place the floors should all be level. Take, for instance, a five-story mill above the basement, we will allow the combined shrinkage of the post caps, girders and joist to be one inch for each story. This would make the first floor a concave of one inch only in depth, not very much and scarcely perceptible in a large floor, but the upper floor, which is liable to contain a great deal of machinery, would have five inches. That is entirely too much for either beauty or convenience. It is true that the mill floors can be shored up and leveled after they have settled by shrinkage, but it is quite a job to do it. It is much better to let it level, or do its own leveling, by natural processes, and so arrange the machinery as to make it easy to keep it leveled up as the floors shrink away from it.

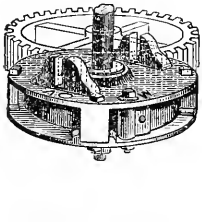
In putting up the shafting these facts should be borne in mind. It must also be remembered that whether the floors have been made crowning or not, the shrinkage will be the same, and that in a little while the shaft will be out of level.

When upright posts are used, as is frequently the case in flour mills, to support the shaft, they should be secured with keys, top and bottom, the bottom keys to level up with and the top keys to tighten with. By this kind of an arrangement the miller, or anyone else in charge, when he finds his shaft getting out of level can loosen the top keys, place his spirit-level on the shaft and drive up the bottom keys until it is right, tighten up the upper keys and go ahead again.

After the shaft has been leveled as often as the keys first provided will allow, the posts will have to be dropped back to their original place, and the shaft readjusted to the posts, when it will be again ready for another series of leveling up. The same rule should be observed in hanging shafting.

If wooden hangers are used, the bridgetrees should be so secured with keys above and below, so as to allow of its being raised or lowered in leveling the shaft.

The same is true when employing iron hangers. They should be adjustable. They are much less troublesome and it is easier in every way to keep the shaft nicely leveled up. No matter what kind of machinery is set up, there ought always to be provision made for easy adjustment, more especially when located where there is a probability of shrinkage or a settling down in any way. And unless such provision is made, machinery will have to run most of the time out of shape, because, as a rule, millers cannot afford to stop oftener than once a year for "lining up," and really do not care to do it oftener.



ARTICLE XIII.

FILLING COG WHEELS.

How to "fill a wheel" properly, and make it work well in every way, is something that is not so well understood, generally, as it should be. Many professional millwrights are ignorant of a correct mode or rule for doing it; while others, who are not millwrights, but who now and then undertake to do it, are deplorably ignorant of every principle connected with it. As an instance in point, the writer was not long since asked some questions about turning off the cogs in a wheel by a carpenter who had just been filling one. On inquiry as to his mode of operation in filling the wheel, the fact was developed that he had shaped and dressed his cogs before driving them; there was no pitch line struck or spacing done after cogs were driven; all was done before. He stated that he had got along very well, and made a good job, at least it worked well; but he did not know how to turn off the face of the cogs without splitting them, and so had to dress them off by hand with a plane.

The incident reminded the author of a little operation of his own while an apprentice. My employer sent myself and a junior apprentice out to do a job in one direction, while he went in another. For boys, we were both fair mechanics; but I, being the senior, assumed to "boss" the job. Among other things we had to do, was to put a gudgeon into an old wooden counter shaft, about sixteen inches in diameter. That sort of a job I had never at that time done, or seen done. This is accounted for by the fact that most of our work was at that time confined to paper mills; and such jobs in a paper mill were very rare, except for wooden water wheels. However, having full confidence in my ability, I proceeded to gudgeon the shaft by first dressing off the end of the stick to fit the bands. How I would afterwards have succeeded in getting the gudgeon in true I have never yet found out; for it so happened that about the time the shaft was ready for the bands a journeyman millwright arrived on the scene of action, sent to take charge of the job. A critical examination of the old shaft on which I had expended my time and talent, resulted in it being condemned and a new one ordered. This let me out of the scrape very handsomely, but I never forgot the lesson.

It is a very rare thing for millwrights to have to get cogs out in these times, as they can usually be bought from the manufacturer much cheaper; but when it is to be done, good well-seasoned hickory or sugar maple should be selected. If in planks, the planks should be ripped into strips the width of the cog, allowing a half inch or so as a margin for dressing and finishing up. The strips must be cut into pieces long enough for two cogs, again allowing a margin of, say three-fourths of an inch, for each cog (less will do); this margin to be left on the end of the cogs, to be cut off after the cogs have been fitted and dressed. After the pieces have been dressed on the edges and one face for convenience, the shape of the shank must be determined by fitting strips of thin wood, tin, sheet-iron, or anything else that will answer the purpose, down through each end of the mortise. If it be a spur wheel, the mortise will be parallel; if a bevel, one side will be wider than the other.

The strips prepared, the cog pieces must be squared or marked around for the shoulder. For spur wheels, square lines are needed; for bevel wheels, bevel lines. The distance from the end of piece to shoulder line must be determined by the depth of the rim of the wheel; to this depth must be added sufficient length for the keys; from an inch to an inch and a half on ordinary sized wheels; for very large wheels, about two inches. It is not really necessary to run bevel shoulder lines across the face of bevel wheel cogs, as the proper bevel can be obtained on the face of the cog in cutting them off after they are driven; and as square shoulder lines are more easily made than bevel lines, it is just as well to make square shoulders on all kinds of cogs.

After the shoulder lines have been laid, the thickness of the shank according to the strips must be marked on the edges of the piece from the shoulder to the end. This can be done by laying the strips on the piece centrally, and marking along the edges of them. The best plan is to provide a strip of board two inches wide, and about the length of the cog piece; to the edge of this may be nailed, or otherwise fastened, a hard-wood strip, the edge of it having the same taper as the little pieces fitted in the mortise of the wheel. (The mortises in all wheels narrow up in the direction of the center so that the shanks of all cogs are tapering.) There must be one of these strips at each end of the piece, so that the edges of both shanks can be marked without moving the pattern. These hard-wood strips should be wide enough to lap over both sides of the piece to which they are fastened, and in such a shape as to mark both edges of the shank, and so adjusted as to bring the shank about the middle of the cog-piece, which, by the way, as we should before have said, ought to be from a half to three-fourths of an inch thicker than the cog is to be when finished. This device, or pattern we will call it, must be used against the face of the cog that has been dressed; and when one side of the shanks have been marked it can be turned, applied to face of cog as before, and the other sides of the shanks marked. The cogs can be marked off more rapidly and more accurately in this way than they can by the other, and those obliged to make cogs by hand ought to adopt this method.

After the cogs have been laid out, the piece can be placed in a vice, the shoulders sawed in, and the shank shaped out to the lines with a chisel. One thing must not be overlooked, and that is, in making arrangements for laying out the shank, at least one-sixteenth of an inch must be allowed to the neat thickness, so as to have something to dress on when fitting the cogs in; otherwise there might be some very loose fits. When the shaping of the shank is finished, key-slots must be cut. The distance from the shoulder of the cog to the shoulder of the key-slot must be a little less than the thickness of the rim of the wheel, so that the key when driven in will bear hard on the iron instead of the shoulder; the key should not be allowed to touch the shoulder. The key-slots for a spur wheel must be, say, an eighth of an inch deeper, ordinarily, on the upper side of the cog to allow draft for the key. For bevel wheels the slots may be the same depth through. After everything in the way of dressing and shaping of the shank has been completed the pieces can be cut in two in the center with a saw, when they will be ready for fitting and driving.

For fitting and driving, if the wheel cannot be brought close to the work-bench and vice, which cannot be done, as a rule, except in shops, (most wheels after being placed in the mills have to be filled in there, and a very awkward place it is to work in generally), a temporary bench and fastening for holding the cogs while chiseling and planing must be fixed up. This is done by fastening two strips to a piece of plank, between which the cogs can lay and be secured with a tapering key. The cog is then first tried in the mortise. The judgment must determine how much to dress off. The second time the cog should be forced in a little way with the hammer, and then backed out again; the marks that have been made by the iron will determine the manner and amount of dressing. If a mortise happens to be irregular in shape, as it often does, it requires a number of trials to get it right, and it should not be left until it is all right, and a good fit in every way. A fit should never be made with a hammer, but always with the chisel or plane. Hammer fits are liable to do mischief; they are liable to break the division between mortises, and burr up under the shoulder, and prevent the cog from being driven up close. Chisel and plane until sure there is no danger of breaking the wheel or burring the cog before driving finally home.

The mode of fitting the keys is somewhat similar to fitting the cogs. They are first ripped out of a plank of the required thickness. They can have an approximate taper only, as it varies frequently, owing to irregularities and other causes in the wheel. Each key must be fitted to its own place, and let remain there until all are fitted in; then in driving they should be struck with the hammer alternately all around the wheel, so as to get them all in about the same time, and about equally tight. If not convenient to drive all around the wheel at once, they can be driven in sections (the space between the arms forming a section). After they have all been driven in, the heads can be sawed off, allowing a projection of one and a half inches, or such a matter.

The next part of the operation is to turn off and establish the pitch line. Before proceeding to turn off, however, the interstices between the cogs should be plugged up with pine, or any other kind of wood, to prevent splitting off the cogs; and, too, before proceeding very far, it is necessary to obtain the diameter of the pitch circle, so as to know just how much to turn off. To do this, the diameter of the pitch circle on the pinion into which the wheel is to gear, must be carefully measured in inches and parts thereof; this diameter must be multiplied by the number of the cogs in the wheel just filled, and the product divided by the number of teeth in the pinion; the result will be the diameter of the pitch circle required for the wheel. The standing rule simply stated is: multiply the number of cogs in wheel by the diameter of pitch circle on pinion, and divide by the number of teeth in pinion. When there are two or more pinions of different sizes gearing into one wheel, the diameter of all must be measured and an average taken. This, of course, cannot occur with a bevel wheel, but often does with large spur wheels driving two or more runs of stones.

Another rule that answers the purpose just as well, and the only one that can be used when the pinion is not available, as is the case when a wheel is taken out of a mill and sent off to a shop to fill, is to multiply the number of cogs in the wheel by the known pitch in inches, reduced to thirty-seconds as a decimal. Thus, a wheel with two and a quarter inch pitch, would have seventy-two-thirty-seconds to the pitch; this would read, as a decimal, seventy-two-hundredths. This rule is, perhaps, as correct in practice as the other, but the other had best be used when it can. When the diameter of pitch circle is obtained, a pair of calipers, if available, large enough to span the circle, must be set exactly to the diameter thus obtained. By trying the wheel with the calipers occasionally, the operator will know when he has enough turned off. If there are no calipers available, something must be devised as a substitute.

The distance from base of tooth to pitch line should be about four-sevenths of the length of tooth. In cogging an old wheel, however, it is best to let the position of pitch circle on pinion determine its place on the wheel. The length of a tooth is a little more than five-eighths—sixty-five-hundredths—of the pitch. Thus, a wheel with two and a quarter inches pitch would have practically a length of cog of one and seven-sixteenths inches. But the length of new cogs in old wheels should be determined by length of teeth in pinion. The pitch circle may be first put on the wheel and then a corresponding circle indicating length of cogs, and by which they must be cut off, must be put on in the same way, that is, by securing a scribe-awl to the rest so that the point of it will strike the cogs in the right place, and holding it steadily; the same as the chisel was held in turning it off, while the wheel is being turned slowly around by hand. It is assumed that the pitch circle when once on the wheel is right, and cannot be disturbed or moved again, therefore, in stepping around with the dividers and spacing off, the dividers, and not the circle, must be changed until it comes out even. The practice is to set the dividers as nearly as possible by measurement to the required length of pitch, and then take as a starting point the middle, or about it, of some one cog in the pitch circle, and then step carefully from one cog to another, keeping constantly on the line until the circuit is completed. It may be the last step will fall a little short of the starting point, or it may reach a little beyond it; in either case the dividers must be changed to suit, either by filing the point a little or by re-setting, and the operation tried over again; and it may have to be repeated a number of times before it is right, but it should be made right before leaving it.

After the spacing has been completed, the thickness of the cogs should be determined and marked on each cog on the pitch circle. The thickness of the cog should be a little less than the space between the teeth on pinion. There is a great deal of disparity in the thickness of cogs and teeth in wheels; some makers have them nearly equal, while others have the wooden cogs in wheel much thicker than the iron teeth in pinion; and there is no doubt but that is the way it should be, as the wood is not capable of standing the same strain as the iron, and in consequence ought to be thicker and heavier. But whatever the thickness may be, the dividers should be set to just one-half of it. Then one point of the dividers should be set in the centers made in spacing, while with the other point a mark must be made on pitch circle on both sides of the center; this marks the thickness of cog on pitch line.

For shaping the cog, a pair of dividers must be set to span a distance equal to one pitch, plus one-half thickness of a cog; with the dividers working from the center of each cog the points of all the cogs can be shaped. The same dividers can be used for shaping the base also in a manner that will suggest itself to the operator. This arbitrary method of forming the teeth or cogs is not theoretically correct for all sizes of wheels, but is practically so for any size; that is, any sized wheel the cogs of which are dressed accurately by this rule, will work smoothly and well. In spur wheels the opposite side of the cogs must be laid out in the same manner, care being taken to have the starting point just right—must start from the same cog; the pitch line being the same it is not much trouble to get the point right.

After the cogs have been shaped or laid out on both sides of the wheel, the ends must be cut off. To get a start, it is best to back two of the cogs out, saw them off neatly to the line and put them back in place; there will then be room enough to work a saw in getting a start on the balance. The saw can be started by sawing into the line gradually, but it is rather more work and trouble than it is to take two of them out. Care should be taken in cutting off these ends not to run over the lines; the lines should be left on as guides for planing and smoothing. When the ends are planed off in good shape, face lines must be made across the ends of the cogs meeting the curved lines on both edges; the cogs are then ready for dressing, which ought to be done very carefully in order to insure a good working job.

There are no square, plumb or parallel lines on the cogs in a bevel wheel; all the lines tend to a common center, therefore, in obtaining the inside pitch circle of a bevel wheel a line must run from the outside pitch circle in the direction of where the centers of the two shafts on which wheel and pinion work would cross each other, were it possible to extend them to that point. The points can be established on a board fixed as a rest and notched out so as to straddle the cogs and rim of wheel. By the aid of this and a thin straight-edge that will work between the cogs, a line can be drawn that will indicate the inside cut-off line. Before this is done, however, the inside of the cogs should be turned off the same as the outside was in getting the pitch-circle. Enough should be taken off to make the cogs the width desired, then the inside cut-off line can be made, and also the inside pitch-circle can be struck according to the directions given. The cogs can then be cut off as before described, and face lines carried over the ends, in substantially the same manner; these lines, however, instead of being parallel must, like the others, run to a common center. The guide-rest put up to obtain the other lines should also assist in getting the lines on end of cogs. A hard wood strip should be so shaped that when it lays on the rest against the end of cogs, its upper edge would point directly to the common center spoken of. The wheel must then be turned and adjusted until a line drawn along the strip will meet one of the curved lines on the outside of the cogs; the wheel must again be turned until the next curved line is reached, and so on until all of the cogs are marked in this way; after which, taking these lines as a guide, the inside of the cog can be shaped with the dividers. It would probably be safe to adopt this method in shaping the under or opposite side of the spur wheel; there would be less liability to get a twist in the cogs. It requires a little more knowledge and skill to properly cog a bevel wheel than it does a spur wheel; but both require to be laid out and dressed carefully, in order to have them work as smoothly and noiselessly as they should. When there is not too much to be cut off the ends of the cogs, it is better, where it can be done, to plug up the interstices all the way across, and turn the face of the wheel off. It is a rather difficult job to hold the tool in cutting against the end of the hard wood, unless the motion is very rapid; but scarcely so tiresome as sawing them off. With a very slow motion turning should not be attempted.

ARTICLE XIV.

WATER WHEELS — STEAM ENGINES.

Comparatively few water wheels other than turbine wheels are now used as motors for flour mills, or, in fact, for any other kind of mills using water power; consequently, a very few remarks, and those confined to overshot wheels, are about all that is needed in this work.

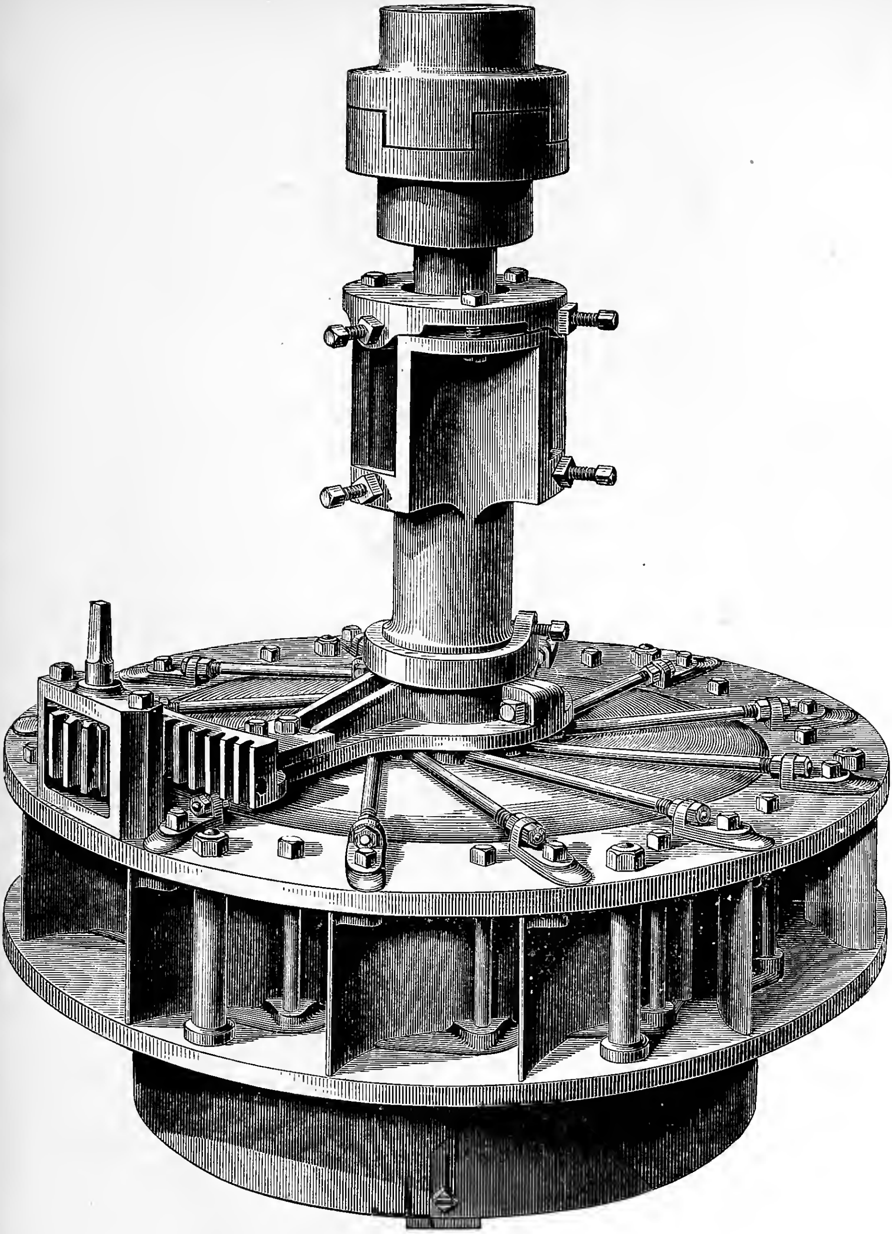
As to whether an overshot or the best make of turbine wheels, will transmit the most power with a given quantity of water and the same head and fall, has not as yet been fully decided. The manufacturers of turbine wheels of course claim the greatest economy in the use of water; they claim that more power can be obtained with the same quantity of water, all other things being equal, by the use of iron turbines than can be obtained by the use of the best constructed overshot. There is, however, this difference: the turbine wheels have many defenders because there are many makers, while the overshot has no defenders, unless, perhaps, now and then a conservative individual, who does not take up with new-fangled notions very readily. But whether or not the turbine wheels give more power than the overshot, certain it is they are rapidly displacing it. But there are other causes besides the difference in power that have taken an active part in bringing about the change. The turbine wheels are less troublesome than the overshot; they do not freeze up in winter time; are durable, occupy less room, and do not require so much gearing to get up speed. These, and other reasons, are strong arguments in favor of turbines, even though parties cannot be convinced that they give more power. But some overshot, and other kinds of wooden wheels, (in the aggregate, a great many), are still in use, and likely to be for some time to come, and for that reason we must give brief direction for the construction and placing in position of an overshot wheel.

The mode of making and putting the gudgeons in the shaft has already been described; but before setting the gudgeons, lines for laying out the arm-mortises should be made along the body of the shaft. Ordinarily, as before stated, water wheel shafts are made sixteen square, and there are eight sets of arms, so that there is an arm-mortise on every other square. In order to have the arms in line with each other and out of wind, it is best to divide the end of the shaft into eight parts, in the same manner as directed for making a conveyor-shaft, only the center, instead of the corner of square, must be taken. When both ends are divided, a straight-edge the length of shaft must be laid on the shaft, and adjusted to meet the lines on the end; then a fine line should be made with a scribe-awl along the straight-edge the whole length of the shaft. This must be repeated on every other square, or on the squares that are to be mortised. These lines form the centers of mortises, which can be laid out on both sides according to size. For light wheels running from twelve to twenty feet in diameter, and three or four feet face, the arms need not be more than three inches thick by seven to eight inches wide. The mortises should be very carefully laid out, and just as carefully cut, not less than six inches in depth, with the bottom smooth and true, so that the end of arm will rest solidly on it. The ends of mortises should be cut beveling, with the outer end running under, so that the outer edge of arm, which is to be cut in a dove-tail shape to suit bevel in mortise, will fit it snugly. The mortise should be about two inches longer than the arm is wide, so as to admit of a heavy key to be driven hard down behind the arm to hold it in place. The mortise must be wide enough to admit the whole body of arm without any tenoning; if the arms are three inches thick the mortise must be three inches wide.

In making the rim, good plank must be selected about the thickness the rim is intended to be. A pattern must then be made, out of an inch board, the length of one section of rim (a wheel with eight arms will have eight sections), and in width equal to depth of rim, allowing something for dressing. This is done by the use of a sweep, fastened by one end with a gimlet to the floor, the other end to have inserted in it a scribe-awl; the distance from gimlet to scribe-awl being just equal to half the outside diameter of the wheel, allowing a half inch for dressing off in finishing. With the sweep thus fixed, strike a circle on board intended for pattern; then move the scribe-awl in toward the center a distance equal to the intended depth of rim, making allowance as before for dressing. The inside circle can then be struck, after which the piece can be dressed out to the marks and cut off the length required. It is then ready for marking out the cants or segments of the rim, which is done by laying it on the plank and marking around it with a heavy lead-pencil or hard red chalk. Where there are no jig-saws convenient for cutting the cants out, an ordinary chopping axe is the best tool to use. The plank must be raised up on timbers or tressles; then by getting on it, the same as getting on a log for scoring-in, a skillful workman with the chopping axe can cut out the sections very neatly. It can also be done with a saw, but it is much harder work and requires more time to do it. It must not be forgotten in calculating the length of the cants, to allow for the lap — at least eight inches for a square lap. This allowance must be made on the pattern.

After everything else is ready, a platform for framing the rim may be erected. It is, though, a very common practice to build the platform first. The mode of doing this is to procure a heavy block of wood (a piece of a round log will do), about two feet high. This should be planted on a level piece of ground under a shade tree, if there is no shop or building that can be used for the purpose. Resting on this block, and running out from it in spider-shape, there must be eight pieces of scantling, four by four will do, and these pieces must be equally spaced. Under the outer end of each piece must be put (a little in from the end) an upright piece to support them. This platform must be perfectly level every way, so that when a rim is framed on it there will be no twist or wind in it. A ninth piece of scantling must be placed in the center of one of the sections so that a cant, when laid on it, will have three supports and lay level while it is being laid out and worked. The laps of each cant should be marked out ready for cutting before beginning to put the frame together; and they can as well all be cut except the last lap; it must be left until all the others are together, when it can be cut to suit and fill its place. The laps must be cut at one end out of one side, and at the other end out of the opposite side. The lap on the inside of rim where the bucket grooves are, must be the heaviest; thus, for instance, in cutting out for lap on inside of rim at one end of cant, an inch and five-eighths must be cut out; at the other end that much must be left standing, cutting out one and three-eighths inches instead. Most millwrights frame with a square lap, while others make a diamond-shaped lap; the latter suits the writer best, probably because he has been more accustomed to it. In using a diamond-shaped lap, the two outside rims of a water wheel must be framed, one with the sun and the other against the sun, so as to have the bucket-grooves come square across the shoulder of the lap, and not parallel with it as in that case, if a bucket-groove were to come too close to the shoulder it would be liable to split out and spoil it.

When the cants have all been made ready, the rim can be put together. This is done by starting at the section of the platform provided with three supports. The first cant, after having the laps neatly dressed, can be laid up, fixed in place by the use of the sweep which is fastened at the center on a block the thickness of the rim so as to have it about level. After the cant has been located, inch holes must be bored through the arms of platform on each side of cant, and



LEFFEL'S WATER WHEEL.

MADE BY JAS. LEFFEL & CO.

Springfield, Ohio, and 109 Liberty Street, New York.

(See Appendix.)

about an inch away from it. Into these holes pins must be driven, and between pins and cant wedges must be driven to hold it in place. As should have been stated before, the arms of platform should extend outside of rim about six inches, or in other words, the diameter of platform should be a foot larger than diameter of rim. After the first cant has been fixed and fastened to platform, the next can be fitted to it, and it in turn fastened in the same way, and then the next, and so on around until the rim is completed. The laps should be draw-bored and pinned temporarily as fast as each one is fitted together, to hold them in place.

When all is done and the face of the rim is planed off smooth and true, it is ready for laying out for elbows and buckets. What we call elbows are the strips that form the bottoms of the buckets. These run in the direction of the center and may be from three to four and a half inches wide, according to the depth of rim, and two inches thick. They should be about one foot apart, and have an even or equal number for each section. A wheel eighteen feet high or in diameter, should have either forty-eight or fifty-six buckets. The elbow centers should be spaced off with a pair of dividers, the same as spacing off a cog-wheel, so arranging as to have the lap points come between the elbows. After being spaced off the grooves can be laid out in length and width to suit the thickness and breadth of the elbow pieces, and about three-fourths of an inch deep. When these are all finished, the bucket-groove can be laid on. This must run out from the outer edge of elbow at an acute angle to be determined by the width of the elbows and the depth of the rim. The angle of the bucket should be just such as would let all the water run out before passing the lower center of the wheel when in position, but not too long before, because in that case water and power would be wasted. A step should be made for laying out the bucket-grooves with the inner end about a sixteenth of an inch narrower than the outer end. This strip should be preserved and afterwards used for marking the ends of the bucket-boards when putting

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them in. When the elbow and bucket-grooves are all completed, the rim must be circled to the true size, inside and out, with the sweep. It can then be taken apart and each segment dressed to the circle with a foot-adze and circular faced plane, after which it can be laid away until the wheel is ready to raise. The second rim is made like the first, except the bucket-grooves run the other way. The angle of the bucket forms a bevel on one edge of the elbows, and also on one edge of the buckets. These bevels should be ascertained and made, and the elbows dressed to a width; the buckets are to be dressed on the beveled-edge only. There should also be facing pieces got out. These should be made of full inch to inch and a half stuff, according to size of wheel, and can be got out by the pattern used for dressing out the cants.

When all the parts have been got out and everything ready, the shaft must be got into position and the wheel raised, which is commenced by putting in and fastening the arms. After the arms are in and fastened, a circle must be struck on them the size of the inside of rim. This can be done by fixing a scribe-awl on a rest, holding it against the arms while the wheel is being slowly turned around. A slot must then be cut down from the end of the arms, on each of them, to the circle. The slot must be two inches wide and two inches from the face or outside of arm. A groove must then be cut across the inside face of cant (if the arm be three inches thick) four inches wide, with a draft on one side for a key. It should, however, be here remarked that these grooves should be cut in the rim before it is taken off the platform where it is framed. They should be midway between each section, and so arranged as to just clear the outer edge of bucket; this will cause the arm to form one side of the elbow-groove. When the arms have been slotted, the cants can be placed in position, each one temporarily fastened until all are in, when they can be keyed, pinned and bolted. There should be, in addition to the pins, three bolts in a diamond and four bolts in a square lap;

a bolt through the slotted part of the arm and rim to clamp the two tightly together, and a key fitted along the arm in the groove across the face of rim.

After all this is done the elbows must be put in place and the soling put in. The soling is generally made of inch and a half stuff, in widths to suit the stuff without ripping, and no dressing done on it except to joint and bevel the edges. In some instances, where large, heavy wheels are made, the soling is dressed out of two inch plank to correspond with circle of wheel. The method of doing this will be found in our remarks on getting out staves. The soling is put in the wheel, section at a time, between each set of arms. The two outside pieces are first notched around the arms half way; then other pieces are selected or made to fill in between, very tight—should be sprung in.

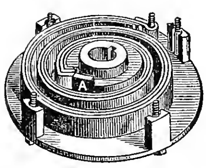
We forgot to say when the rims of wheel were up, the face pieces should be fitted in between the arms, and nailed fast to rim. These pieces should also be wide enough to cover the ends of the soling. After the soling has all been put in and spiked fast, the buckets may be put in. One end of the bucket can be cut off square and the length taken before the other end is cut off. This should be done with every bucket, as there may be some variation in length, owing to warp or twist in rims. The strip used for laying out bucket-grooves must then be laid against the end of bucket, and the bucket marked and dressed accordingly. This can be done with a jack-plane, crosswise; the bucket will then go in its place tight and snug. When driven home and nailed, it must be dressed off with axe, adze and plane, even with rim of wheel. When putting in the buckets the wheel must be turned upwards from you, so as to have a chance to fasten the buckets to the elbows either with nails or bolts.

This sketch is merely an outline general plan for building a wheel. Many things may require a modification of the plan, but once the general plan is understood, modifications, when necessary, will suggest themselves. Thus, for instance, where very high and heavy wheels are needed, it may not do to mortise arms in shaft; on the contrary, there may have to be a heavy frame made to lock around the shaft, and other different arrangements used.

Forebays are constructed according to circumstances and to suit the place. The common plan is to make a series of yoke-frames the width and depth the forebay is intended to be. These are placed at proper intervals on two or more stringer or stream sills, running back from the wheel and supported next the wheel by strong gallows frames, and at the other end by mother earth, or walls laid for the purpose. The end of stream-sills next the wheel are beveled and set, say, two inches away from the wheel. When the yoke frames are all fixed they are planked around solidly on the inside, and connected with the wing-frame, which either runs across the end of mill-race or along the side of it. This frame should run two feet below the bottom of race and eight or ten feet into the bank on both sides of forebay, and then puddled or graveled all around to prevent leak. The bottom side plank of the wheel-end of forebay must extend over and beyond the center of wheel two or three feet, according to size of wheel, and will have to be circled out over the center of wheel: these planks form the guide for the water. When a wheel has one or more middle rims, there will have to be, also, middle guides to correspond. Between these guides shute-plank will have to be laid; in most instances these are merely a continuation of the bottom of the forebay; others, however, lay the bottom first and then the sheet-plank on it. When the shute is formed in that way the plank must be got out long enough to extend back about eighteen inches past or inside of front end of forebay, and should be dressed wedge-shape the whole length, having the points next the wheel about a half inch thick, while the butts should be left the full thickness of two inches. A shute made in this way inclines the course of the water downward and more directly into the bucket. The wheel end of shute should be just far enough back of the center to insure the water to strike the buckets fairly without running over the wheel.

The best kind of gate to use for an overshot wheel is what is generally styled a valve gate. When closed it has the appearance of a corner strip in a conveyor-box, one edge resting on shute-plank and the other against the inside of the end of forebay. The upper edge is hinged with strips of leather or other material, while near the lower edge a staple is driven to which is attached a chain, and that in turn to a windlass-like arrangement running across the top of forebay. In starting the wheel the gate has to be raised by a turn of the windlass; the pressure of the water will close it, and keep it closed when the wheel is not running.

There are, perhaps, as many or more flour mills run by steam as by water, but as the millwright never has to build the steam engine or have anything, as a rule, to do with them, it is entirely unnecessary to have anything in this connection to say about the steam engine.



ARTICLE XV.

GEARING—TABLES FOR DETERMINING THE REQUIRED PITCH FOR DEVELOPING A GIVEN NUMBER OF HORSE POWERS FOR SPUR AND BEVEL IRON-TEETH WHEELS—RULES FOR THE HORSE POWER OF MORTISE, SPUR AND BEVEL WHEELS.

A careful examination of the field of mechanical literature fails to develop any clear, concise or simple method of determining how to select a pair of cog wheels of the required strength to develop a given amount of power. In view of the absence of any such method, the writer thinks a table that will enable the millwright or miller to select at a glance the wheel he needs, would be very useful in this work, and has, therefore, with care, compiled such a table.

It is true, that calculated tables have existed for many years purporting to give the desired information, and so they will to the clear-headed mathematical millwright, who has the time to study and cipher it out. But as very many of our millwrights who are good, practical mechanics, have not the mathematical skill to do the necessary ciphering, the tables to them at least are useless, while others who have the skill, rarely have the time; hence the tables in a large measure, fail of their design. The most of the tables used to determine the strength of teeth and cogs have been compiled from the calculations and works of old English mechanics, and, as a rule, more material is needed to meet the requirements of these tables than the necessities of the case demand. The English mechanics have ever been and are yet famous for making ponderous machinery. It is not a bad fault, but it is useless to carry it to excess. The tables used in this work are intended, to some extent, to correct these faults, and are, therefore, compiled more in harmony with the usages and practice of American mechanics. The calculations made here are uniform from low to high rate of speed, no allowance being made for unusual jar, generally supposed to exist in very high motion.

The principle involved is that a cog wheel making twenty revolutions per minute is capable of transmitting just twice the power of the same wheel making but ten revolutions per minute, all other things being equal, and this principle has been adhered to throughout; consequently, there would seem to be too great a difference in pitch for low speed and high speed, but both are correct. We would, however, owing to the more rapid wear of wheels running at a high rate of speed, as a matter of economy, recommend somewhat heavier wheels, as a rule, than the table calls for, as they would not have to be replaced so often. This, however, must be left to the judgment of the mechanic, as there is no uniform mode of determining the wear of wheels under all the various circumstances in which they run. The author would never, willingly, use cog wheels running at high rates of speed, but use belts instead.

For flour mill work (for which these tables are prepared more especially), the motions are supposed to be smooth, whether fast or slow; and where they are not, should be made so by the use of springs or otherwise — consequently, the table is adapted without change, except to counteract rapid wear. But for corn-shelling, driving trip-hammers, or for such other purposes, where it is next to impossible to control the motion, heavier high-motion wheels than the table calls for, ought to be used.

The first column in each table indicates the number of feet the wheels travel per second; the succeeding columns indicate the pitch necessary to develop the horse-power indicated at the top of columns. To use the table, we will say, for instance, it is required to have a wheel transmit 100 horse-power on a shaft making sixty revolutions per minute; it will be first necessary to determine about what size in diameter the wheel must be. In this case will say a wheel about 7 feet in diameter may be used; a wheel 7 feet in diameter is 21 feet in circumference, consequently, a 7-foot wheel, making 60 revolutions per minute, will have a velocity of 21 feet per second. We will now turn to the table and to the 21-feet line, and trace it to the 100 horse-power column; we there find 2.17 to be the pitch. We will next turn to the pattern list or lists, of which every millwright should have a supply, find the $2\frac{1}{8}$ and the $2\frac{1}{4}$ pitch columns, and trace them until a wheel about 7 feet in diameter is obtained. The $2\frac{1}{8}$ and $2\frac{1}{4}$ pitch are the nearest to the required pitch, but if the wheel cannot be found in them, it must be looked for in another pitch column, as near the required as can be found.

It may be, in order to suit room and other speeds, that a wheel 5 feet in diameter can be used; then, to ascertain the circumference we will multiply the diameter by 3.1416, which makes 15.7080 feet, or in practice 16 feet per second. Turning to this line in the table, we trace as before to the 100 horse-power column, and find the pitch to be 2.47 inches. We then again turn to the $2\frac{1}{2}$ pitch in pattern list and hunt for a wheel about 5 feet in diameter. It is a very rare thing that a wheel can be found just the size wanted in any pattern list, consequently, changes have to be made all through to get speeds right. The following rule for finding the wheel required by table should be committed to memory:

Rule—First fix the diameter of the wheel to be found in feet, then multiply diameter by 3.1416 to get the circumference; then by the number of revolutions the shaft makes per minute, and divide the product by 60, which will give the velocity of the wheel in feet per second, then proceed to find the pitch by tracing from this figure in velocity column to the required horse-power column.

Example—Required, to find the pitch of a cog-wheel to transmit 80 horse-power on a shaft making 75 revolutions per minute.

Solution — Say the wheel must be 4 feet in diameter, then:

```
      3.1416
           4
     -------
     12.5664
          75
     -------
      628320
     879648
     --------
60 )9424800 (15.708
     60
     ---
     342
     300
     ---
      424
      420
      ----
       480
       480
```

The 15.708 feet per second, the result obtained, we will call 16 feet, it being nearest to that number. From 16 in the velocity column we will trace to the 80 horse-power column, where will be found 2.23 inches pitch. By referring to the $2\frac{1}{4}$ pitch column in pattern list, the 4-foot wheel, or as near to it as possible, can be found.

The tables are made for solid iron wheels; the first for spur wheels and the other for bevel wheels. To obtain the pitch of mortise wheels with wooden cogs running at a stated speed and transmitting a given power, the pitch in the tables must be multiplied by 1.375, by proceeding in this wise: First fix the diameter of wheel as before directed in rule—multiply by 3.1416, and then by the number of revolutions the shaft makes, and divide by 60; the result will be the velocity in feet per second. This must be traced from the velocity column in table to the required horse-power column; the pitch thus found must be multiplied by 1.375, which will give the pitch for the mortise wheel required; then turn to mortise wheel column in pattern list, find the pitch and also the wheel.

Example — Required, the pitch of a spur-mortise wheel to transmit 60 horse-power on a shaft revolving 50 times per minute.

Solution—Say the wheel must be $4\frac{1}{2}$ feet in diameter, then:

```
       3.1416
          4.5
       ------
       157080
      125664
     --------
     14.13720
           50
     --------
60 ) 706.86000 ( 11.7810
     60
     --
     106
      60
     ---
      468
      420
      ---
       486
       480
       ---
         60
         60
```

The result is 11.7810, which means 12 in the velocity column. By turning to 12 in that column and tracing it to the 60 horse-power column, we find 2.22, which we multiply by 1.375; thus,

```
   1,375
    2.22
   -----
    2750
   2750
  2750
 -------
 3.05250
```

This gives us a little more than 3 1-20 inches pitch for mortise wheel, and we will take the 3, $3\frac{1}{8}$ or $3\frac{1}{4}$ pitch column in pattern list to find the wheel required.

To obtain the pitch of a bevel mortise wheel the same rule must be observed, but the pitch must be found in the bevel wheel table. For spur wheels gearing into two, three or more pinions, as is often the case in mills where two or more runs of burrs are driven by one wheel, no greater strength of cogs or larger pitch is needed than if but one run of stone is driven, except to save in wear, (the wear is much faster), but the arms and rim must be proportionately stronger for driving two or more run than for one only.

IRON-TEETH SPUR WHEELS.

H. P.	2	4	6	8	10	12	14
Velocity in feet per Second.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.
2	1	1.4	1.7	2	2.23	2.44	2.64
3	.81	1.13	1.37	1.62	1.80	1.97	2.13
4	.70	.98	1.19	1.40	1.56	1.70	1.84
5	.63	.88	1.07	1.26	1.42	1.53	1.66
6	.58	.81	.98	1.16	1.29	1.41	1.53
7	.53	.75	.90	1.06	1.18	1.29	1.39
8	.50	.70	.85	1	1.11	1.22	1.32
9	.47	.65	.80	.94	1.05	1.14	1.24
10	.448	.627	.76	.896	.997	1.10	1.18
11	.427	.597	.725	.854	.952	1.04	1.12
12	.408	.571	.693	.816	.910	.995	1.07
13	.393	.551	.668	.786	.876	.958	1.03
14	.378	.529	.642	.756	.845	.922	.997
15	.362	.506	.615	.724	.817	.883	.955
16	.353	.494	.600	.706	.786	.861	.931
17	.343	.480	.583	.686	.764	.836	.905
18	.333	.466	.566	.666	.736	.812	.885
19	.324	.453	.550	.648	.722	.790	.855
20	.316	.442	.537	.632	.704	.771	.834
21	.308	.431	.523	.616	.686	.751	.813
22	.300	.420	.510	.600	.669	.732	.792
23	.294	.411	.499	.588	.655	.717	.776
24	.288	.403	.489	.576	.642	.702	.760
25	.283	.396	.481	.566	.631	.690	.747
26	.277	.387	.470	.554	.617	.675	.731
27	.272	.380	.462	.544	.606	.663	.718
28	.267	.373	.453	.534	.595	.651	.704
29	.263	.368	.447	.526	.586	.641	.694
30	.258	.361	.438	.516	.575	.629	.681
31	.254	.355	.431	.508	.563	.619	.670
32	.250	.350	.425	.500	.557	.610	.660
33	.246	.344	.418	.492	.548	.600	.649
34	.242	.338	.411	.484	.539	.590	.638
35	.239	.334	.406	.478	.532	.583	.630
36	.235	.329	.399	.470	.524	.573	.620

IRON-TEETH SPUR WHEELS.

H. P.	16	18	20	22	24	26	28
Velocity in feet per Second.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.
2	2.82	3	3.16	3.31	3.46	3.60	3.74
3	2.28	2.43	2.55	2.68	2.80	2.91	3.02
4	1.97	2.10	2.21	2.31	2.42	2.52	2.61
5	1.77	1.89	1.99	2.08	2.17	2.26	2.35
6	1.63	1.74	1.83	1.91	2	2.08	2.16
7	1.49	1.59	1.67	1.75	1.83	1.90	1.98
8	1.41	1.50	1.58	1.65	1.73	1.80	1.87
9	1.32	1.41	1.48	1.55	1.62	1.69	1.75
10	1.26	1.34	1.41	1.48	1.55	1.61	1.67
11	1.20	1.28	1.34	1.41	1.47	1.53	1.59
12	1.15	1.22	1.28	1.34	1.41	1.46	1.52
13	1.10	1.17	1.24	1.30	1.35	1.41	1.46
14	1.06	1.13	1.19	1.25	1.30	1.36	1.41
15	1.02	1.08	1.14	1.19	1.25	1.30	1.35
16	.995	1.05	1.11	1.16	1.22	1.27	1.32
17	.967	1.02	1.08	1.13	1.18	1.23	1.28
18	.939	.999	1.05	1.10	1.15	1.19	1.24
19	.913	.972	1.02	1.07	1.12	1.16	1.21
20	.891	.948	.998	1.04	1.09	1.13	1.18
21	.868	.924	.973	1.01	1.06	1.10	1.15
22	.846	.900	.948	.993	1.03	1.08	1.12
23	.829	.882	.929	.972	1.01	1.05	1.09
24	.812	.864	.910	.953	.990	1.03	1.07
25	.798	.849	.894	.936	.979	1.01	1.05
26	.781	.831	.875	.916	.958	.997	1.03
27	.767	.816	.859	.900	.941	.979	1.01
28	.752	.801	.843	.883	.923	.961	.998
29	.741	.789	.831	.870	.909	.943	.983
30	.727	.774	.815	.853	.893	.928	.964
31	.716	.762	.802	.840	.878	.910	.946
32	.705	.750	.790	.827	.865	.900	.934
33	.693	.738	.777	.814	.851	.885	.920
34	.682	.726	.764	.800	.837	.871	.907
35	.674	.717	.755	.791	.826	.860	.893
36	.662	.705	.742	.777	.813	.846	.878

IRON-TEETH SPUR WHEELS.

H. P.	30	32	34	36	38	40	42
Velocity in feet per Second.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.
2	3.87	4	4.12	4.24	4.35	4.47	4.58
3	3.13	3.24	3.33	3.43	3.52	3.62	3.71
4	2.70	2.80	2.88	2.96	3.04	3.12	3.20
5	2.43	2.52	2.59	2.67	2.74	2.81	2.88
6	2.24	2.32	2.38	2.45	2.52	2.59	2.65
7	2.04	2.12	2.18	2.24	2.30	2.36	2.42
8	1.93	2	2.06	2.12	2.17	2.23	2.29
9	1.81	1.88	1.92	1.99	2.04	2.11	2.15
10	1.73	1.79	1.84	1.89	1.94	2	2.05
11	1.65	1.70	1.75	1.81	1.85	1.90	1.95
12	1.57	1.62	1.65	1.72	1.77	1.81	1.86
13	1.51	1.57	1.61	1.67	1.70	1.75	1.79
14	1.46	1.51	1.55	1.60	1.64	1.68	1.73
15	1.40	1.44	1.49	1.53	1.57	1.62	1.65
16	1.36	1.41	1.45	1.49	1.53	1.57	1.60
17	1.32	1.37	1.41	1.45	1.49	1.53	1.57
18	1.28	1.33	1.37	1.41	1.44	1.48	1.52
19	1.25	1.29	1.33	1.37	1.40	1.44	1.48
20	1.22	1.26	1.30	1.33	1.37	1.41	1.44
21	1.19	1.23	1.26	1.30	1.33	1.38	1.41
22	1.16	1.20	1.23	1.27	1.30	1.34	1.37
23	1.13	1.17	1.21	1.24	1.27	1.31	1.34
24	1.11	1.15	1.18	1.22	1.25	1.28	1.31
25	1.09	1.13	1.16	1.19	1.23	1.26	1.29
26	1.07	1.10	1.14	1.17	1.20	1.23	1.26
27	1.05	1.08	1.12	1.15	1.18	1.21	1.24
28	1.03	1.06	1.10	1.13	1.16	1.19	1.22
29	1.01	1.05	1.08	1.11	1.14	1.17	1.20
30	.997	1.03	1.06	1.09	1.12	1.15	1.18
31	.982	1.01	1.04	1.07	1.10	1.13	1.16
32	.967	1	1.03	1.06	1.08	1.11	1.14
33	.952	.984	1.01	1.04	1.07	1.09	1.12
34	.936	.968	.997	1.02	1.05	1.08	1.10
35	.924	.956	.984	1.01	1.03	1.06	1.09
36	.909	.940	.967	.996	1.02	1.05	1.07

IRON-TEETH SPUR WHEELS.

H. P.	44	46	48	50	60	70	80
Velocity in feet per Second.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.
2	4.69	4.79	4.89	5	5.47	5.91	6.32
3	3.79	3.87	3.96	4.05	4.43	4.78	5.11
4	3.28	3.35	3.42	3.50	3.82	4.13	4.42
5	2.95	3.01	3.08	3.15	3.44	3.72	3.98
6	2.72	2.77	2.83	2.90	3.17	3.42	3.66
7	2.48	2.53	2.59	2.65	2.89	3.13	3.34
8	2.34	2.39	2.44	2.50	2.73	2.95	3.16
9	2.20	2.25	2.29	2.35	2.57	2.77	2.97
10	2.09	2.14	2.19	2.24	2.45	2.64	2.83
11	2	2.04	2.08	2.13	2.33	2.51	2.69
12	1.90	1.94	1.99	1.02	2.22	2.40	2.57
13	1.84	1.88	1.92	1.96	2.14	2.32	2.48
14	1.77	1.81	1.85	1.89	2.06	2.23	2.38
15	1.69	1.72	1.77	1.81	1.98	2.13	2.28
16	1.65	1.69	1.72	1.76	1.93	2.08	2.23
17	1.60	1.64	1.67	1.71	1.87	2.02	2.16
18	1.56	1.59	1.62	1.66	1.82	1.96	2.10
19	1.51	1.55	1.58	1.62	1.77	1.91	2.04
20	1.48	1.51	1.54	1.58	1.72	1.86	1.99
21	1.44	1.47	1.50	1.54	1.67	1.82	1.94
22	1.40	1.43	1.46	1.50	1.64	1.77	1.89
23	1.37	1.40	1.43	1.47	1.60	1.73	1.85
24	1.35	1.37	1.40	1.44	1.57	1.70	1.82
25	1.32	1.35	1.38	1.41	1.54	1.67	1.78
26	1.29	1.32	1.35	1.38	1.51	1.63	1.75
27	1.27	1.29	1.33	1.36	1.48	1.60	1.71
28	1.25	1.27	1.30	1.33	1.46	1.57	1.68
29	1.23	1.25	1.28	1.31	1.43	1.55	1.66
30	1.21	1.23	1.26	1.29	1.41	1.52	1.63
31	1.19	1.21	1.24	1.27	1.38	1.50	1.60
32	1.17	1.19	1.22	1.25	1.36	1.47	1.58
33	1.15	1.17	1.20	1.23	1.34	1.45	1.55
34	1.13	1.15	1.18	1.21	1.32	1.43	1.52
35	1.12	1.14	1.16	1.19	1.30	1.41	1.51
36	1.10	1.12	1.14	1.17	1.28	1.38	1.48

IRON-TEETH SPUR WHEELS.

H. P.	90	100	125	150	175	200	250
Velocity in feet per Second.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.
2	6.70	7.07	7.90	8.65	9.30	10	11.18
3	5.42	5.72	6.39	7	7.53	8.10	9.05
4	4.69	4.99	5.53	6.05	6.51	7	7.82
5	4.22	4.45	4.97	5.44	5.85	6.30	7.04
6	3.88	4.10	4.58	5.01	5.39	5.80	6.48
7	3.55	3.74	4.18	4.58	4.92	5.30	5.92
8	3.35	3.53	3.95	4.32	4.65	5	5.59
9	3.14	3.32	3.71	4.06	4.37	4.70	5.25
10	3	3.16	3.52	3.87	4.16	4.48	5
11	2.86	3.01	3.37	3.69	3.91	4.27	4.77
12	2.73	2.87	3.21	3.52	3.78	4.07	4.55
13	2.63	2.77	3.10	3.40	3.65	3.93	4.39
14	2.53	2.67	2.98	3.26	3.51	3.78	4.22
15	2.42	2.55	2.85	3.13	3.36	3.62	4.04
16	2.36	2.47	2.78	3.05	3.28	3.53	3.93
17	2.29	2.42	2.70	2.96	3.18	3.43	3.83
18	2.23	2.35	2.63	2.88	3.09	3.33	3.72
19	2.17	2.29	2.55	2.80	3.01	3.24	3.62
20	2.11	2.23	2.48	2.73	2.93	3.16	3.53
21	2.06	2.17	2.43	2.66	2.86	3.08	3.44
22	2.01	2.12	2.37	2.59	2.79	3	3.35
23	1.96	2.07	2.32	2.54	2.73	2.94	3.28
24	1.92	2.03	2.27	2.49	2.67	2.88	3.21
25	1.89	2	2.23	2.44	2.63	2.83	3.16
26	1.85	1.95	2.18	2.41	2.57	2.77	3.09
27	1.82	1.92	2.14	2.35	2.52	2.72	3.04
28	1.78	1.88	2.10	2.30	2.48	2.67	2.98
29	1.76	1.85	2.07	2.27	2.44	2.63	2.94
30	1.72	1.82	2.03	2.23	2.39	2.58	2.88
31	1.70	1.79	2	2.19	2.36	2.54	2.83
32	1.67	1.76	1.97	2.16	2.32	2.50	2.79
33	1.64	1.73	1.94	2.12	2.28	2.46	2.75
34	1.62	1.70	1.91	2.09	2.25	2.42	2.70
35	1.60	1.68	1.88	2.06	2.22	2.39	2.67
36	1.57	1.66	1.85	2.03	2.18	2.35	2.63

IRON-TEETH BEVEL WHEELS.

H. P.	2	4	6	8	10	12	14
Velocity in feet per Second.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.
2	1.2	1.68	2.04	2.40	2.67	2.92	3.17
3	.972	1.35	1.64	1.94	2.16	2.36	2.56
4	.840	1.17	1.42	1.68	1.87	2.04	2.20
5	.756	1.05	1.28	1.51	1.70	1.83	1.99
6	.696	.912	1.16	1.39	1.54	1.69	1.83
7	.636	.900	1.08	1.27	1.41	1.54	1.66
8	.600	.840	1.02	1.20	1.33	1.46	1.58
9	.564	.780	.960	1.12	1.26	1.35	1.48
10	.531	.752	.912	1.07	1.19	1.32	1.41
11	.512	.716	.870	1.02	1.14	1.24	1.34
12	.489	.685	.831	.979	1.09	1.19	1.28
13	.471	.661	.801	.943	1.05	1.14	1.25
14	.453	.634	.770	.907	1.01	1.10	1.19
15	.434	.607	.738	.868	.980	1.05	1.14
16	.423	.592	.720	.847	.943	1.03	1.11
17	.411	.576	.699	.823	.916	1	1.08
18	.399	.559	.679	.799	.883	.974	1.05
19	.388	.543	.660	.777	.866	.948	1.02
20	.379	.530	.644	.758	.844	.925	1
21	.369	.517	.627	.739	.823	.901	.975
22	.360	.504	.612	.720	.802	.878	.950
23	.352	.493	.598	.705	.786	.860	.931
24	.345	.483	.586	.691	.770	.842	.912
25	.339	.475	.577	.679	.756	.828	.896
26	.332	.465	.564	.664	.740	.810	.877
27	.326	.456	.554	.652	.727	.795	.861
28	.320	.447	.543	.640	.714	.781	.844
29	.315	.441	.536	.631	.703	.769	.832
30	.309	.433	.525	.619	.690	.754	.817
31	.304	.426	.517	.609	.675	.742	.804
32	.300	.420	.510	.600	.668	.732	.792
33	.295	.412	.501	.590	.657	.720	.778
34	.290	.405	.493	.580	.646	.708	.765
35	.286	.400	.487	.573	.638	.699	.756
36	.282	.394	.478	.564	.628	.687	.744

IRON-TEETH BEVEL WHEELS.

H. P.	16	18	20	22	24	26	28
Velocity in feet per Second.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.
2	3.38	3.60	3.79	3.97	4.15	4.32	4.48
3	2.73	2.91	3.06	3.21	3.36	3.49	3.62
4	2.36	2.52	2.65	2.77	2.90	3.02	3.13
5	2.12	2.26	2.38	2.49	2.60	2.71	2.82
6	1.95	2.08	2.19	2.29	2.40	2.49	2.59
7	1.78	1.90	2	2.10	2.19	2.28	2.37
8	1.68	1.80	1.89	1.98	2.07	2.16	2.24
9	1.58	1.69	1.77	1.86	1.94	2.02	2.10
10	1.51	1.60	1.69	1.77	1.86	1.93	2
11	1.44	1.53	1.60	1.69	1.76	1.83	1.90
12	1.38	1.46	1.53	1.60	1.69	1.75	1.82
13	1.32	1.40	1.48	1.56	1.62	1.69	1.75
14	1.27	1.35	1.42	1.50	1.56	1.63	1.69
15	1.22	1.29	1.36	1.42	1.50	1.56	1.62
16	1.19	1.26	1.33	1.39	1.46	1.52	1.58
17	1.14	1.22	1.29	1.35	1.41	1.47	1.53
18	1.12	1.19	1.26	1.32	1.38	1.42	1.48
19	1.09	1.16	1.22	1.28	1.34	1.39	1.45
20	1.06	1.13	1.19	1.24	1.30	1.35	1.41
21	1.04	1.10	1.16	1.21	1.27	1.32	1.38
22	1.01	1.08	1.13	1.19	1.23	1.29	1.34
23	.994	1.05	1.11	1.16	1.21	1.26	1.30
24	.974	1.03	1.09	1.14	1.18	1.23	1.28
25	.957	1.01	1.07	1.12	1.17	1.21	1.26
26	.937	.997	1.05	1.09	1.14	1.19	1.23
27	.921	.979	1.03	1.08	1.12	1.17	1.21
28	.902	.961	1.01	1.05	1.10	1.15	1.19
29	.889	.946	.997	1.04	1.09	1.13	1.17
30	.872	.928	.978	1.02	1.07	1.12	1.15
31	.859	.914	.962	1	1.05	1.10	1.13
32	.846	.900	.948	.992	1.03	1.08	1.12
33	.831	.885	.932	.976	1.02	1.06	1.10
34	.818	.871	.916	.960	1	1.04	1.08
35	.808	.860	.906	.949	.991	1.03	1.07
36	.794	.846	.890	.932	.975	1.01	1.05

IRON-TEETH BEVEL WHEELS.

H. P.	30	32	34	36	38	40	42
Velocity in feet per Second	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.
2	4.64	4.80	4.94	5.08	5.22	5.36	5.49
3	3.75	3.88	3.99	4.11	4.22	4.34	4.45
4	3.24	3.36	3.45	3.55	3.64	3.74	3.84
5	2.91	3.02	3.17	3.20	3.28	3.37	3.45
6	2.68	2.78	2.85	2.94	3.02	3.10	3.18
7	2.44	2.54	2.61	2.68	2.76	2.83	2.90
8	2.31	2.40	2.47	2.51	2.60	2.67	2.74
9	2.17	2.25	2.30	2.38	2.44	2.53	2.58
10	2.07	2.14	2.20	2.26	2.32	2.40	2.46
11	1.98	2.04	2.10	2.17	2.22	2.28	2.34
12	1.88	1.94	2	2.06	2.12	2.17	2.25
13	1.81	1.88	1.93	2	2.04	2.10	2.14
14	1.75	1.81	1.86	1.92	1.96	2.01	2.07
15	1.68	1.72	1.78	1.83	1.88	1.94	1.98
16	1.63	1.69	1.74	1.78	1.83	1.88	1.92
17	1.58	1.64	1.69	1.74	1.78	1.83	1.88
18	1.53	1.59	1.64	1.69	1.72	1.77	1.82
19	1.50	1.54	1.59	1.64	1.68	1.72	1.77
20	1.46	1.51	1.56	1.59	1.64	1.69	1.72
21	1.42	1.47	1.51	1.56	1.59	1.65	1.69
22	1.39	1.44	1.47	1.52	1.56	1.60	1.64
23	1.35	1.40	1.45	1.48	1.52	1.57	1.60
24	1.33	1.38	1.41	1.46	1.50	1.53	1.57
25	1.30	1.35	1.39	1.42	1.47	1.51	1.54
26	1.28	1.32	1.36	1.40	1.44	1.47	1.51
27	1.26	1.29	1.34	1.38	1.41	1.45	1.48
28	1.23	1.27	1.32	1.35	1.39	1.42	1.46
29	1.21	1.26	1.29	1.33	1.36	1.40	1.44
30	1.19	1.23	1.27	1.30	1.34	1.38	1.41
31	1.17	1.21	1.24	1.28	1.32	1.35	1.39
32	1.16	1.20	1.23	1.27	1.29	1.33	1.36
33	1.14	1.18	1.21	1.24	1.28	1.30	1.34
34	1.12	1.16	1.19	1.22	1.26	1.29	1.32
35	1.10	1.15	1.18	1.21	1.23	1.27	1.30
36	1.09	1.12	1.16	1.19	1.22	1.26	1.28

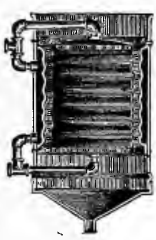
IRON-TEETH BEVEL WHEELS.

H. P.	44	46	48	50	60	70	80
Velocity in feet per Second.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.
2	5.62	5.74	5.86	6	6.56	7.08	7.58
3	4.54	4.64	4.75	4.86	5.31	5.73	6.13
4	3.93	4.02	4.10	4.20	4.58	4.93	5.30
5	3.54	3.61	3.69	3.78	4.12	4.46	4.77
6	3.26	3.32	3.39	3.48	3.80	4.10	4.39
7	2.97	3.03	3.10	3.18	3.46	3.75	4
8	2.80	2.86	2.92	3	3.27	3.54	3.79
9	2.64	2.70	2.74	2.82	3.08	3.32	3.56
10	2.50	2.56	2.62	2.68	2.94	3.16	3.39
11	2.40	2.44	2.49	2.55	2.79	3.01	3.22
12	2.28	2.32	2.38	2.43	2.66	2.88	3.08
13	2.20	2.25	2.30	2.35	2.56	2.78	2.97
14	2.12	2.17	2.22	2.26	2.47	2.67	2.85
15	2.02	2.06	2.12	2.17	2.37	2.55	2.73
16	1.98	2.02	2.06	2.11	2.31	2.49	2.67
17	1.92	1.96	2	2.05	2.24	2.42	2.59
18	1.87	1.90	1.94	1.99	2.18	2.35	2.52
19	1.81	1.86	1.89	1.94	2.12	2.29	2.44
20	1.77	1.81	1.84	1.89	2.06	2.23	2.38
21	1.72	1.76	1.80	1.84	2	2.18	2.32
22	1.68	1.71	1.75	1.80	1.96	2.12	2.26
23	1.64	1.68	1.71	1.76	1.92	2.07	2.22
24	1.62	1.64	1.68	1.72	1.88	2.04	2.18
25	1.58	1.62	1.65	1.69	1.84	2	2.13
26	1.54	1.58	1.62	1.65	1.81	1.95	2.10
27	1.52	1.54	1.59	1.63	1.77	1.92	2.05
28	1.50	1.52	1.56	1.59	1.75	1.88	2.01
29	1.47	1.50	1.53	1.57	1.71	1.86	1.99
30	1.45	1.47	1.51	1.54	1.69	1.82	1.95
31	1.42	1.45	1.48	1.52	1.65	1.80	1.92
32	1.40	1.42	1.46	1.50	1.63	1.76	1.89
33	1.38	1.40	1.44	1.47	1.60	1.74	1.86
34	1.35	1.38	1.41	1.45	1.58	1.71	1.82
35	1.34	1.36	1.39	1.42	1.56	1.69	1.81
36	1.32	1.34	1.36	1.40	1.53	1.65	1.77

IRON-TEETH BEVEL WHEELS.

H. P.	**90**	**100**	**125**	**150**	**175**	**200**	**250**
Velocity in feet per Second.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.	Pitch.
2	8.04	8.48	9.48	10.3	11.6	12	13.4
3	6.50	6.86	7.66	8.40	9.03	9.72	10.8
4	5.62	5.98	6.63	7.26	7.82	8.40	9.38
5	5.06	5.34	5.96	6.52	7.02	7.56	8.44
6	4.67	4.92	5.49	6.02	6.46	6.96	7.77
7	4.26	4.48	5.01	5.49	5.90	6.36	7
8	4.02	4.23	4.74	5.18	5.58	6	6.70
9	3.76	3.98	4.45	4.87	5.24	5.64	6.30
10	3.60	3.79	4.22	4.64	4.99	5.37	6
11	3.43	3.61	4.04	4.42	4.79	5.12	5.72
12	3.27	3.44	3.85	4.22	4.53	4.84	5.46
13	3.15	3.32	3.71	4.08	4.38	4.71	5.26
14	3.03	3.20	3.57	3.91	4.21	4.53	5.06
15	2.90	3.06	3.44	3.75	4.03	4.34	4.80
16	2.83	2.97	3.33	3.66	3.92	4.23	4.71
17	2.74	2.90	3.24	3.55	3.81	4.12	4.59
18	2.67	2.83	3.15	3.44	3.70	3.99	4.46
19	2.60	2.76	3.06	3.36	3.61	3.88	4.32
20	2.53	2.67	2.97	3.27	3.51	3.79	4.23
21	2.47	2.60	2.91	3.19	3.43	3.69	4.12
22	2.41	2.54	2.84	3.10	3.34	3.60	4.02
23	2.35	2.48	2.78	3.04	3.27	3.52	3.93
24	2.30	2.43	2.72	2.98	3.20	3.45	3.85
25	2.26	2.40	2.67	2.92	3.15	3.39	3.79
26	2.22	2.35	2.61	2.89	3.08	3.32	3.70
27	2.18	2.30	2.56	2.82	3.02	3.26	3.64
28	2.14	2.27	2.52	2.76	2.97	3.20	3.58
29	2.11	2.22	2.48	2.72	2.92	3.15	3.52
30	2.07	2.18	2.43	2.67	2.86	3.09	3.45
31	2.04	2.14	2.40	2.62	2.83	3.04	3.39
32	2	2.11	2.36	2.59	2.78	3	3.34
33	1.96	2.07	2.32	2.54	2.73	2.95	3.30
34	1.94	2.04	2.29	2.50	2.70	2.90	3.24
35	1.92	2.01	2.24	2.47	2.66	2.86	3.20
36	1.88	1.99	2.22	2.43	2.61	2.82	3.15

We should have stated in our previous remarks in reference to the foregoing tables that the calculations are based on a unit of width for teeth or cogs; consequently, as the pitch increases the cogs become relatively stronger, because they are usually made wider. This is just as it should be, for the reason that the coarser the pitch the fewer the cogs that bear at one time. For instance, if it should ever become necessary to use a wheel having a pitch equal to the coarsest named in the tables, one cog at a time would have to do all the work in the main, while with finer pitch two or more cogs have a constant bearing on the work. But we do not consider, even with that difference, that the full pitch is necessary for the work named in the table; consequently we would say as a guide for those not well posted as to the strength of wheels, in looking for wheels less than a half-inch pitch, look for a pitch greater than that the tables call for, as a matter of economy in saving wear and tear; in looking for a wheel more than five inches pitch, select a pitch somewhat less than the tables call for. This is also done for economy in material, and for convenience as well. There is ample strength margin in all the heavy wheels to draw on.



ARTICLE XIV.

BELTING.

One of the vexed questions among millers, millwrights and others interested in the matter, is just how to determine, under all circumstance, what width of belt is necessary to transmit a given amount of power. It is generally known that the faster a belt travels the more power it transmits; and it is also generally supposed that the larger the pulleys the more power is transmitted. This, however, is true only in part. If by increasing the size of the pulleys the speed of the belt is increased, then will there be a gain of power; but if the size of pulleys is increased without increasing the travel of the belt, then will there be no appreciable gain. This, however, is not liable to occur, as an increase in the size of pulleys (both pulleys) means an increase in the speed of the belt, otherwise the speed of whatever machinery is being driven would be changed, and, hence the belt, by its increased velocity in feet per minute, accomplishes what is very frequently attributed to increased pulley surface. The principle involved is that a belt having a one hundred and eighty degree bearing on a twenty-four inch pulley, and traveling at a given velocity, will transmit the same amount of power that the same kind of a belt having the same bearing (180°), the same tension, and moving at the same rate of speed, would on a forty-eight inch pulley; provided, of course, that all other things are equal. The belt must be of the same material, the same weight, and the pulley the same kind and made in the same way. The power transmitted by a belt is proportionate to the width of belt, the speed it travels, and the arc of contact on the same pulley without any special reference to the size of pulley. We, of course, except very small pulleys. Where pulleys are very small it makes the curve of the belt so short that it can't or don't have the same effect as on large pulleys. In order to establish a uniform method of determining the required width of belt, and to assist those not well versed in the theory and practice of belt transmission, we have carefully, and as accurately as possible, prepared a table for determining the horse-power different widths of belts will transmit at the same and at different speeds, bearing on five different divisions or arcs of pulley. The table is based on pulleys of one foot in diameter and upward; for pulleys much less than one foot in diameter reasonable allowance must be made. The top of each column of figures indicates the arc of contact, both in degrees and in divisions of halves, quarters, eighths and sixteenths. In order to use the table certainly, first ascertain as nearly as possible the number of horse-powers to be transmitted, then a diagram of pulleys and belt should be made, and the smaller pulley divided into sixteen parts by stepping around with the dividers. By that means the number of sixteenths that the belt touches can be ascertained. If it should be five-sixteenths, for instance, then examine the five-sixteenths column opposite the speed the belt travels, until the horse-power intended to be transmitted is found; above that will be the width of belt required.

As an example, require the width of belt it will take to transmit nineteen horse-power, running 2500 feet per minute, and having a 5-16, or $112\frac{1}{2}°$, bearing on small pulley. To find it, run down the first left-hand column until the 2500 is reached, then follow the line to the right, examining each 5-16 column until the 19 is found. Above that it will be found—an 8-inch belt is required.

To ascertain the power of a one, three, five and seven-inch belt, or such as are not named in the table, their relation to the width of any other belt named in the list, should be found. Thus, a three-inch belt will transmit one and a half times as much power as a two-inch belt, with the same tension, traveling at the same speed and having the same arc of contact. The same is also true in relation to the different speeds. A two-inch belt traveling at the rate of one hundred and fifty feet per minute will transmit one and a half times the power of the same belt traveling one hundred feet per minute, the other conditions being the same. By paying strict attention to these two facts, there will be no trouble in ascertaining, by the use of the table, the power that any width belt will transmit, running at any speed and having any arc of contact named in the table.

These calculations and tables are designed only for single leather belts. We do not assume to know whether leather or rubber will transmit the most power, all things being equal; in that respect would be willing to risk either; but for other reasons would, for flour-mill work generally, prefer leather. Double leather belts are supposed to transmit about one-third more power than single, and that allowance can be made on table calculations. Pulleys, covered with leather, add about twenty-five per cent. to their effectiveness. Belts should run with the grain side to the pulley. When cross belts or tighteners are used, it is so much of a gain in power, by increasing the arc of contact. We would advise, though, not to use cross belts, unless very narrow or running very slow, except when it cannot be avoided. Tighteners should always bear against the slack side of the belt; never against the tight or working side. Belts to produce table results must have a reasonable tension; such a tension as the judgment of most practical mechanics give belts. By the judgment only can we measure the tension as a general rule.

Velocity in feet per Minute.	2-inch Belt.					4-inch Belt.				
	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°
100	.25	.23	.21	.19	.16	.5	.46	.42	.38	.32
200	.5	.46	.42	.38	.32	1.	.92	.84	76	.64
300	.75	.69	.63	.57	.48	1.5	1.38	1.26	1.14	.96
400	1	.92	.84	.76	.64	2	1.84	1.68	1.52	1.28
500	1.25	1.15	1.05	.95	.80	2.5	2.30	2.1	1.9	1.6
600	1.5	1.38	1.26	1.14	.96	3	2.76	2.52	2.28	1.92
700	1.75	1.61	1.47	1.33	1.12	3.5	3.22	2.94	2.66	2.24
800	2	1.84	1.68	1.52	1.28	4	3.68	3.36	3.04	2.56
900	2.25	2.07	1.89	1.71	1.44	4.5	4.14	3.78	3.42	2.88
1000	2.5	2.30	2.1	1.9	1.6	5	4.6	4.2	3.80	3.2
1100	2.75	2.53	2.31	2.09	1.76	5.5	5.06	4.62	4.18	3.52
1200	3	2.76	2.52	2,28	1.92	6	5.52	5.04	4.56	3.84
1300	3.25	2.99	2.73	2.47	2.08	6.5	5.98	5.46	4.94	4.16
1400	3.5	3.22	2.94	2.66	2.24	7	6.44	5.88	5.32	4.48
1500	3.75	3.45	3.15	2.85	2.4	7.5	6.9	6.3	5.7	4.8
1600	4	3.68	3.36	3.04	2.56	8	7.36	6.72	6.08	5.12
1700	4.25	3.91	3.57	3.23	2.72	8.5	7.82	7.14	6.46	5.44
1800	4.45	4.14	3.78	3.42	2.88	9	8.28	7.56	6.84	5.76
1900	4.75	4.37	3.99	3.61	3.04	9.5	8.74	7.98	7.22	6.08
2000	5	4.6	4.2	3.8	3.2	10	9.2	8.4	7.6	6.4
2100	5.25	4.83	4.41	3.99	3.36	10.5	9.66	8.82	7.98	6.72
2200	5.5	5.06	4.62	4.18	3.52	11	10.12	9.24	8.36	7.04
2300	5.75	5.29	4.83	4.37	3.68	11.5	10.58	9.66	8.74	7.36
2400	6	5.52	5.04	4.56	3.84	12	11.04	10.08	9.12	7.68
2500	6.25	5.75	5.25	4.75	4	12.5	11.5	10.5	9.5	8
2600	6.5	5.98	5.46	4.94	4.16	13	11.96	10.92	9.88	8.32
2700	6.75	6.21	5.67	5.13	4.32	13.5	12.42	11.34	10.26	8.64
2800	7	6.44	5.88	5.32	4.48	14	12.88	11.76	10.64	8.96
2900	7.25	6.67	6.09	5.51	4.64	14.5	13.34	12.18	11.02	9.28
3000	7.5	6.90	6.3	5.70	4.8	15	13.8	12.6	11.4	9.60
3100	7.75	7.13	6.51	5.89	4.96	15.5	14.26	13.02	11.78	9.94
3200	8	7.36	6.72	6.08	5.12	16	14.72	13.44	12.16	10.24
3300	8.25	7.59	6.93	6.27	5.28	16.5	15.18	13.86	12.54	10.56
3400	8.5	7.82	7.14	6.46	5.44	17	15.64	14.28	12.92	10.88
3500	8.75	8.05	7.35	6.55	5.6	17.5	16.1	14.7	13.3	11.2
3600	9	8.28	7.56	6.84	5.76	18	16.56	15.12	13.68	11.52
3700	9.25	8.51	7.77	7.03	5.92	18.5	17.02	15.54	14.06	11.84
3800	9.5	8.74	7.98	7.22	6.08	19	17.48	15.96	14.44	12.16
3900	9.75	8.97	8.19	7.41	6.24	19.5	17.94	16.38	14.82	12.48
4000	10	9.2	8.4	7.6	6.4	20	18.4	16.8	15.2	12.8
4200	10.5	9.66	8.82	7.98	6.72	21	19.32	17.64	15.96	13.44
4400	11	10.12	9.24	8.36	7.4	22	20.24	18.48	16.72	14.08
4600	11.5	10.58	9.66	8.74	7.36	23	21.16	19.32	17.48	14.72
4800	12	11.04	10.08	9.12	7.68	24	22.08	20.16	18.24	15.36
5000	12.5	11.5	10.5	9.5	8	25	23	21	19	16
5400	13.5	12.42	11.34	10.26	8.64	27	24.84	22.68	20.52	17.28
5800	14.5	13.34	12.18	11.02	9.28	29	26.68	24.36	22.04	18.56
6200	15.5	14.26	13.02	11.78	9.92	31	28.52	26.04	23.56	19.84

Velocity in feet per Minute.	6-inch Belt.					8-inch Belt.				
	1-2 or 180°.	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°
100	.75	.69	.63	.57	.48	1	.92	.84	.76	.64
200	1.5	1.38	1.26	1.14	.96	2	1.84	1.68	1.52	1.28
300	2.25	2.07	1.89	1.71	1.44	3	2.76	2.52	2.28	1.92
400	3	2.76	2.52	2.28	1.92	4	3.68	3.36	3.04	2.56
500	3.75	3.45	3.15	2.85	2.4	5	4.6	4.2	3.8	3.20
600	4.5	4.14	3.78	3.42	2.88	6	5.52	5.04	4.56	3.84
700	5.25	4.83	4.41	3.99	3.36	7	6.44	5.88	5.32	4.48
800	6	5.52	5.04	4.56	3.84	8	7.36	6.72	6.08	5.12
900	6.75	6.21	5.67	5.13	4.32	9	8.28	7.56	6.84	5.76
1000	7.5	6.9	6.3	5.70	4.8	10	9.2	8.4	7.6	6.4
1100	8.25	7.59	6.93	6.27	5.28	11	10.12	9.24	8.36	7.04
1200	9	8.28	7.56	6.84	5.76	12	11.04	10.08	9.12	7.68
1300	9.75	8.97	8.19	7.41	6.24	13	11.96	10.92	9.88	8.32
1400	10.5	9.66	8.82	7.98	6.72	14	12.88	11.76	10.64	8.96
1500	11.25	10.35	9.45	8.55	7.2	15	13.8	12.6	11.4	9.6
1600	12	11.04	10.08	9.12	7.68	16	14.72	13.44	12.16	10.24
1700	12.75	11.73	10.71	9.69	8.16	17	15.64	14.28	12.92	10.88
1800	13.5	12.42	11.34	10.26	8.64	18	16.56	15.12	13.68	11.52
1900	14.25	13.11	11.97	10.83	9.12	19	17.48	15.96	14.44	12.16
2000	15	13.08	12.6	11.4	9.6	20	18.4	16.8	15.2	12.8
2100	15.75	14.49	13.23	11.97	10.08	21	19.32	17.64	15.96	13.44
2200	16.5	15.18	13.86	12.54	10.56	22	20.24	18.48	16.72	14.08
2300	17.25	15.87	14.49	13.11	11.04	23	21.16	19.32	17.48	14.72
2400	18	16.56	15.12	13.68	11.52	24	22.08	20.16	18.24	15.36
2500	18.75	17.25	15.75	14.25	12	25	23	21	19	16
2600	19.5	17.94	16.38	14.82	12.48	26	23.92	21.84	19.76	16.64
2700	20.25	18.63	17.01	15.39	12.96	27	24.84	22.68	20.52	17.28
2800	21	19.32	17.64	15.96	13.44	28	25.76	23.52	21.28	17.92
2900	21.75	20.01	18.27	16.53	13.92	29	26.68	24.36	22.04	18.56
3000	22.5	20.7	18.90	17.1	14.4	30	27.6	25.2	22.8	19.2
3100	23.25	21.39	19.53	17.67	14.88	31	28.52	26.04	23.56	19.84
3200	24	22.08	20.16	18.24	15.36	32	29.44	26.88	24.32	20.48
3300	24.75	22.77	20.79	18.81	15.84	33	30.36	27.72	25.08	21.12
3400	25.5	23.46	21.42	19.38	16.32	34	31.28	28.56	25.84	21.76
3500	26.25	24.15	22.05	19.95	16.8	35	32.2	29.4	26.6	22.4
3600	27	24.84	22.68	20.52	17.28	36	33.12	30.24	27.56	23.04
3700	27.75	25.53	23.31	21.09	17.76	37	34.04	31.08	28.12	23.68
3800	28.5	26.22	23.94	21.66	18.24	38	34.96	31.92	28.88	24.32
3900	29.25	26.91	24.57	22.23	18.72	39	35.88	32.76	29.64	24.96
4000	30	27.6	25.2	22.8	19.2	40	36.8	33.6	30.4	25.6
4200	31.5	28.98	26.46	23.94	20.16	42	38.64	35.28	31.92	26.88
4400	33	30.36	27.72	25.08	21.12	44	40.48	36.96	33.44	28.16
4600	34.5	31.74	28.98	26.22	22.08	46	42.32	38.64	34.96	29.44
4800	36	33.12	30.24	27.36	23.04	48	44.16	40.32	36.48	30.72
5000	37.5	34.5	31.5	28.5	24	50	46	42	38	32
5400	40.5	37.26	34.02	30.78	25.92	54	49.68	45.36	41.04	34.56
5800	43.5	40.02	36.54	33.06	27.84	58	53.36	48.72	44.08	37.02
6200	46.5	42.78	39.06	35.34	29.76	62	57.06	52.08	47.12	39.58

Velocity in feet per Minute.	10-inch Belt.					12-inch Belt.				
	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°
100	1.25	1.15	1.05	.95	.8	1.5	1.38	1.26	1.14	.96
200	2.5	2.3	2.1	1.9	1.6	3	2.76	2.52	2.28	1.92
300	3.75	3.45	3.15	2.85	2.4	4.5	4.14	3.78	3.42	2.88
400	5	4.6	4.2	3.8	3.2	6	5.52	5.04	4.56	3.84
500	6.25	5.75	5.25	4.75	4	7.5	6.9	6.3	5.7	4.8
600	7.5	6.9	6.3	5.7	4.8	9	8.28	7.56	6.84	5.76
700	8.75	8.05	7.35	6.65	5.6	10.5	9.66	8.82	7.98	6.72
800	10	9.2	8.4	7.6	6.4	12	11.04	10.08	9.12	7.68
900	11.25	10.35	9.45	8.55	7.2	13.5	12.42	11.34	10.26	8.64
1000	12.5	11.5	10.5	9.5	8	15	13.8	12.6	11.4	9.6
1100	13.75	12.65	11.55	10.45	8.8	16.5	15.18	13.86	12.54	10.56
1200	15	13.8	12.6	11.4	9.6	18	16.56	15.12	13.68	11.52
1300	16.25	14.95	13.65	12.35	10.4	19.5	17.94	16.38	14.82	12.48
1400	17.5	16.1	14.7	13.3	11.2	21	19.32	17.64	15.96	13.44
1500	18.75	17.25	15.75	14.25	12	22.5	20.7	18.9	17.1	14.4
1600	20	18.4	16.8	15.2	12.8	24	22.08	20.16	18.24	15.36
1700	21.25	19.55	17.85	16.15	13.6	25.5	23.46	21.42	19.38	16.32
1800	22.5	20.7	18.9	17.2	14.4	27	24.84	22.68	20.52	17.28
1900	23.75	21.85	19.95	18.05	15.2	28.5	26.22	23.94	21.66	18.24
2000	25	23	21	19	16	30	27.6	25.2	22.8	19.2
2100	26.25	24.15	22.05	19.95	16.8	31.5	28.98	26.46	23.94	20.16
2200	27.5	25.3	23.1	20.9	17.6	33	30.36	27.72	25.08	21.12
2300	28.75	26.45	24.15	21.85	18.4	34.5	31.74	28.98	26.22	22.08
2400	30	27.6	25.2	22.8	19.2	36	33.12	30.24	27.36	23.04
2500	31.25	28.75	26.25	23.75	20	37.5	34.5	31.5	28.5	24
2600	32.5	29.9	27.3	24.7	20.8	39	35.88	32.76	29.64	24.96
2700	33.75	31.05	28.35	25.65	21.6	40.5	37.26	34.02	30.78	25.92
2800	35	32.2	29.4	26.6	22.4	42	38.64	35.28	31.92	26.88
2900	36.25	33.35	30.45	27.55	23.2	43.5	40.02	36.54	33.06	27.84
3000	37.5	34.5	31.5	28.5	24	45	41.4	37.8	34.2	28.8
3100	38.75	35.65	32.55	29.45	24.8	46.5	42.78	39.06	35.34	29.76
3200	40	36.8	33.6	30.4	25.6	48	44.16	40.32	36.48	30.72
3300	41.25	37.95	34.65	31.15	26.4	49.5	45.54	41.58	37.62	31.68
3400	42.5	39.1	35.7	32.3	27.2	51	46.92	42.84	38.76	32.64
3500	43.75	40.25	36.75	33.25	28	52.5	48.3	44.1	39.9	33.6
3600	45	41.4	37.8	34.2	28.8	54	49.68	45.36	41.04	34.56
3700	46.25	42.55	38.85	35.15	29.6	55.5	51.06	46.62	42.18	35.52
3800	47.5	43.7	39.9	36.1	30.4	57	52.44	47.88	43.32	36.48
3900	48.75	44.85	40.95	37.05	31.2	58.5	53.82	49.14	44.46	37.44
4000	50	46	42	38	32	60	55.2	50.4	45.6	38.4
4200	52.5	48.3	44.1	39.9	33.6	63	57.96	52.92	47.88	40.32
4400	55	50.6	46.2	41.8	35.2	66	60.72	55.44	50.16	42.24
4600	57.5	52.9	48.3	43.7	36.8	69	63.48	57.96	52.44	44.16
4800	60	55.2	50.4	45.6	38.4	72	66.24	60.48	54.72	46.08
5000	62.5	57.5	52.5	47.5	40	75	69	63	57	48
5400	67.5	62.1	56.7	51.3	43.2	81	74.52	68.04	61.56	51.84
5800	72.5	66.7	60.9	55.1	46.4	87	80.04	73.08	66.12	55.68
6200	77.5	71.3	65.1	58.9	49.6	93	85.56	78.12	70.68	59.52

Velocity in feet per Minute.	14-inch Belt.					16-inch Belt.				
	1-2 or 180°.	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°
100	1.75	1.61	1.47	1.33	1.22	2	1.84	1.68	1.52	1.28
200	3.5	3.22	2.94	2.66	2.44	4	3.68	3.36	3.04	2.56
300	5.25	4.83	4.41	3.99	3.66	6	5.52	5.04	4.56	3.84
400	7	6.44	5.88	5.32	4.88	8	7.36	6.72	6.08	5.12
500	8.75	8.05	7.35	6.65	6.1	10	9.2	8.4	7.6	6.4
600	10.5	9.66	8.82	7.98	7.32	12	11.04	10.08	9.12	7.68
700	12.25	11.27	10.29	9.31	8.54	14	12.88	11.76	10.64	8.96
800	14	12.88	11.76	10.64	9.76	16	14.72	13.44	12.16	10.24
900	15.75	14.49	13.23	11.97	10.98	18	16.56	15.12	13.68	11.52
1000	17.5	16.1	14.7	13.3	12.2	20	18.4	16.8	15.2	12.8
1100	19.25	17.71	16.17	14.63	13.42	22	20.24	18.48	16.72	14.08
1200	21	19.32	17.64	15.96	14.64	24	22.08	20.16	18.24	15.36
1300	22.75	20.93	19.11	17.29	15.86	26	23.92	21.84	19.76	16.64
1400	24.5	22.54	20.58	18.62	17.08	28	25.76	23.52	21.28	17.92
1500	26.25	24.15	22.05	19.95	18.3	30	27.6	25.2	22.8	19.2
1600	28	25.76	23.52	21.28	19.52	32	29.44	26.88	24.32	20.48
1700	29.75	27.37	24.99	22.61	20.74	34	31.28	28.56	25.84	21.76
1800	31.5	28.98	26.46	23.94	21.96	36	33.12	30.24	27.36	23.04
1900	33.25	30.59	27.93	25.27	23.18	38	34.96	31.92	28.88	24.32
2000	35	32.20	29.4	26.6	24.4	40	36.8	33.6	30.4	25.6
2100	36.75	33.81	30.87	27.93	25.62	42	38.64	35.28	31.92	26.88
2200	38.5	35.42	32.34	29.26	26.84	44	40.48	36.96	33.44	28.16
2300	40.25	37.02	33.81	30.59	28.06	46	42.32	38.64	34.96	29.44
2400	42	38.64	35.28	31.92	29.28	48	44.16	40.32	36.48	30.72
2500	43.75	40.25	36.75	33.25	30.5	50	46.	42	38	32
2600	45.5	41.86	38.22	34.58	31.72	52	47.84	43.68	39.52	33.28
2700	47.25	43.47	39.69	35.91	32.94	54	49.68	45.36	41.04	34.56
2800	49	45.08	41.16	37.24	34.16	56	51.52	47.04	42.56	35.84
2900	50.75	46.69	42.63	38.57	32.38	58	53.36	48.72	44.08	37.12
3000	52.5	48.3	44.1	39.9	36.6	60	55.2	50.4	45.6	38.4
3100	54.25	49.91	45.57	41.23	37.82	62	57.04	52.08	47.12	39.68
3200	56	51.52	47.04	42.56	39.04	64	98.88	53.76	48.64	40.96
3300	57.75	53.13	48.51	43.89	40.26	66	60.72	55.44	50.16	42.24
3400	59.5	54.74	49.98	45.22	41.48	68	62.56	57.12	51.68	43.52
3500	61.25	56.35	51.45	46.55	42.7	70	64.4	58.8	53.2	44.8
3600	63	57.96	52.92	47.88	43.92	72	66.24	60.48	54.72	46.08
3700	64.75	59.57	54.39	49.21	45.14	74	68.08	62.16	56.24	47.36
3800	66.5	61.18	55.86	50.54	46.36	76	69.92	63.84	57.76	48.64
3900	08.25	62.79	57.33	51.87	47.58	78	71.76	65.52	59.18	49.92
4000	70	64.4	58.8	53.2	48.8	80	73.6	67.2	60.8	51.2
4200	73.5	67.62	61.74	55.86	51.24	84	77.28	70.56	63.84	53.76
4400	77	70.84	64.68	58.22	53.68	88	80.96	73.92	66.88	56.32
4600	80.5	74.06	67.42	61.18	56.12	92	84.64	77.28	69.92	58.88
4800	84	77.28	70.56	63.84	58.56	96	88.32	80.64	72.96	61.44
5000	87.5	80.5	73.5	66.5	61	100	92	84	76	64
5400	94.5	86.84	79.38	71.82	65.88	108	99.36	90.72	82.08	69.12
5800	101.5	93.38	85.16	77.14	70.76	116	106.72	97.44	88.16	74.32
6200	108.5	96.82	91.14	82.46	75.64	124	114.08	104.16	94.24	79.36

Velocity in feet per Minute.	18-inch Belt.					20-inch Belt.				
	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°
100	2.25	2.07	1.89	1.71	1.44	2.5	2.3	2.1	1.9	1.6
200	4.5	4.14	3.78	3.42	2.88	5	4.6	4.2	3.8	3.2
300	6.75	6.21	5.67	5.13	4.32	7.5	6.9	6.3	5.7	4.8
400	9	8.28	7.56	6.84	5.76	10	9.2	8.4	7.6	6.4
500	11.25	10.35	9.45	8.55	7.2	12.5	11.5	10.5	9.5	8
600	13.5	12.42	11.34	10.26	8.64	15	13.8	12.6	11.4	9.6
700	15.75	14.49	13.23	11.97	10.08	17.5	16.1	14.7	13.3	11.2
800	18	16.56	15.12	13.68	11.52	20	18.4	16.8	15.2	12.8
900	20.25	18.63	17.01	15.39	12.96	22.5	20.7	18.9	17.1	14.4
1000	22.5	20.7	18.9	17.1	14.4	25	23	21	19	16
1100	24.75	22.77	20.79	18.81	15.84	27.5	25.3	23.1	20.9	17.6
1200	27	24.84	22.68	20.52	17.28	30	27.6	25.2	22.8	19.2
1300	29.25	26.91	24.57	22.23	18.72	32.5	29.9	27.3	24.7	20.8
1400	31.5	28.98	26.46	23.94	20.16	35	32.2	29.4	26.6	22.4
1500	33.75	31.05	28.35	25.65	21.6	37.5	34.5	31.5	28.5	24
1600	36	33.12	30.24	27.36	23.04	40	36.8	33.6	30.4	25.6
1700	38.25	35.19	32.13	29.07	24.48	42.5	39.1	35.7	32.3	27.2
1800	40.5	37.26	34.02	30.78	25.92	45	41.4	37.8	34.2	28.8
1900	42.75	39.33	35.91	32.49	27.36	47.5	43.7	39.9	36.1	30.4
2000	45	41.4	37.8	34.2	28.8	50	46	42	38	32
2100	47.25	43.47	39.69	35.91	30.24	52.5	48.3	44.1	39.9	33.6
2200	49.5	45.54	41.58	37.62	31.68	55	50.6	46.2	41.8	35.2
2300	51.75	47.61	43.47	39.33	33.12	57.5	52.9	48.3	43.7	36.8
2400	54	49.68	45.36	41.04	34.56	60	55.2	50.4	45.6	38.4
2500	56.25	51.75	47.25	42.75	36	62.5	57.5	52.5	47.5	40
2600	57.5	53.82	49.14	44.46	37.44	66	59.8	54.6	49.4	41.6
2700	60.75	55.89	51.03	46.17	38.88	67.5	62.1	56.7	51.3	43.2
2800	63	57.96	52.92	47.88	40.32	70	64.4	58.8	53.2	44.8
2900	65.25	60.03	54.81	49.59	41.76	72.5	66.7	60.9	55.1	46.4
3000	67.5	62.1	56.7	51.3	43.2	75	69	63	57	48
3100	69.75	64.17	58.59	53.01	44.64	77.5	71.3	65.1	58.9	49.6
3200	72	66.24	60.48	54.72	46.08	80	73.2	67.2	60.8	51.2
3300	74.25	68 31	62.37	56.43	47.52	82.5	75.9	69.3	62.7	52.8
3400	76.5	70.38	64.26	58.14	48.96	85	78.2	71.4	64.6	54.4
3500	78.75	72.45	66.15	59.85	50.4	87.5	80.5	73.5	66.5	56
3600	81	74.52	68.04	61.56	51.84	90	82.8	75.6	68.4	57.6
3700	83.25	76.59	69.93	63.27	53.28	92.5	85.1	77.7	70.3	59.2
3800	85.5	78.66	71.82	64.98	54.72	95	87.4	79.8	72.2	60.8
3900	87.75	80.73	73.71	66.69	56.16	97.5	89.7	81.9	74.1	62.4
4000	90	82.8	75.6	68.4	57.6	100	92	84	76	64
4200	94.5	86.94	79.38	71.82	60.48	105.5	96.6	88.2	79.8	67.2
4400	99	91.08	83.16	75.24	63.36	110	100.2	92.4	83.6	70.4
4600	103.5	95.22	86.74	78.66	66.24	115	105.8	96.6	87.4	73.6
4800	108	99.36	90.72	82.08	69.12	120	110.4	100.8	91.2	76.8
5000	112.5	103.5	94.5	85.5	72	125	115	105	95	80
5400	121.5	111.78	102 06	92.34	77.76	135	124.2	113.4	102.6	86.4
5800	130.5	120.06	109.62	99.18	83.52	145	133.4	121.8	110.2	92.8
6200	139.5	128.34	117.18	106.02	89.28	155	142.6	130.2	117.8	99.2

Velocity in feet per Minute.	22-inch Belt.					24-inch Belt.				
	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°
100	2.75	2.53	2.31	2.09	1.76	3	2.76	2.52	2.28	1.92
200	5.5	5.06	4.62	4.18	3.52	6	5.52	5.04	4.56	3.84
300	8.25	7.59	6.93	6.27	5.28	9	8.28	7.56	6.84	5.76
400	11	10.12	9.24	8.36	7.04	12	11.04	10.08	9.12	7.68
500	13.75	12.65	11.55	10.45	8.8	15	13.8	12.6	11.4	9.6
600	16.5	15.18	13.86	12.54	10.56	18	16.56	15.12	13.68	11.52
700	19.25	17.71	16.17	14.63	12.32	21	19.32	17.64	15.96	13.44
800	22	20.24	18.48	16.72	14.08	24	22.08	20.16	18.24	15.36
900	24.75	22.77	20.79	18.81	15.84	27	24.84	22.68	20.52	17.28
1000	27.5	25.3	23.1	20.9	17.6	30	27.6	25.2	22.8	19.2
1100	30.25	27.83	25.41	22.99	19.36	33	30.36	27.72	25.08	21.12
1200	33	30.36	27.72	25.08	21.12	36	33.12	30.24	27.36	23.04
1300	35.75	32.89	30.03	27.17	22.88	39	35.88	32.76	29.64	24.96
1400	38.5	35.42	32.34	29.26	24.64	42	38.64	35.28	31.92	26.88
1500	41.25	37.95	34.65	33.35	26.4	45	41.4	37.8	34.2	28.8
1600	44	40.48	36.96	33.44	28.16	48	44.16	40.32	36.48	30.72
1700	46.75	43.01	39.27	35.53	29.92	51	46.92	42.84	38.76	32.64
1800	49.5	45.54	41.58	37.62	31.68	54	49.68	45.36	41.04	34.56
1900	52.25	48.07	43.89	39.71	33.44	57	52.4	47.88	43.32	36.48
2000	55	50.6	46.2	41.8	35.2	60	55.52	50.4	45.6	38.4
2100	57.75	53.13	48.5	43.89	36.96	63	57.96	52.92	47.88	40.32
2200	60.5	55.66	50.82	45.98	38.72	66	60.72	55.44	50.16	42.24
2300	63.25	58.19	53.13	48.07	40.48	69	63.48	57.96	52.44	44.16
2400	66	60.72	55.44	50.16	42.24	72	66.24	60.48	54.72	46.08
2500	68.75	63.25	57.75	52.25	44	75	69	63	57	48
2600	71.5	65.78	60.06	54.34	45.76	78	71.76	65.52	59.28	49.92
2700	74.25	68.31	62.37	56.43	47.52	81	74.52	68.04	61.56	51.84
2800	77	70.84	64.68	58.52	49.28	84	77.28	70.56	63.84	53.76
2900	79.75	73.37	66.99	60.61	51.04	87	80.04	73.08	66.12	55.68
3000	82.5	75.9	69.3	62.7	52.8	90	82.8	75.6	68.4	57.6
3100	85.25	78.43	71.61	64.79	54.56	93	85.56	78.12	70.68	59.52
3200	88	80.96	73.92	66.88	56.32	96	88.32	80.64	72.96	61.44
3300	90.75	83.49	76.23	68.97	58.08	99	91.08	83.16	75.24	63.36
3400	93.5	86.02	78.54	71.06	59.84	102	93.84	85.68	77.52	65.28
3500	96.25	88.55	80.85	73.15	61.6	105	96.6	88.2	79.8	67.2
3600	99	91.08	83.16	75.24	63.36	108	99.36	90.72	82.08	69.12
3700	101.75	93.61	85.47	77.33	65.12	111	102.12	93.24	84.36	71.04
3800	104.5	96.14	87.78	79.42	66.88	114	104.88	95.76	86.64	72.96
3900	107.25	98.67	90.09	81.51	68.64	117	107.64	98.28	88.92	74.88
4000	110	101.2	92.4	83.6	70.4	120	110.4	100.8	91.1	76.8
4200	115.5	106.26	97.02	87.78	73.92	126	115.92	105.84	95.16	80.64
4400	121	111.32	101.64	91.96	77.44	132	121.44	110.88	100.32	84.48
4600	126.5	116.38	106.26	96.14	80.96	138	126.96	115.92	104.88	88.32
4800	132	121.44	110.88	100.32	84.48	144	132.48	120.96	109.42	92.16
5000	137.5	126.5	115.5	104.5	88	150	138	126	114	96
5400	148.5	136.62	124.74	112.86	95.04	162	149.04	136.16	123.12	104.68
5800	159.5	144.74	133.98	121.22	102.08	174	160.08	146.32	132.24	112.36
6200	170.5	156.86	143.22	129.58	109.12	186	171.12	156.48	141.36	116.04

Velocity in ft. per Min.	26-inch Belt.					28-inch Belt.				
	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°
100	3.25	2.99	2.73	2.47	2.08	3.5	3.22	2.94	2.66	2.24
200	6.5	5.98	5.46	4.94	4.16	7	6.44	5.88	5.32	4.48
300	9.75	8.97	8.19	7.41	6.24	10.5	9.66	8.82	7.98	6.72
400	13	11.96	10.92	9.88	8.32	14	12.88	11.76	10.64	8.96
500	16.25	14.95	13.65	12.35	10.4	17.5	16.1	14.7	13.3	11.2
600	19.5	17.94	16.38	14.82	12.48	21	19.32	17.64	15.96	13.44
700	22.75	20.93	19.11	17.29	14.56	24.5	22.54	20.58	18.62	15.68
800	26	23.92	21.84	19.76	16.64	28	25.76	23.52	21.28	17.92
900	29.25	26.91	24.57	22.23	18.72	31.5	28.98	26.46	23.94	20.16
1000	32.5	29.9	27.3	24.7	20.8	35	32.2	29.4	26.6	22.4
1100	35.75	32.89	30.03	27.17	22.88	38.5	35.42	32.34	29.26	24.64
1200	39	35.88	32.76	29.64	24.96	42	38.64	35.28	31.92	26.88
1300	42.25	38.87	35.49	32.11	27.04	45.5	41.86	38.22	34.58	29.12
1400	45.5	41.86	38.22	34.58	29.12	49	45.08	41.16	37.24	31.36
1500	48.75	44.85	40.95	37.06	31.2	52.5	48.3	44.1	39.97	33.6
1600	52	47.84	43.68	39.52	33.28	56	51.52	47.04	42.56	35.84
1700	55.25	50.83	46.41	41.99	35.36	59.5	54.74	49.98	45.22	38.08
1800	58.5	53.82	49.14	44.46	37.44	63	57.96	52.92	47.88	40.32
1900	61.75	56.81	51.87	46.93	39.52	66.5	61.18	55.86	50.54	42.56
2000	65	59.8	54.6	49.4	41.6	70	64.4	58.8	53.2	44.8
2100	68.25	62.79	57.33	51.87	43.68	73.5	67.62	61.74	55.86	47.04
2200	71.5	65.78	60.06	54.34	45.76	77	70.84	64.68	58.52	49.28
2300	74.75	68.77	62.79	56.81	47.84	80.5	74.06	67.62	61.18	51.52
2400	78	71.76	65.52	59.28	49.92	84	77.28	70.56	63.84	53.76
2500	81.25	74.75	68.25	61.75	52	87.5	80.5	73.5	66.5	56
2600	84.5	77.74	70.98	64.22	54.08	91	83.72	76.44	69.16	58.24
2700	87.75	80.73	73.71	66.69	56.16	94.5	86.94	79.38	71.82	60.48
2800	90	83.72	76.44	69.16	58.24	98	90.16	82.32	74.58	62.72
2900	93.25	86.71	79.17	71.63	60.32	101.5	93.38	85.26	77.14	64.96
3000	97.5	89.7	81.9	74.1	62.4	105	96.6	88.2	79.8	67.2
3100	100.75	91.69	84.63	76.57	63.48	109.5	99.82	91.14	82.5	69.44
3200	104	95.68	87.36	79.04	66.56	112	103.04	94.08	85.12	71.68
3300	107.25	98.67	90.09	81.51	68.64	115.5	106.26	97.02	87.78	73.92
3400	110.5	101.66	92.82	83.98	70.72	119	109.48	99.96	90.44	76.16
3500	113.75	104.65	95.55	86.45	72.8	122.5	112.7	102.9	93.1	78.4
3600	116	107.64	98.28	89.92	74.88	126	115.92	105.84	95.76	80.64
3700	119.25	110.63	101.01	92.39	76.96	129.5	119.14	108.78	98.42	82.9
3800	123.5	113.62	103.74	93.86	79.04	133	122.36	111.72	101.08	85.14
3900	126.75	116.61	106.47	96.33	81.12	136.5	125.58	114.66	103.74	87.38
4000	130	119.6	109.2	98.8	83.2	140	128.8	117.6	106.4	89.62
4200	136.5	124.58	114.66	103.74	87.36	147	135.24	123.48	111.62	94.08
4400	143	131.56	120.12	108.68	91.52	154	141.68	129.36	117.04	98.56
4600	148.5	137.54	125.58	113.62	95.68	161	148.12	135.24	122.36	103.04
4800	156	143.52	131.04	118.56	99.84	168	154.56	141.12	127.68	107.52
5000	162.5	149.5	136.5	123.5	104	175	161	147	133	112
5400	175.5	161.46	147.42	133.38	112.32	189	173.88	158.76	143.64	120.96
5800	186.5	173.42	158.34	143.26	120.64	203	186.76	170.32	154.28	129.92
6200	201.5	183.58	169.26	153.14	128.92	217	199.64	182.28	164.92	138.88

Velocity in ft. per Min.	30-inch Belt.					82-inch Belt.				
	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°
100	3.75	3.45	3.15	2.85	2.4	4	3.68	3.36	3.04	2.56
200	7.5	6.9	6.3	5.7	4.8	8	7.36	6.72	6.08	5.12
300	11.25	10.35	9.45	8.55	7.2	12	11.04	10.08	9.12	7.68
400	15	13.8	12.6	11.4	9.6	16	14.72	13.44	12.16	10.24
500	18.75	17.25	15.75	14.25	12	20	18.4	16.8	15.2	12.8
600	22.5	20.7	18.9	17.1	14.4	24	22.08	20.16	18.24	15.36
700	26.25	24.15	22.05	19.85	16.8	28	25.76	23.52	21.28	17.92
800	30	27.6	25.2	22.8	19.2	32	26.44	26.88	24.32	20.48
900	33.75	31.05	28.35	25.65	21.6	36	33.12	30.24	27.36	23.04
1000	37.5	34.5	31.5	28.5	24	40	36.8	33.6	30.4	25.6
1100	41.25	37.95	34.65	31.35	26.4	44	40.48	36.96	33.44	28.16
1200	45	41.4	37.8	34.2	28.8	48	44.16	40.32	36.48	30.72
1300	48.75	44.85	40.95	37.05	31.2	52	47.84	43.68	39.52	33.28
1400	52.5	48.3	44.1	39.9	33.6	56	51.52	47.04	42.56	35.84
1500	56.25	51.75	47.25	42.75	36	60	55.2	50.4	45.6	38.4
1600	60	55.2	50.4	45.6	38.4	64	58.88	53.76	48.64	40.96
1700	63.75	58.65	53.55	48.45	40.4	68	62.56	57.12	51.68	43.52
1800	67.5	62.1	56.7	51.3	43.2	72	66.24	60.48	54.72	46.08
1900	71.25	65.55	59.85	54.15	45.6	76	69.92	63.84	57.76	48.64
2000	75	60	63	57	48	80	73.6	67.2	60.8	51.2
2100	78.75	72.45	66.15	59.85	50.4	84	77.28	70.56	63.84	53.76
2200	82.5	75.9	69.3	62.7	52.8	88	80.96	75.92	66.88	56.32
2300	86.25	79.35	72.45	65.55	55.2	92	84.64	77.28	69.92	58.88
2400	90	82.8	75.6	68.4	57.6	96	88.32	80.64	72.96	61.44
2500	93.75	86.25	78.75	71.25	60	100	92	84	76	64
2600	97.5	89.7	81.9	74.1	62.4	104	95.68	87.36	79.04	66.56
2700	101.25	93.15	85.05	76.95	64.8	108	99.36	90.72	82.08	69.12
2800	105	96.6	88.2	79.8	67.2	112	103.04	94.08	85.12	71.68
2900	108.75	100.05	91.35	82.65	69.6	116	106.71	97.44	88.16	74.24
3000	112.5	103.5	94.5	85.5	72	120	110.4	100.8	91.2	76.8
3100	116.25	106.95	97.65	88.35	74.4	124	114.08	104.16	94.26	79.36
3200	120	109.4	100.8	91.2	76.8	128	117.76	107.52	97.28	81.92
3300	123.75	113.85	103.95	94.05	79.2	132	121.44	110.88	100.32	84.48
3400	127.5	117.3	107.1	96.9	81.6	136	123.12	114.24	103.36	82.04
3500	131.25	120.75	110.25	99.75	84	140	128.8	117.6	106.4	89.6
3600	135	124.2	113.4	102.6	86.4	144	132.48	120.96	109.44	92.16
3700	138.75	127.65	116.55	105.45	88.8	148	136.16	124.32	112.48	94.72
3800	142.5	131.1	119.7	108.3	91.2	152	139.84	127.68	115.52	97.28
3900	146.25	134.55	122.85	111.15	93.6	156	143.52	131.04	118.56	99.84
4000	150	138	126.	114	96	160	147.2	134.4	121.6	102.4
4200	157.5	144.9	132.3	119.7	100.8	168	154.56	141.12	127.68	107.52
4400	165	151.8	138.6	125.4	105.6	176	161.92	147.84	133.76	112.64
4600	172.5	158.7	144.9	131.1	110.4	184	169.28	154.56	139.84	117.76
4800	180	165.6	151.2	136.8	115.2	192	176.64	161.28	145.92	122.88
5000	187.5	172.5	157.5	142.5	120	200	184	168	152	128
5400	202.5	186.3	170.1	153.9	129.6	216	198.72	181.44	164.16	138.24
5800	217.5	200.1	182.7	165.3	139.2	232	213.44	194.88	176.32	148.48
6200	232.5	213.9	195.3	176.7	148.8	248	228.16	208.32	188.48	158.72

Velocity in feet per Minute.	34-inch Belt.					36-inch Belt.				
	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°
100	4.25	3.91	3.57	3.23	2.72	4.5	4.14	3.78	3.42	2.88
200	8.5	7.82	7.14	6.46	5.44	9	8.28	7.56	6.84	5.76
300	12.75	11.73	10.71	9.69	8.16	13.5	12.42	11.34	10.26	8.64
400	17	15.64	14.28	12.92	10.88	18	16.56	15.12	13.68	11.52
500	21.25	19.55	17.85	16.15	13.6	22.5	20.7	18.9	17.1	14.4
600	25.5	23.46	21.42	19.38	16.32	27	24.84	22.68	20.52	17.28
700	29.75	27.37	24.99	22.61	19.04	31.5	28.98	26.46	23.94	20.16
800	34	31.28	28.56	25.84	21.76	36	33.12	30.24	27.36	23.04
900	38.25	35.19	32.13	29.07	24.48	40.5	37.26	34.02	30.78	25.92
1000	42.5	39.1	35.70	32.3	27.2	45	41.4	37.8	34.2	28.8
1100	46.75	43.01	39.27	35.53	29.92	49.5	45.54	41.58	37.62	31.68
1200	51	46.92	42.84	38.76	32.64	54	49.68	45.36	41.04	34.56
1300	55.25	50.83	46.41	41.99	35.36	58.5	53.82	49.14	44.46	37.44
1400	59.5	54.74	49.98	45.22	38.08	63	57.96	52.92	47.88	40.32
1500	63.75	58.65	53.55	48.45	40.8	67.5	62.1	56.7	51.3	43.2
1600	68	62.56	57.12	51.68	43.52	72	66.24	60.48	54.72	46.08
1700	72.25	66.47	60.69	54.91	46.24	76.5	70.38	64.26	58.14	48.96
1800	76.5	70.38	64.26	58.14	48.96	81	74.52	68.04	61.56	51.84
1900	80.75	74.29	67.83	61.37	51.68	85.5	78.66	71.82	64.98	54.72
2000	85	78.2	71.4	64.6	54.4	90	82.8	75.6	68.4	57.6
2100	89.25	82.11	74.97	67.83	57.12	94.5	86.94	79.38	71.82	60.48
2200	93.5	86.02	78.54	71.06	59.84	99	91.08	83.16	75.24	63.36
2300	97.75	89.93	82.11	74.29	62.56	103.5	95.22	86.94	78.66	66.24
2400	102	93.84	85.68	77.52	65.28	108	99.36	90.72	82.08	69.12
2500	106.25	97.75	89.25	80.75	68.72	112.5	103.5	94.5	85.5	72
2600	110.5	101.66	92.82	83.98	70.72	117	107.64	98.28	88.92	74.88
2700	114.75	105.57	96.39	87.21	73.44	121.5	111.78	102.06	92.34	77.76
2800	119	109.48	99.96	90.44	76.16	126	115.92	105.84	95.72	80.64
2900	123.25	113.39	103.53	93.67	78.88	130.5	120.06	109.62	99.18	83.52
3000	127.5	117.3	107.1	96.9	81.6	135	124.2	113.4	102.6	86.4
3100	131.75	121.21	110.67	100.13	84.32	139.5	128.34	117.18	106.02	89.28
3200	136	124.12	114.24	103.36	87.04	144	132.48	120.96	109.44	92.16
3300	140.25	129.03	117.81	106.59	89.76	148.5	136.62	124.74	112.86	95.04
3400	144.5	132.94	121.38	109.82	92.48	153	140.76	128.52	116.28	97.92
3500	148.75	136.85	124.95	113.05	95.2	157.5	144.9	132.3	119.7	100.8
3600	153	140.76	128.52	116.28	97.92	162	149.04	136.08	123.12	103.68
3700	157.25	144.67	132.09	119.51	100.64	166.5	153.18	139.86	126.54	106.56
3800	161.5	148.58	135.66	122.74	103.36	171	157.32	143.64	129.96	109.44
3900	165.75	152.49	139.23	125.97	106.08	175.5	161.46	147.42	133.38	112.32
4000	170	156.4	142.8	129.2	108.8	180	165.6	151.2	136.8	115.2
4200	178.5	164.22	149.94	135.66	114.24	189	173.88	158.76	143.64	120.96
4400	187	172.04	157.08	142.12	119.68	198	182.16	166.32	150.48	126.72
4600	195.5	179.86	164.22	148.58	125.12	207	190.44	173.88	157.32	132.48
4800	204	187.68	171.36	155.04	130.56	216	198.72	181.44	164.16	138.24
5000	212.5	195.5	178.5	161.5	136	225	207	189	171	144
5400	229.5	221.14	192.78	174.42	146.88	243	223.56	204.12	184.68	155.52
5800	246.5	236.17	207.06	187.34	157.76	261	240.12	219.24	198.36	167.04
6200	263.5	252.42	221.34	200.26	168.64	279	256.68	234.36	212.04	178.56

Velocity in feet per Minute.	38-inch Belt.					40-inch Belt.				
	1-2 or 180°.	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°
100	4.75	4.37	3.99	3.61	3.04	5	4.6	4.2	3.8	3.2
200	9.5	8.74	7.98	7.22	6.08	10	9.2	8.4	7.6	6.4
300	14.25	13.11	11.97	10.83	9.12	15	13.8	12.6	11.4	9.6
400	19	17.48	15.96	14.44	12.16	20	18.4	16.8	15.2	12.8
500	23.75	21.85	19.95	18.05	15.2	25	23	21	19	16
600	28.5	26.22	23.94	21.66	18.24	30	27.6	25.2	22.8	19.2
700	33.25	30.59	27.93	25.27	21.28	35	32.2	29.4	26.6	22.4
800	38	34.96	31.92	28.38	24.32	40	36.8	33.6	30.4	25.6
900	42.75	39.33	35.91	32.49	27.36	45	41.4	37.8	34.2	28.8
1000	47.5	43.7	39.9	36.1	30.4	50	46	42	38	32
1100	52.25	48.07	43.89	39.71	33.44	55	50.6	46.2	41.8	35.2
1200	57	52.44	47.88	43.32	36.48	60	55.2	50.4	45.6	38.4
1300	61.75	56.81	51.87	46.93	39.52	65	59.8	54.6	49.4	41.6
1400	66.5	61.18	55.86	50.54	42.56	70	64.4	58.8	53.2	44.8
1500	71.25	65.55	59.85	54.15	45.6	75	69	63	57	48
1600	76	69.92	63.84	57.76	48.64	80	73.6	67.2	60.8	51.2
1700	80.75	74.29	67.83	61.37	51.68	85	78.2	71.4	64.6	54.4
1800	85.5	78.66	71.82	64.98	54.72	90	82.8	75.6	68.4	57.6
1900	90.25	83.03	75.81	68.59	57.76	95	87.4	79.8	72.2	60.8
2000	95	87.4	79.8	72.2	60.8	100	92	84	76	64
2100	99.75	91.77	83.79	75.81	63.84	105	96.6	88.2	79.8	67.2
2200	104.5	96.14	87.78	79.42	66.88	110	101.2	92.4	83.6	70.4
2300	109.25	100.51	91.77	83.03	69.92	115	105.8	96.6	87.4	73.6
2400	114	104.88	95.76	86.64	72.96	120	110.4	100.8	91.2	76.8
2500	118.75	109.25	99.75	90.25	76	125	115	105	95	80
2600	123.5	113.62	103.74	93.86	79.04	130	119.6	109.2	98.8	83.2
2700	128.25	117.99	107.73	97.47	82.08	135	124.2	113.4	102.6	86.4
2800	133	122.36	111.72	101.08	85.12	140	128.8	117.6	106.4	89.6
2900	137.75	126.73	115.71	104.69	88.16	145	133.4	121.8	110.2	92.8
3000	142.5	131.1	119.7	108.3	91.2	150	138	126	114	96
3100	147.25	135.47	123.69	111.91	94.24	155	142.6	130.2	117.8	99.2
3200	152	139.84	127.68	115.52	97.28	160	147.2	134.4	121.6	102.4
3300	156.75	144.21	131.67	119.13	100.32	165	151.8	138.6	125.4	105.6
3400	161.5	148.58	135.66	122.74	103.36	170	156.4	142.8	129.2	108.8
3500	166.25	152.95	139.65	126.35	106.4	175	161	147	133	112
3600	171	157.32	143.64	129.96	109.44	180	165.6	151.2	136.8	115.2
3700	175.75	161.69	147.63	133.57	112.48	185	170.2	155.4	140.6	118.4
3800	180.5	166.06	151.62	137.18	115.52	190	174.8	159.6	144.4	121.6
3900	185.25	170.43	155.61	140.79	118.56	195	179.4	163.8	148.2	124.8
4000	190	174.8	159.6	144.4	121.6	200	184	168	152	128
4200	199.5	183.54	167.58	151.62	127.68	210	193.2	176.4	159.6	134.4
4400	209	192.8	175.56	158.84	133.76	220	202.4	184.8	167.2	140.8
4600	218.5	201.02	183.54	166.06	139.84	230	211.6	193.2	174.8	147.2
4800	228	209.76	191.52	173.28	145.92	240	220.8	201.6	182.4	153.6
5000	237.5	218.5	199.5	180.5	152	250	230	210	190	160
5400	256.5	235.98	215.46	194.94	164.16	270	248.4	226.8	205.2	172.8
5800	275.5	253.46	231.42	209.38	176.32	290	266.8	243.6	220.4	185.6
6200	294.5	270.94	247.38	223.82	188.48	310	285.2	260.4	235.6	198.4

Velocity in ft. per Min.	42-inch Belt.					44-inch Belt.				
	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°
100	5.25	4.83	4.41	3.99	3.36	5.5	5.06	4.62	4.18	3.52
200	10.5	9.66	8.82	7.98	6.72	11	10.12	9.24	8.36	7.04
300	15.75	14.49	13.23	11.97	10.08	16.5	15.18	13.86	12.54	10.56
400	21	19.32	17.64	15.96	13.44	22	20.24	18.48	16.72	14.08
500	26.25	24.15	22.05	19.85	16.8	27.5	25.3	23.1	20.9	17.6
600	31.5	28.98	26.46	23.94	20.16	33	30.36	27.72	25.08	21.12
700	36.75	33.81	30.89	27.93	23.52	38.5	35.42	32.34	29.26	24.64
800	42	38.64	35.28	31.92	26.88	44	40.48	36.96	33.44	28.16
900	47.25	43.47	39.69	35.91	30.24	49.5	45.54	41.58	37.62	31.68
1000	52.5	48.3	44.1	39.9	33.6	55	50.6	46.2	41.8	35.2
1100	57.75	53.13	48.51	43.89	36.96	60.5	55.66	50.82	45.98	38.72
1200	63	57.96	52.92	47.88	40.32	66	60.72	55.44	50.16	42.24
1300	68.25	62.79	57.33	51.87	43.68	71.5	65.78	60.06	54.34	45.76
1400	73.5	67.62	61.74	55.86	47.04	77	70.84	64.68	58.52	49.28
1500	78.75	72.45	66.15	59.85	50.4	82.5	75.9	69.3	62.7	52.8
1600	84	77.28	70.56	63.84	53.76	88	80.96	73.92	66.88	56.32
1700	89.25	82.11	74.97	67.83	57.12	93.5	86.02	78.54	71.06	59.84
1800	94.5	86.94	79.38	71.82	60.48	99	91.08	83.16	75.24	63.36
1900	99.75	91.77	83.79	75.81	63.84	104.5	96.14	87.78	79.42	66.88
2000	105	96.6	88.2	79.8	67.2	110	101.2	92.4	83.6	70.4
2100	110.25	101.43	92.61	83.79	70.56	115.5	106.26	97.02	87.78	73.92
2200	115.5	106.26	97.02	87.78	73.92	121	111.32	101.64	91.96	77.44
2300	120.75	111.09	101.43	91.77	77.28	126.5	116.38	106.26	96.14	80.96
2400	126	115.92	105.84	95.76	80.64	132	121.44	110.88	100.32	84.48
2500	131.25	120.75	110.25	99.75	84	137.5	126.5	115.5	104.5	88
2600	136.5	125.58	114.66	103.74	87.36	143	131.56	120.12	108.68	91.52
2700	141.75	130.41	119.07	107.73	90.72	148.5	136.62	124.74	112.86	95.04
2800	147	135.24	123.48	111.72	94.08	154	141.68	129.36	117.04	98.56
2900	152.25	140.07	127.89	115.71	97.44	159.5	146.74	133.98	121.22	102.08
3000	157.5	144.9	132.3	119.7	100.8	165	151.8	138.6	125.4	105.6
3100	162.75	149.73	136.71	123.69	104.16	170.5	156.86	143.22	129.58	109.12
3200	168	154.56	141.12	127.68	107.52	176	161.92	147.84	133.76	112.64
3300	173.25	159.39	145.53	131.67	110.88	181.5	166.98	152.46	137.94	116.16
3400	178.5	164.22	149.94	135.66	114.24	187	172.04	157.08	142.12	119.68
3500	183.75	169.05	154.35	139.65	117.6	192.5	177.1	161.7	146.3	123.2
3600	189	173.88	158.76	143.64	120.96	198	182.16	166.32	150.48	126.72
3700	194.25	178.71	163.17	147.63	124.32	203.5	187.22	170.94	154.66	130.24
3800	199.5	183.54	167.58	151.62	127.68	209	192.28	175.56	158.84	133.76
3900	204.75	188.37	171.99	155.61	131.94	214.5	197.34	180.18	163.02	137.28
4000	210	193.2	176.4	159.6	134.4	220	202.4	184.8	167.2	140.8
4200	220.5	202.86	185.22	167.58	141.12	231	212.52	194.04	175.56	147.84
4400	231	212.52	194.04	175.56	147.84	242	222.64	203.28	183.92	154.88
4600	241.5	222.18	202.86	183.54	154.56	253	232.76	212.52	192.28	161.92
4800	252	231.84	211.68	191.52	161.28	264	242.88	221.76	200.64	168.96
5000	262.5	241.5	220.5	199.5	168	275	253	231	209	175
5400	283.5	260.82	238.14	215.46	181.44	297	273.24	249.48	221.54	189.08
5800	304.5	280.14	255.78	231.42	194.88	319	293.48	267.96	234.08	203.16
6200	325.5	299.46	273.42	247.38	208.32	341	310.72	286.44	246.62	217.24

Velocity in feet per Minute.	46-inch Belt.					48-inch Belt.				
	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°	1-2 or 180°	7-16 or 157½°	3-8 or 135°	5-16 or 112½°	1-4 or 90°
100	5.75	5.29	4.83	4.37	3.68	6	5.52	5.04	4.56	3.84
200	11.5	10.58	9.66	8.74	7.36	12	11.04	10.08	9.12	7.68
300	17.25	15.87	14.49	13.11	11.04	18	16.56	15.12	13.68	11.52
400	23	21.16	19.32	17.48	14.72	24	22.08	20.16	18.24	15.36
500	28.75	26.45	24.15	21.85	18.4	30	27.6	25.2	22.8	19.2
600	34.5	31.74	28.98	26.22	22.08	36	33.12	30.24	27.36	23.04
700	40.25	37.03	33.81	30.59	25.76	42	38.64	35.28	31.92	26.88
800	46	42.32	38.64	34.96	29.44	48	44.16	40.32	36.48	30.72
900	51.75	47.61	43.47	39.33	33.12	54	49.68	45.36	41.04	34.56
1000	57.5	52.9	48.3	43.7	36.8	60	55.2	50.4	45.6	38.4
1100	63.25	58.19	53.13	48.07	40.48	66	60.72	55.44	50.16	42.24
1200	69	63.48	57.96	52.44	44.16	72	66.24	60.48	54.72	46.08
1300	74.75	68.77	62.79	56.81	47.84	78	71.76	65.52	59.28	49.92
1400	80.5	74.06	67.62	61.18	51.52	84	77.28	70.56	63.84	53.76
1500	86.25	79.35	72.45	65.55	55.2	90	82.8	75.6	68.4	57.6
1600	92	84.66	77.28	69.92	58.88	96	88.32	80.64	72.96	61.44
1700	97.75	89.93	82.11	74.29	62.56	102	93.84	85.68	77.52	65.28
1800	103.5	95.22	86.94	78.66	66.24	108	99.36	90.72	82.08	69.12
1900	109.25	100.51	91.77	83.03	69.92	114	104.88	95.76	86.64	72.96
2000	115	105.8	96.6	87.4	73.6	120	110.4	100.8	91.2	76.8
2100	120.75	111.09	101.43	91.77	77.28	126	115.92	105.84	95.76	80.64
2200	126.5	116.38	106.26	96.14	80.96	132	121.44	110.88	100.32	84.48
2300	132.25	121.67	111.09	100.51	84.64	138	126.96	115.92	104.88	88.32
2400	138	126.96	115.92	104.88	88.32	144	132.48	120.96	109.52	92.16
2500	143.75	132.25	120.75	109.25	92	150	138	126	114	96
2600	149.5	137.54	125.58	113.62	95.68	156	143.52	131.04	118.56	99.84
2700	155.25	142.83	130.41	117.99	99.36	162	149.04	136.08	123.12	103.68
2800	161	148.12	135.24	122.36	103.04	168	154.56	141.12	127.68	107.52
2900	166.75	153.41	140.07	126.73	106.72	174	160.08	146.16	132.24	111.36
3000	172.5	158.7	144.9	131.1	110.4	180	165.6	151.2	136.8	115.2
3100	178.25	162.99	149.73	135.47	114.08	186	171.12	156.24	141.36	119.04
3200	184	169.28	154.56	139.84	117.76	192	176.64	161.28	145.92	122.88
3300	189.75	174.57	159.39	144.21	121.44	198	182.16	166.32	150.48	126.72
3400	195.5	179.86	164.22	148.58	125.12	204	187.68	171.36	155.04	130.56
3500	201.25	185.15	169.05	152.95	128.8	210	193.2	176.4	159.6	134.4
3600	207	190.44	173.88	157.32	132.48	216	198.72	181.44	164.16	138.24
3700	212.75	195.73	178.71	161.69	136.16	222	204.24	186.48	168.72	142.08
3800	218.5	201.02	183.54	166.06	139.84	228	209.76	191.52	173.28	145.92
3900	224.25	206.31	188.37	170.43	143.52	234	215.28	196.56	177.84	149.76
4000	230	211.6	193.2	174.8	147.2	240	220.8	201.6	182.4	153.6
4200	241.5	222.18	202.86	183.54	154.56	252	231.84	211.68	191.52	161.28
4400	253	232.76	212.52	192.28	161.92	264	242.88	221.76	200.64	168.96
4600	264.5	243.34	222.18	201.02	169.28	276	253.92	231.84	209.76	176.64
4800	276	253.92	231.84	209.76	176.64	288	266.96	241.92	218.88	184.32
5000	287.5	265.3	241.5	218.5	184	300	276	252	228	192
5400	310.5	285.66	260.82	235.98	198.72	324	298.08	272.16	246.24	207.36
5800	333.5	306.82	280.14	253.46	213 44	348	320.16	292.32	264.48	222.72
6200	356.5	325.98	299.46	270.94	228.16	372	342.32	312.48	282.72	238.08

ARTICLE XV.

SHAFTING—SOME TABLES FOR DETERMINING THE HORSE-POWER THAT CAN BE TRANSMITTED BY SHAFTING OF DIFFERENT SIZES AND AT DIFFERENT SPEEDS.

In order to the more readily determine the horse-power that can be safely transmitted by different sized shafting, running at different velocities, we have prepared a table by which the millwright can tell at a glance just what he wants. These tables are prepared with the view of resistance to torsion, without reference to transverse strain. To produce results in harmony with the table, the shafting should be well put up, in perfect line, and good bearings at reasonable intervals; and for fast moving shafts, the pulleys and wheels should be well balanced. For prime movers, such as engine crank-shafts, and others, that have to be burdened with heavy wheels, there should be at least one-third added to the strength by having the shaft much heavier in proportion.

Some experimenters with shafting have declared, logically, we think, small shafts are less liable to fracture on account of torsional twist than large ones, for the reason of their greater elasticity, for this reason: that when shafts are used for transmitting power alone, and not required to carry any considerable amount of weight in the way of heavy gearing or pulleys, the sizes given in the table should never be exceeded. We have purposely dropped off the heavy shafting as we advanced in velocity, for the reason that very heavy shafts are not required to run at high rates of speed.

HORSE-POWER OF SHAFTING.

The heavy-faced figures at top of columns indicate the revolutions per minute.

Size Shaft in Inches	5	6	7	8	9	10	11	12	13	14	15	16
1	.125	.15	.175	.2	.225	.25	.275	.3	.325	.35	.375	.4
1⅛	.178	.214	.249	.285	.320	.356	.392	.417	.463	.498	.534	.57
1¼	.244	.293	.341	.39	.439	.488	.537	.586	.634	.683	.732	.781
1⅜	.325	.39	.455	.52	.585	.65	.715	.78	.845	.91	.975	1.04
1½	.422	.506	.581	.675	.759	.844	.928	.901	1.09	1.18	1.26	1.35
1⅝	.536	.643	.75	.857	.964	1.07	1.18	1.29	1.39	1.5	1.6	1.71
1¾	.67	.804	.938	1.07	1.2	1.34	1.47	1.61	1.7	1.88	2.01	2.14
1⅞	.824	.989	1.15	1.31	1.48	1.65	1.81	1.98	2.14	2.32	2.47	2.64
2	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8	3	3.2
2¼	1.42	1.704	1.98	2.27	2.56	2.84	3.12	3.41	3.69	3.98	4.26	4.54
2½	1.95	2.34	2.73	3.12	3.51	3.9	4.29	4.68	5.07	5.46	5.85	6.24
2¾	2.6	3.12	3.64	4.16	4.68	5.2	5.72	6.24	6.76	7.28	7.8	8.32
3	3.375	4.05	4.72	5.4	6.07	6.75	7.42	8.1	8.77	9.45	10.12	10.8
3¼	4.29	5.15	6.01	6.86	7.72	8.58	9.43	10.29	11.15	12.01	12.87	13.73
3½	5.36	6.43	7.5	8.57	9.64	10.72	11.79	12.86	13.94	15.01	16.08	17.15
3¾	6.59	7.91	9.22	10.54	11.8	13.18	14.5	15.81	17.13	18.45	19.77	21.
4	8	9.6	11.21	12.8	14.4	16	17.5	19.2	20.8	22.4	24	25.6
4¼	9.6	11.52	13.44	15.36	17.28	19.2	21.12	23.04	24.96	26.9	28.8	30.72
4½	11.39	13.67	15.94	18.22	20.5	22.78	25.06	27.33	29.61	31.89	34.17	36.45
4¾	13.39	16.07	18.74	21.42	24.1	26.78	29.46	32.13	34.81	37.49	40.17	42.85
5	15.625	18.75	21.87	25	28.12	31.25	34.37	37.5	40.62	43.75	46.87	50.
5½	20.79	24.95	29.11	33.26	37.42	41.58	45.74	49.89	54.05	58.21	62.37	66.53
6	27	32.4	37.8	43.2	48.6	54	59.4	64.8	70.2	75.6	81	86.4
6½	34.32	41.18	48.05	55.91	61.78	68.64	75.5	82.36	89.23	96.1	102.96	109.82
7	42.875	51.44	60	68.6	77.17	85.75	94.32	102.9	111.47	120.15	128.62	137.2
8	64	76.8	89.6	102.4	115.2	128	140.8	153.6	166.4	179.2	192	204.8

HORSE-POWER OF SHAFTING.

The heavy-faced figures at top of columns indicate the revolutions per minute.

Size Shaft in Inches	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**30**	**35**	**40**
1	.425	.45	.475	.5	.525	.55	.575	.6	.625	.75	.875	1
$1\frac{1}{8}$	.606	.641	.676	.71	.748	.783	.818	.854	.89	1.06	1.25	1.42
$1\frac{1}{4}$	.829	.879	.927	.97	1.03	1.07	1.12	1.17	1.22	1.46	1.71	1.95
$1\frac{3}{8}$	1.11	1.17	1.23	1.3	1.36	1.43	1.49	1.56	1.62	1.95	2.27	2.6
$1\frac{1}{2}$	1.43	1.52	1.6	1.69	1.77	1.86	1.94	2.02	2.11	2.53	2.95	3.37
$1\frac{5}{8}$	1.82	1.93	2.03	2.14	2.25	2.36	2.46	2.57	2.68	3.26	3.75	4.28
$1\frac{3}{4}$	2.27	2.41	2.55	2.68	2.81	2.95	3.08	3.22	3.35	4.02	4.69	5.36
$1\frac{7}{8}$	2.8	2.97	3.13	3.3	3.46	3.62	3.79	3.95	4.12	4.94	5.77	6.59
2	3.4	3.6	3.8	4	4.2	4.4	4.6	4.8	5	6	7	8
$2\frac{1}{4}$	4.82	5.11	5.4	5.68	5.96	6.22	6.53	6.82	7.1	8.52	9.94	11.36
$2\frac{1}{2}$	6.63	7.02	7.41	7.8	8.19	8.58	8.97	9.36	9.7	11.7	13.65	15.6
$2\frac{3}{4}$	8.84	9.36	9.88	10.4	10.92	11.44	11.96	12.48	13	15.6	18.2	20.8
3	11.47	12.15	12.82	13.5	14.17	14.85	15.52	16.2	16.87	20.25	23.62	27
$3\frac{1}{4}$	14.58	15.44	16.3	17.16	18.02	18.88	19.73	20.58	21.45	25.74	30.03	34.32
$3\frac{1}{2}$	18.22	19.29	20.37	21.44	22.31	23.58	24.65	25.72	26.8	32.16	37.52	42.88
$3\frac{3}{4}$	22.4	23.72	25.04	26.36	27.68	29.09	30.31	31.62	32.95	39.54	46.13	52.72
4	27.2	28.8	30.4	32	33.6	35.2	36.8	38.4	40	48	56	64
$4\frac{1}{4}$	32.64	34.56	36.48	38.4	40.32	42.24	44.16	46.08	48	57.6	67.2	76.8
$4\frac{1}{2}$	38.72	41	43.28	45.56	47.84	50.2	52.39	54.66	56.95	68.34	79.73	91.12
$4\frac{3}{4}$	45.52	48.2	50.88	53.56	56.24	58.92	61.59	64.26	66.95	80.34	93.73	107.12
5	53.12	56.25	59.37	62.5	65.62	68.75	71.87	75	78.12	93.75	109.37	125
$5\frac{1}{2}$	70.68	74.84	79	83.16	87.32	91.48	95.63	99.78	103.95	124.4	145.53	166.32
6	91.8	97.2	102.6	108	113.4	112.2	124.2	129.6	135	162	189	216
$6\frac{1}{2}$	116.68	123.55	130.42	137.28	144.14	151.01	157.8	164.72	171.6	204	240.24	274.56
7	145.87	154.35	162.92	171.5	180.07	188.65	197.2	205.8	204.36	257.25	300.12	343
8	217.6	230.4	243.2	256	268.8	281.6	294.4	307.2	320	384	448	512

HORSE-POWER OF SHAFTING.

The heavy-faced figures at top of columns indicate the revolutions per minute.

Size Shaft in Inches	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
1	1.12	1.25	1.37	1.5	1.62	1.75	1.87	2	2.12	2.25	2.37	2.5
$1\frac{1}{8}$	1.6	1.78	1.95	2.14	2.31	2.49	2.67	2.8	3.03	3.2	3.38	3.56
$1\frac{1}{4}$	2.19	2.44	2.68	2.93	3.17	3.42	3.66	3.9	4.05	4.39	4.63	4.88
$1\frac{3}{8}$	2.92	3.25	3.57	3.9	4.22	4.55	4.87	5.2	5.52	5.85	6.17	6.51
$1\frac{1}{2}$	3.79	4.22	4.64	5.06	5.48	5.91	6.34	6.75	7.17	7.59	8.02	8.44
$1\frac{5}{8}$	4.82	5.36	5.9	6.43	6.97	7.51	8.04	8.58	9.11	9.64	10.2	10.7
$1\frac{3}{4}$	6.03	6.7	7.36	8.04	8.71	9.38	10.05	10.72	11.39	12	12.73	13.4
$1\frac{7}{8}$	7.42	8.24	9.06	9.88	10.71	11.54	12.36	13.18	14	14.8	15.66	16.5
2	9	10	11	12	13	14	15	16	17	18	19	20
$2\frac{1}{4}$	12.78	14.2	15.62	17.04	18.46	19.88	21.3	22.72	24.14	25.6	26.98	28.4
$2\frac{1}{2}$	17.55	19.5	21.45	23.4	25.35	27.3	29.25	31.2	33.15	35.1	37.05	39
$2\frac{3}{4}$	23.4	26	28.6	31.2	33.8	36.4	39	41.6	44.2	46.8	49.4	52
3	30.37	33.75	37.12	40.5	43.87	47.25	50.62	54	57.37	69.7	64.12	67.5
$3\frac{1}{4}$	38.61	42.9	47.19	51.48	55.72	60.06	64.35	68.64	72.93	77.2	81.31	85.8
$3\frac{1}{2}$	48.24	53.6	58.96	64.32	69.68	75.04	80.4	85.76	91.02	96.4	101.84	107.2
$3\frac{3}{4}$	59.31	65.9	72.49	79.06	85.67	92.26	98.85	105.44	112.03	118.6	125.21	131.8
4	72	80	88	96	104	112	120	128	136	144	152	160
$4\frac{1}{4}$	86.4	96	105.6	115.2	124.8	134.4	144	153.6	163.2	172.8	182.4	192
$4\frac{1}{2}$	102.51	113.9	125.9	136.7	148.07	159.46	170.85	182.2	193.63	205	216.41	227.8
$4\frac{3}{4}$	120.51	133.9	147.22	160.6	174.07	187.46	200.85	214.24	227.63	241	254.41	267.8
5	140.62	156.25	172.87	187.5	203.06	218.75	234.37	250	265.62	281.2	296.87	312.5
$5\frac{1}{2}$	187.11	207.9	228.7	249.5	270.27	291.06	311.85	332.64	353.43	374.2	395.01	415.8
6	243	270	297	324	351	378	405	432	459	486	513	540
$6\frac{1}{2}$	308.88	343.2	377.52	411.8	446.16	480.48	514.8	549.12	583.44	617.8	652.08	686.4
7	385.87	428.75	471.62	514.5	557.37	600.25	643.12	686	728.87	771.7	814.62	857.5
8	576	640	704	768	832	896	960	1024	1088	1152	1216	1280

HORSE-POWER OF SHAFTING.

The heavy-faced figures at top of columns idicates the revolutions per minute.

Size Shaft in Inches	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**	**200**	**210**	**220**
1	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5	5.25	5.5
1⅛	3.92	4.27	4.63	4.98	5.34	5.7	6.06	6.41	6.76	7.1	7.48	7.83
1¼	5.37	5.86	6.34	6.83	7.32	7.81	8.29	8.79	9.27	9.76	10.3	10.7
1⅜	7.15	7.8	8.45	9.1	9.75	10.4	11.1	11.7	12.3	13	13.6	14.3
1½	9.28	10.1	10.9	11.8	12.66	13.5	14.3	15.2	16	16.9	17.7	18.6
1⅝	11.8	12.9	13.9	15	16.08	17.1	18.2	19.3	20.3	21.4	22.5	23.6
1¾	14.7	16.1	17.4	18.8	20.1	21.4	22.7	24.1	25.5	26.8	28.1	29.5
1⅞	18.1	19.8	21.4	23.1	24.72	26.4	28	29.7	31.3	33	34.6	36.2
2	22	24	26	28	30	32	34	36	38	40	42	44
2¼	31.2	34.1	36.9	39.8	42.6	45.4	48.2	51.1	54	56.8	59.6	62.2
2½	42.9	46.8	50.7	54.6	58.5	62.4	66.3	70.2	74.1	78	81.9	85.8
2¾	57.2	62.4	67.6	72.8	78	83.2	88.4	93.6	98.8	104	109.2	114.4
3	74.2	81	87.7	94.5	101.2	108	114.7	121.5	128.2	135	141.7	148.5
3¼	94.3	102.9	111.5	120.1	128.7	137.3	144.8	154.4	163	171.6	180.2	188.8
3½	117.9	128.6	139.4	150.1	160.8	171.5	182.2	192.9	203.7	214.4	225.1	235.8
3¾	145	158.1	171.3	184.5	197.7	210	224	237.2	250.4	263.6	276.8	290.9
4	176	192	208	224	240	256	272	288	304	320	336	352
4¼	211.2	230.4	249.6	269	288	307.2	326.4	345.6	364.8	384	403.2	422.4
4½	250.6	273.3	296.1	318.9	341.7	364.3	387.2	410	432.8	455.6	478.4	502
4¾	294.6	321.3	348.1	374.9	401.7	428.5	455.2	482	508.8	535.6	562.4	589.2
5	345.7	375	406.2	437.5	468.7	500	531.2	562.5	593.7	625	656.2	687.5
5½	457.4	498.9	540.5	582.1	623.7	665.3	706.8	748.4	790	831.6	873.2	914.8
6	594	648	702	756	810	864	918	972	1026	1080	1134	1188
6½	755	823.6	892.3	961	1029.6	1098.2	1166.8	1235.5	1304.2	1372.8	1441.4	1510.1
7	943.2	1029	1114.7	1201.5	1286.2	1372	1458.7	1545.5	1629.2	1715	1800.7	1886.5
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HORSE-POWER OF SHAFTING.

The heavy-faced figures at top of columns indicate the revolutions per minute.

Size Shaft in Inches	**230**	**240**	**250**	**260**	**270**	**280**	**290**	**300**	**310**	**320**	**330**	**340**
1	5.75	6	6.25	6.5	6.75	7	7.25	7.5	7.75	8	8.25	8.5
1⅛	8.18	8.54	8.9	9.3	9.6	9.9	10.3	10.6	10.9	11.4	11.7	12.1
1¼	11.2	11.7	12.2	12.7	13.2	13.6	14.1	14.6	15	15.6	16.1	16.5
1⅜	14.9	15.6	16.2	16.9	17.5	18.2	18.8	19.5	20.1	20.8	21.4	22.2
1½	19.4	20.2	21.1	21.8	22.6	23.6	24.4	25.3	26.1	27	27.8	28.6
1⅝	24.6	25.7	26.8	27.8	28.9	30	31.1	32.1	33.2	34.2	35.4	36.4
1¾	30.8	32.2	33.5	34.8	36.1	37.4	38.8	40.2	41.5	42.8	44.1	45.4
1⅞	37.9	39.5	41.2	42.8	44.4	46.2	47.8	49.4	51	52.8	54.3	56
2	46	48	50	52	54	56	58	60	62	64	66	68
2¼	65.3	68.1	71	73.8	76.6	79.6	82.4	85.2	88	90.8	93.6	96.4
2½	89.7	93.6	97.5	101.4	105.2	109.2	113.1	117	120.9	124.8	128.7	132.6
2¾	119.6	124.8	130	135.2	140.6	145.6	151	156	161.4	166.4	171.6	176.8
3	155.2	162	168.7	175.4	181.9	189	196.6	202.5	209	216	222.6	229.4
3¼	197.3	205.8	214.5	223	231.6	240.2	248.7	257.4	265.9	274.6	282.9	291.6
3½	246.5	257.2	268½	278.8	289.5	300.2	310.7	321.6	332.3	343	353.7	364.4
3¾	303.1	316.2	329.5	342.6	355.8	366.9	384	395.4	408.6	420.8	435	448
4	368	384	400	416	432	448	464	480	496	512	528	544
4¼	441.6	460.8	480	499.2	518.4	538	557.2	576	595.2	614.4	633.6	652.8
4½	523.9	546.6	569.5	592.2	615	637.8	660.6	683.4	706.1	729	751.8	774.4
4¾	615.9	642.6	669.5	696.2	722	749.8	776.6	803.4	829.2	857	883.8	910.4
5	718.7	750	781.2	812.4	844.6	875	906.2	937.5	968.7	1000	1031.1	1062.4
5½	956.3	997.8	1039.5	1081	1122.6	1164.2	1205.8	1247.4	1288.9	1330.6	1372.2	1413.6
6	1242	1296	1350	1404	1458	1512	1566	1620	1674	1728	1782	1836
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HORSE-POWER OF SHAFTING.

The heavy-faced figures at top of columns indicate the revolutions per minute.

Size, Shaft in Inches	**350**	**360**	**370**	**380**	**390**	**400**	**410**	**420**	**430**	**440**	**450**	**460**
1	8.75	9	9.25	9.5	9.75	10	10.25	10.5	10.75	11	11.25	11.5
1⅛	12.4	12.8	13.1	13.5	13.8	14.2	14.5	14.9	15.3	15.6	16	16.3
1¼	17	17.5	18	18.5	19	19.5	20	20.6	21	21.4	21.9	22.4
1⅜	22.7	23.4	24	24.6	25.3	26	26.6	27.2	27.9	28.6	29.2	29.8
1½	29	30.4	31.2	32	32.7	33.7	34.6	35.4	36.2	37.1	37.9	38.8
1⅝	37.5	38.6	39.6	40.6	41.7	42.8	43.9	45	46	47.2	48.2	49.2
1¾	46.9	48.2	49.5	51	52.2	53.6	54.9	56.2	57.6	59.2	60.3	61.6
1⅞	57.5	59.4	60.9	62.6	64.2	65.9	67.5	69.2	70.8	72.4	74.2	75.8
2	70	72	74	76	78	80	82	84	86	88	90	92
2¼	99	102.2	105	108	110.7	113.6	116.4	119.2	121.1	124.4	127.8	130.6
2½	136.5	140.4	144.3	148.2	152.1	156	159.9	163.8	167.7	171.6	175.5	179.4
2¾	182	187.2	192.4	197.6	202.8	208.2	213.2	218.4	223.6	228.8	234	239.2
3	236	243	249.7	256.4	263.1	270	276.7	283.4	290.2	297	303.7	310.4
3¼	300.5	308.8	317.4	326	334.5	343.2	351.7	360.4	368.9	377.6	386.1	394.6
3½	375	385.8	396.6	407.4	418.2	428.8	439.5	450.2	460.9	471.6	482.4	493
3¾	461	474.4	487.6	500.8	513.9	527.2	540.3	553.6	566.7	580.8	593.1	606.2
4	560.5	576	592	608	624	640	656	672	688	704	720	736
4¼	672	691.2	710.4	729.6	748.8	768	787.2	806.4	825.6	844.8	864	883.2
4½	797	820	842.8	865.6	888.3	911.2	933.9	956.8	979.5	1004	1025.1	1047.8
4¾	937	964	990.8	1017.6	1044.3	1071.2	1098.9	1124.8	1151.5	1178.4	1205.1	1231.8
5	1093.5	1125	1156.2	1187.5	1218.7	1250	1281.2	1312.5	1343.7	1375	1406.2	1437.5
5½	1455.5	1496.8	1538.4	1579.9	1621.4	1662.9	1704.3	1745.8	1788.3	1828.8	1870.3	1911.8
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HORSE-POWER OF SHAFTING.

The heavy-faced figures at top of columns indicate the revolutions per minute.

Size Shaft in Inches	**475**	**500**	**525**	**550**	**575**	**600**	**625**	**650**	**675**	**700**	**725**	**750**
1	11.87	12.5	13.12	13.75	14.37	15	15.62	16.25	16.87	17.5	18.12	18.75
$1\frac{1}{8}$	16.9	17.8	18.6	19.5	20.4	21.4	22.2	23.1	24	24.9	25.8	26.7
$1\frac{1}{4}$	23.1	24.4	25.6	26.8	28	29.3	30.5	31.7	32.9	34.2	35.3	36.6
$1\frac{3}{8}$	30.8	32.5	34.1	35.7	37.3	39	40.6	42.2	43.8	45.5	47.1	48.7
$1\frac{1}{2}$	40.1	42.2	44.5	46.4	48.5	50.6	52.7	54.8	56.9	59.1	61.2	63.4
$1\frac{5}{8}$	50.9	53.6	56.2	59	61.6	64.3	67	69.7	72.3	75.1	77.7	80.4
$1\frac{3}{4}$	63.6	67	70.3	73.6	77	80.4	83.7	87.1	90.4	93.8	97.1	100.5
$1\frac{7}{8}$	78.2	82.4	86.5	90.6	94.7	98.8	103	107.1	111.2	115.4	119.4	123.6
2	95	100	105	110	115	120	125	130	135	140	145	150
$2\frac{1}{4}$	134.9	142	149.1	156.2	163.3	170.4	177.5	184.6	191.7	198.8	205.9	213
$2\frac{1}{2}$	185.2	195	204.7	214.5	224.2	234	243.7	253.5	263.2	273	282.7	292.5
$2\frac{3}{4}$	247	260	273	286	299	312	325	338	351	364	377	390
3	320.7	337.5	354.3	371.2	388.1	405	421.8	438.7	455.6	472.5	489.3	506.2
$3\frac{1}{4}$	407.5	429	450.4	471.9	493.3	514.8	536.2	557.2	579.1	600.6	622	643.5
$3\frac{1}{2}$	509.2	536	562.8	589.6	616.4	643.2	670	696.8	723.6	750.4	777.2	804
$3\frac{3}{4}$	626	659	691.8	724.9	751.8	790.6	823.7	856.7	889.6	922.6	955.5	988.5
4	760	800	840	880	920	960	1000	1040	1080	1120	1160	1200
$4\frac{1}{4}$	912	960	1008	1056	1104	1152	1200	1248	1296	1344	1392	1440
$4\frac{1}{2}$	1082	1139	1195.8	1253	1309.8	1367	1423.7	1480.7	1537.6	1594.6	1651.2	1708.5
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HORSE-POWER OF SHAFTING.

The heavy-faced figures at top of columns indicate the revolutions per minute.

Size Shaft in Inches	**775**	**800**	**825**	**850**	**875**	**900**	**950**	**1000**	**1050**	**1100**	**1150**	**1200**
1	19.37	20	20.62	21.25	21.87	22.5	23.75	25	26.25	27.5	28.75	30
$1\frac{1}{8}$	27.5	28.5	29.3	30.3	31.1	32	33.8	35.6	37.4	39.1	40	42.8
$1\frac{1}{4}$	37.8	39	40.2	41.5	42.8	43.9	46.3	48.8	51.2	53.7	56	58.6
$1\frac{3}{8}$	50.3	52	53.6	55.2	56.8	58.5	61.7	65.1	68.2	71.5	74.6	78
$1\frac{1}{2}$	65.4	67.5	69.6	71.7	73.8	75.9	80.2	84.4	89	92.8	97	101.2
$1\frac{5}{8}$	83	85.7	88.4	91.1	93.7	96.4	102	107.2	112.4	118	123.2	128.6
$1\frac{3}{4}$	103.8	107.2	110.5	113.9	117.2	120	127.3	134	140.6	147.2	154	160.8
$1\frac{7}{8}$	127.7	131.8	135.9	140	144.2	148	156.6	164.8	173	181.2	189.4	197.6
2	155	160	165	170	175	180	190	200	210	220	230	240
$2\frac{1}{4}$	220	227.2	234.3	241.4	248.5	255.6	269.8	284	298.2	312.4	326.6	340.8
$2\frac{1}{2}$	302.2	312	321.7	331.5	341.2	351	370.5	390	409.4	427	448.4	468
$2\frac{3}{4}$	403	416	429	442	455	468	494	520	546	572	598	624
3	523.1	540	556.8	573.7	590.5	607	641.2	675	708.6	742.4	776.2	810
$3\frac{1}{4}$	664.9	686.4	707.8	729.3	750.5	772	813.1	858	900	943.8	986.6	1029.6
$3\frac{1}{2}$	830.8	857.6	884.4	910.2	938	964	1018.4	1072	1125.6	1179.2	1232.8	1286.4
$3\frac{3}{4}$	1021.4	1054	1087.3	1120.3	1153	1186	1251.1	1318	1384.9	1451.8	1518.7	1585.6
4	1240	1280	1320	1360	1400	1440	1520	1600	1680	1760	1840	1920
..	......	......	......	......	......	......	......	......	......	......	......	......
..	......	......	......	......	......	......	......	......	......	......	......	......
..	......	......	......	......	......	......	......	......	......	......	......	......
..	......	......	......	......	......	......	......	......	......	......	......	......
..	......	......	......	......	......	......	......	......	......	......	......	......
..	......	......	......	......	......	......	......	......	......	......	......	......
..	......	......	......	......	......	......	......	......	......	......	......	......
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..	......	......	......	......	......	......	......	......	......	......	......	......

HORSE-POWER OF SHAFTING.

The heavy-faced figures on top of columns indicate the revolutions per minute.

Size Shaft in Inches	**1250**	**1300**	**1350**	**1400**	**1450**	**1500**	**1600**	**1700**	**1800**	**1900**	**2000**	**2100**
1	31.25	32.5	33.75	35	36.25	37.5	40	42.5	45	47.5	50	52.5
$1\frac{1}{8}$	44.4	46.2	48	49.8	51.6	53.4	57	60.6	64.1	67.6	71.2	74.8
$1\frac{1}{4}$	61	63.4	65.8	68.4	70.6	73.2	78.1	83	87.8	92.6	97.6	102.4
$1\frac{3}{8}$	81.2	84.4	87.6	91	94.2	97.4	104	110.6	117	123.4	130.2	136.4
$1\frac{1}{2}$	105.4	109.6	113.8	118.2	122.4	126.8	135	143.4	151.8	160.4	168.8	178
$1\frac{5}{8}$	134	139.4	144.6	150.2	155.4	160.8	171.4	182.2	192.8	204	214.4	224.8
$1\frac{3}{4}$	167.4	174.2	180.8	187.6	194.2	201	214.4	227.8	240	254.6	268	281.2
$1\frac{7}{8}$	206	214.2	222.4	230.8	238.8	247.2	263.6	280	296	313.2	329.6	346
2	250	260.	270	280	290	300	320	340	360	380	400	420
$2\frac{1}{4}$	355	369.2	383.4	397.6	411.8	426	454.4	482.8	511.2	539.6	568	596.4
$2\frac{1}{2}$	487.4	507	526.4	546	565.4	585	624	663	702	741	780	818.8
$2\frac{3}{4}$	650	676	702	728	754	780	832	884	936	988	1040	1092
3	843.6	877.4	911.2	945	978.6	1012.4	1080	1147.4	1214	1282.4	1350	1417.2
$3\frac{1}{4}$	1072.4	1114.4	1158.2	1201.2	1244.1	1287	1373	1448	1544	1630	1715	1802
$3\frac{1}{2}$	1340	1393.6	1447.2	1500	1554.2	1608	1715	1822	1929	2087	2144	2251

ARTICLE XVI.

SOME USEFUL RULES AND OTHER INFORMATION OF A SPECIFIC CHARACTER.

The following rules for calculating the sizes, speeds, etc., of pulleys and gear-wheels, and accompanying remarks, will be found useful and instructive:

The diameter and revolutions of first *driver* and last *driven* being given, to find the diameters of pulleys for intermediate shaft.

Rule.—First multiply the revolutions of the *driver* by its diameter; then for the intermediate *driven* pulley, take any diameter, (say one-half the diameter of first *driver*,) and divide the product by it; the quotient gives the revolutions of intermediate pulleys. *Second.* Multiply the revolutions of last *driven* by its diameter and divide the product by the revolutions of intermediate pulleys; the quotient is the diameter of the intermediate driving pulley.

As an example, it will be required to find the diameter of driven pulley on an intermediate counter-shaft for driving a smutter, making 600 revolutions and having an 8-inch pulley; the leading shaft makes 150 revolutions per minute, and has a 24-inch pulley.

The rule says to first multiply the speed of the leading shaft by the diameter of the pulley, which, in this case, is 150 multiplied by 24 equals 3600; then select, by the judgment, a diameter for the driven pulley on the intermediate counter-shaft; in this case, for a trial, the half-diameter of the driver, or 12 inches as the diameter of the driven, which we divide into the result obtained above, thus: 3600 divided by 12 equals 300, the speed of the intermediate shaft and pulley.

The rule says, second, to multiply the speed of the last driven, or in other words, the smutter, by the diameter of the pulley on it, and divide the product by the revolutions of the intermediate shaft, which would be 600 multiplied by 8 divided by 300 equals 16. The last result being the diameter of the second driving pulley. Or, the whole operation is stated and performed simply in this way:

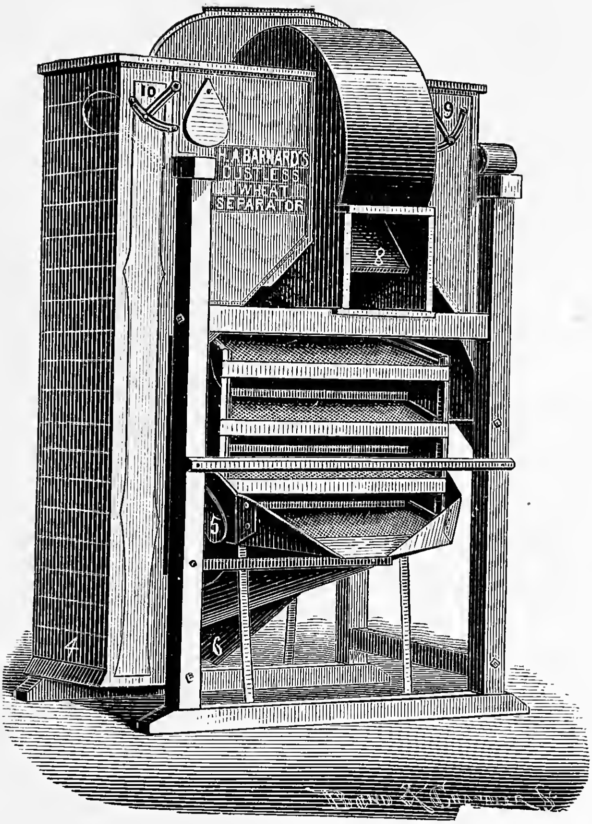
$150 \times 24 \div 12 = 300.$
$600 \times 8 \div 300 = 16.$

```
        150                  600
         24                    8
        ---                 ----
        600     300 ) 4800 ( 16
       300            300
       ----           ----
12 ) 3600 ( 300       1800
                      1800
```

It is not often in practice that a problem of this kind is so easy of solution; the extremes are generally wider apart, as, for instance, it is not uncommon to have to get up speed for a smutter, separator, or other fast running machines, off a shaft making not over sixty revolutions per minute, or even less. In such a case, judgment must be exercised, and care taken not to get too great a disproportion in sizes of pulleys and speeds. It is evident that when the first motion is very slow, the driven pulley on the counter-shaft cannot be half the size of the first driver, otherwise the second driver will be much too large. The chief value of an intermediate shaft is to increase speed gradually and prevent too great a difference between the sizes of drivers and driven.

The proportions can be obtained and maintained exactly by observing the following rule and notes:

Rule.—When it is desired to find the speed of an intermediate shaft, the extreme speeds being given, divide the lower speed into the greater, extract the square root of the product, and either multiply the first speed by it or divide the last speed by it; the result will be the speed of the intermediate shaft required.



BARNARD'S OAT AND WEED EXTRACTOR SEPARATOR.

Made by BARNARD & LEAS MFG. CO., Moline, Ill.

(See Appendix.)

As a test of the rule we will take the previous example. What should be the speed of the counter-shaft, the main driving shaft making 150 revolutions, and the smutter 600? Six hundred divided by 150, results in four times; the square root of four is two; then 150 multiplied by 2, equals 300, or 600 divided by 2 equals 300; the speed of center shaft required and the speed obtained by the other process.

To still further illustrate, we will suppose it necessary to obtain a speed of 1350 by the use of an intermediate shaft from a first mover making 150 revolutions per minute. Thirteen hundred and fifty divided by 150 results in nine times; the square root of nine is three; then 150 multiplied by 3, equals 450, or, 1350 divided by 3, equals 450, the speed of intermediate shaft required. This method, when it can be resolved into an easy problem, simplifies the whole question, because the same root or figure can be used for obtaining the size of pulleys required. To get the diameter of the first driven pulley on the counter-shaft, divide; to get the size of second driver, multiply. Thus, suppose the first driving pulley was forty-eight inches in diameter, and the last driven pulley ten inches in diameter, then 48 divided by 3, equals 16 inches, diameter of first driven, and 10 multiplied by 3, equals 30 inches, diameter of second driver.

The objection to this mode of calculating is that dividing one speed into another, the result in practice is rarely ever even. In such cases obtaining the square root is not so easy. Many of our mechanics are plain, practical men, of great worth, but who, if they did learn anything about extracting roots in their school days, have long since forgotten all about it, and do not care to be bothered with it. Still we would say that in our judgment it would be a great saving to all of them if they would spare time and exercise patience enough to learn how to solve these shafting problems as here indicated. We very earnestly urge this upon young men and apprentices.

The introduction of two intermediate or counter-shafts is sometimes necessary. To get the speeds of these shafts the lesser speed must be divided into the greater as before, and the cube root of this result extracted. By this root the speed of the first driver must be multiplied to get the speed of the first counter-shaft, and the last speed divided by the same figure to get the speed of the second counter; or, the speed of first counter can be multiplied by the root, and the result will be the speed of the second counter.

As an example. Required: to obtain the speed of two intermediate shafts, the speed of the first mover being 50 revolutions per minute, and the last 1350. Thirteen hundred and fifty divided by 50, results in 27. The cube root of 27 is 3; then 50 multiplied by 3 ,equals 150, speed of first counter-shaft; and 1350 divided by 3, equals 450, speed of second counter-shaft. As the speeds are three to one all the way through, so also will the pulleys be three to one; that is to say, each driving pulley will have three times the diameter of its driven.

When three intermediate shafts are used, the one extreme must be divided into the other, as before, and the square root taken twice, or the square root of the square root, when the same mode of multiplying and dividing, as in the other cases, must be followed. It would be well to notice here that in putting up a series of shafts for getting up speed, the pulleys for the first belt should be relatively larger than for the next, or in other words, as the speed increases the pulleys may be relatively smaller. This is done to make the belt on the slower motions travel as fast as possible, as on the speed of the belt its transmitting power depends chiefly. There need not then be so much difference in the width of the belts; although, of course, as the speed increases, the belts *may* be narrowed, or as speed decreases belts *must* be widened in order to produce the desired result.

It is now desired (the speed of the first mover, the number of mover and the size of pulleys being given,) to ascertain the speed of the last mover.

RULE.—Multiply the diameters of all the driving pulleys together, and that product by the speed of the first mover; then multiply the diameters of all the driven pulleys together, and divide the product into the sums of the others.

Example—Required: the speed of the last shaft in a train of four shafts. The speed of the first mover being 150 revolutions per minute, and the size of the first driver 20 inches in diameter, the second 16, and the third 12. The diameter of the first driven is 12 inches, the second 10, and the third 8.

Solution—20 multiplied by 16 multiplied by 12 multiplied by 150, equals 576,000; 16 multiplied by 12 multiplied by 8, equals 960.

```
960 ) 576000 ( 600
      5760
      ----
        00
```

Six hundred, the last result obtained, is the speed of the last shaft required.

To find the number of revolutions a counter-shaft will make, the speed of the driving shaft, the diameter of the driving and driven pulleys being given, the following rule may be adopted:

RULE.—Multiply the number of revolutions of driving shaft by the diameter of the driving pulley, and divide by the diameter of driven pulley.

To obtain the size of driven pulley, the speed of driving shaft and the size of driving pulley being given, the above rule will be changed to read thus:

RULE.—Multiply the velocity of the driving pulley by its diameter, and divide the product by the number of revolutions it is desired the counter-shaft should make, and the result will be the diameter of the driven pulley required.

To ascertain the size of the driving pulley, its speed and the size of driven pulley being known, observe the following rule:

RULE.—Multiply the diameter of driven pulley by the number of revolutions it is desired it should make, and divide the product by the number of revolutions the driver makes; the result will be the diameter of driving pulley required.

Before leaving the question of pulleys, it would be as well to give a few words of advice in reference to the different widths of belts to be used for transmitting power over a series of intermediate shafts. The theory is: if the belt connecting the first mover with the first intermediate shaft, travels but half the number of feet per minute that the belt connecting the intermediate shaft to the machine or a second intermediate shaft, and the relative sizes of the pulleys are the same with both, then the first belt must be twice the width of the second, to produce the same effect; and if all other things are equal and alike, it is true in practice as well as theory. In overlooking this fact, mistakes are invariably made in arranging shafts and belts for driving machines, such as smutters, separators, purifiers, etc. It is too often the case that where a machine requires a five or six.inch belt to drive it, running up to its own speed, that a seven-inch belt is used from the main shaft to the counter, and sometimes moving very slow at that. Now this is out of all proportion and reason. The only proper way to determine the width of belts needed for driving machines is to first determine what width of belt is needed to drive the machine with ease. This is done by ascertaining the speed of the machine and the size of the pulley on it. The circumference of the pulley in feet and fractions thereof must be multiplied by the number of revolutions it makes, which gives the speed of the belt; then the number of degrees of contact that the belt will have with the machine pulley must be ascertained as nearly as possible, and then by reference to the table the width of belt can be selected. Of course, the number of horse-power required to drive the machine must be known. If this information is not furnished by the manufacturer it can be approximated to closely, by most practical mechanics; and in the absence of both a table of approximate horse-powers that will be useful to the uninitiated, will be found a little further on in this article.

After the necessary width of belt is known for driving the machine, that must be taken as a basis for ascertaining the width of preceding belt or belts. If, as we have already said, each set of pulleys bear the same relation in size—that is to say, if the pulley on machine is ten inches in diameter, and its driver twenty, and the diameter of driven pulley on counter-shaft is fifteen inches, and the first driver thirty, and the distance between centers in both cases about the same, then the width of the first belt will be in proportion to the number of feet it travels per minute, taking the speed of the second or machine belt as a basis or unit.

As an example, we will suppose that a smutter, or other machine, requires a belt five inches wide and making 1500 feet per minute to run it, what would be the width of the first belt, making only 1200 feet per minute. To make a simple proportion question of it, we will say, as 1200 is to 1500, so is five inches in width to the width required; or, as

```
1200 : 1500 : : 5
          5
        ----
1200 ) 7500 ( 6.25
       7200
       ----
        3000
        2400
        ----
         6000
         6000
```

This calls for a belt six and a quarter inches wide. A seven-inch belt should be selected, as it is safer to go above than below the calculation. The foregoing example is based on the proportions of speed that we have recommended and shows more reasonable results. But to illustrate the difference between a fair proportion in speeds we will give an example in practice that has come under the author's notice quite recently, and which is but a fair sample of many others that have come up and are coming up continually. The case in view was that of a heavy grading separator, the belt of which was five inches wide and traveled at the rate of about 2,000 feet per minute, while the first belt made only about 700 feet. By the above rule the width of first belt should have been thus:

$$
\begin{array}{l}
700 : 2000 : : 5 \\
5 \\
\hline
700\,)\,10000\,(\,14.28 \\
700 \\
\hline
3000 \\
2800 \\
\hline
2000 \\
1400 \\
\hline
6000 \\
5600 \\
\hline
400
\end{array}
$$

Measured by the same rule fourteen inches at least should have been the width, but instead, it was only eight inches wide. The belt was crossed, which gave it some advantage in having a greater number of degrees of pulley contact, but, after making that allowance, there should have been at least a twelve-inch belt to have made it equal. In this case the belt could not be made to hold until after the pulley had been leathered and the belt made very tight. Such blundering in belting as this frequently occurs, and will until mechanics quit guessing instead of making systematic inquiries as to the requirements of the case. It is true, it may be said that, to some extent, owing to the many variations and different conditions, the whole thing is largely a guess; but even allowing that to be true, it is still better to do systematic and scientific guessing than to be going it "blind" constantly. It would save lots of trouble, vexation and annoyance.

GEARING.

In calculating for teethed gearing, the rules to be used are much the same, except that the number of teeth should be taken instead of the diameter in inches.

As an example. Required: the number of teeth in a pinion on a third mover, to make 75 revolutions, the first mover making 25 revolutions and having on it a driving wheel with 96 teeth, gearing into a pinion with 48 teeth on a second mover, which has a driving wheel with 60 teeth intended to gear into the pinion required.

Rule.—Multiply the number of teeth in the two driving wheels together, and then by the number of revolutions the first mover makes; then multiply the number of teeth in the pinion given by the number of revolutions to be made by the third mover, and then divide the last product into the first.

Thus: 96 × 60 × 25, = 144000.
48 × 75 = 3600.

Or,	96	48	
	60	75	
	5760	240	
	25	336	
	28800	3600)	144000 (40
	11520		14400
	144000		0

The pinion on third mover will require to have forty teeth. The proportions in speed are not carried out so well in this example as they should be, nor as they are recommended where belting is used. It is, of course, not as important with gear wheels as with belts, as there can be no slip or tendency to slip with wheels; but in cases of rapid motion a very small pinion should never be geared into a large wheel, as it wears out with great rapidity; in other words, a high rate of speed should be obtained gradually. A wheel thirty-six inches in diameter gearing into a pinion of six inches, and running the latter from 150 to 200 revolutions per minute, makes it a very severe task for the pinion, and one that it cannot stand very long.

To find the speed of third mover, the number of teeth in drivers, the number of teeth in pinions, and the speed of first mover being given, the following modification of the rule will do.

Rule.—Multiply the number of teeth in the driving wheels and the number of revolutions of first mover together, and then the number of teeth in the pinions together, and then divide the latter into the former.

Example—Required: the speed of a third mover, the speed of the first being 25, the first driving wheel having 96 teeth, the second 60; the first pinion has 48, and the second 40.

Thus: $96 \times 60 \times 25 = 144000.$
$48 \times 40 = 1920.$

Or,

```
   96          48
   60          40
 ----         ----
 5760         1920 ) 144000 ( 75
   25                13440
 ----                -----
28800                 9600
11520                 9600
------
144000
```

Seventy-five revolutions per minute is the speed required.

When it is desired to get the size of the first driver, when its speed and the number of teeth of the other driver and the pinions are given, and the speed of the last mover, this rule will answer:

Rule.—First multiply the number of teeth in the last pinion by its number of revolutions; divide this product by the number of teeth in the driver; the result will be the speed of the second mover; then multiply the last obtained result by the number of teeth in the first pinion, and divide by the number of revolutions made by the first mover.

Example—Required: the number of teeth for a first driving wheel making 25 revolutions, gearing into a pinion with

48 teeth, followed by a second driver with 60 teeth, gearing into a pinion with 40 teeth, and making 75 revolutions.

Thus: $75 \times 40 \div 60 = 50.$
$50 \times 48 \div 25 = 96.$

Or,

```
        75              50
        40              48
      ----             ---
60 ) 3000 ( 50         400
     300               200
     ----             ----
        0      25 ) 2400 ( 96
                    225
                    ---
                    150
                    150
```

The driving-wheel wanted will require to have ninety-six teeth.

Required: the number of teeth in a pinion that is to make 96 revolutions, gearing into a driving wheel with 112 teeth, making 42 revolutions.

Rule.—Multiply the number of teeth in the wheel by the number of revolutions the pinion is to make.

Thus: $112 \times 42 \div 96 = 49.$

Or,

```
          112
           42
          ---
          224
         448
         ----
   96 ) 4704 ( 49
         384
         ----
          864
          864
```

The number of teeth in driving wheel, its speed and the number of teeth in pinion being given, required: the speed of pinion.

Example—A driving wheel has 112 teeth and makes 42 revolutions, gears into a pinion with 49 teeth. What is the speed of pinion?

Rule.—Multiply the number of teeth in driving wheel by its speed and divide by the number of teeth in pinion.

Thus: $112 \times 42 \div 49 = 96.$

Or,

```
      112
       42
      ---
      224
     448
     ----
49 )4704( 96
    441
    ---
     294
     294
```

The few simple rules here given, will, we think, enable the young mechanic to solve most problems in gearing that may be presented. The whole system is simple, and when the principle is understood, but little difficulty is experienced in adapting the rules to any combination of gearing. It is often the case in spur wheels that a number of them gear into each other continuously, as in the case of large bolting chests driven by spur wheels. At first glance it would seem necessary to calculate the whole combination to get at the sizes and speeds of extremes, but this is not so. No matter how many intermediate wheels there may be in a gang of this kind, the first and last bear the same relation to each other in size and speed as though they geared into each other, and should be calculated in that way only.

MISCELLANEOUS.

As has been before stated in this work a quick method of ascertaining the width of an eight-square is to multiply by five and divide by twelve; this rule also applies to the corner strip in a conveyor-box or, anything else of a similar character.

Example—Required: the width of corner strip for a conveyor-box twelve inches in the clear.

$12 \times 5 \div 12 = 5.$

For this purpose the rule may not be mathematically exact, but near enough for practice.

The following approximates of the horse-power necessary to drive the different machines, and other named devices, will be found useful:

A Smutter	cleaning	15	bushels	per hour	2
"	"	30	"	"	2½
"	"	50	"	"	3½
"	"	75	"	"	5
"	"	100	"	"	7
"	"	150	"	"	9
Separators	cleaning	25	"	"	2
"	"	50	"	"	2½
"	"	75	"	"	3
"	"	100	"	"	4
"	"	150	"	"	5
"	"	1000	"	"	7
"	"	1500	"	"	8
Brush machines	cleaning	15	bushels	per hour	3
"	"	30	"	"	4
"	"	50	"	"	5
"	"	75	"	"	6
"	"	100	"	"	8
"	"	150	"	"	10

A four-foot burr making 150 revolutions per minute and grinding 5 to 8 bushels per hour, averages	8
3½-feet burrs	7
3 "	6
2½ "	5
2 "	4

The last named burrs are to have the same proportionate speed and feed. Purifiers, as now built, will require from one to four horse-power, according to size.

A 2-run flour mill should have	30
3 " " "	40
4 " " "	50
5 " " "	60
6 " " "	75
8 " " "	100
10 " " "	125

It is but just to say that many of the best makes of smutters, separators and brush machines do not require the power named above. The table is intended to cover the heaviest running machines made; but where belts are used for driving, it will be well to select a belt adapted to the power named, no matter what kind of machine is used, as it will save trouble with slipping belts.

ARTICLE XVII.

SOME RULES, AND OTHER USEFUL INFORMATION OF A GENERAL CHARACTER, PICKED UP HERE AND THERE.

To find the Circumference of a Cone, or of a Pulley: Multiply the diameter by 3.1416; or as 7 is to 22 so the diameter to the circumference.

To Compute the diameter of a Circle, or of a Pulley: Divide the circumference by 3.1416; or multiply the circumference by .3183; or as 22 is to 7 so is the circumference to the diameter.

To Compute the area of a Circle: Multiply the circumference by one-quarter of the diameter; or multiply the square of the diameter by .7854; or multiply the square of the circumference by .07958; or multiply half the circumference by half the diameter; or multiply the square of half the diameter by 3.1416.

To find the Area of a Right-angled Triangle: Multiply the base by the perpendicular height and half the product will be the area.

To find the Area of a Triangle by the length of its sides: From half the sum of the three sides subtract each side separately; then multiply the half sum and the three remainders continually together, and the square root of the product will be the area.

To find the Length of one side of a Right-angled Triangle, when the Lengths of the other two sides are given. To find the Hypothenuse: Add together the square of the two legs and subtract the square root of that sum. *To find one of the legs:* Subtract the square of the leg, of which the length is known, from the square of the hypothenuse, and the square root of the difference will be the answer.

To find the Solidity of a Cone or Pyramid: Multiply the area of the base by the height and one-half the product will be the content.

To find the Solidity of the Frustrum of a Cone: Divide the difference of the cubes of the diameters of the two ends by the difference of the diameters; this quotient, multiplied by .7854, and again by one-third of the height, will give the solidity.

To find the Solidity of the Frustrum of a Pyramid: Add to the areas of the two ends of the frustrum the square root of their product, and this sum, multiplied by one-half of the height, will give the solidity.

To find the Solidity of a Sphere: Multiply the cube of the diameter by .5236, and the product is the solidity.

How to Compute the Contents of a Hopper: Multiply the length by the breadth, in inches, and this product by one-third of the extreme depth; divide the last product by 2,150, (the number of cubic inches in a bushel), and the quotient thus obtained will be the contents of the hopper in bushels.

The contents of a bin or box with perpendicular sides is found by multiplying the length by the breadth, in inches, and this product by the depth, and divided as above, will give the number of bushel measurement.

The U. S. standard bushel, grain measure, contains 2150.44 cubic inches.

The U. S. standard bushel, grain measure, is 18½ inches diameter, 8 inches depth.

The U. S. standard half bushel, grain measure, is 14 inches diameter, 7 inches depth.

The U. S. standard gallon, liquid measure, contains 231 cubic inches.

USUAL WEIGHT PER BUSHEL OF ARTICLES OF PRODUCE.

Wheat, 60 lbs.; barley, 48 lbs.; flax seed, 56 lbs., timothy, 56 lbs.; corn, shelled, 56 lbs.; in ear, 70 lbs.; corn meal, 50 lbs.; oats, 32 lbs.; clover, 60 lbs.; rye, 56 lbs.; buckwheat, 52 lbs.; dried apples, 24 lbs.; dried peaches, 33 lbs.; coal, 80 lbs.; salt, 50 lbs.

HAY.

10 cubic yards of meadow hay weigh a ton. When the hay is taken out of large or old stacks, 8 and 9 yards will make a ton.

11 to 12 cubic yards of clover, when dry, weigh a ton.

WEIGHTS OF VARIOUS SUBSTANCES.

	Cubic foot in lbs.	Cubic inch in lbs.
Cast iron	450.55	.2607
Wrought iron	486.65	.2816
Steel	489.8	.2834
Copper	555.	.32118
Lead	708.75	.41015
Brass	537.75	.3112
Tin	456.	.263
White Pine	29.56	.0171
Yellow Pine	33.81	.019
White Oak	70	.026
Live Oak	45.2	.040
Salt Water (sea)	64.3	03721
Fresh Water	62.5	.03616
Air	.07529	.....
Steam	.03689	.....

	Pounds.		Pounds.
Loose earth or sand	95	Clay and stones	160
Common soil	124	Cork	15
Strong soil	127	Tallow	59
Clay	135	Brick	125

EXCAVATIONS.

A load equals 1 cubic yard of 27 cubic feet, or 21 even bushels (not heaped).

River sand, 1 ton equals 21 cubic feet.

Pit sand, 1 ton equals 22 cubic feet.

Gravel, coarse, 1 ton equals 23 cubic feet.

Earth, mould, 1 ton equals 33 cubic feet.

An ordinary cart, 6 feet long by 3¼ feet wide and 2⅓ feet deep, will hold 45 cubic feet, or about 2½ tons of earth.

An ordinary earth wagon will hold 1 cubic yard.

An ordinary wheel-barrow holds one-tenth cubic yard.

Day's work of one man: Digging 1,200 superficial square feet, and one foot deep. In estimating depth, the distance below surface lessens the amount, also the solidity of the earth.

MASONRY.

Stone walls are measured by the perch (24¾ cubic feet). Openings less than three feet wide are counted solid, over three feet deducted; but 18 inches are added to the running measure for each jamb built. Arches are counted solid from their spring. Corners of buildings are measured twice. Pillars less than three feet are counted on three sides as lineal, multiplied by fourth side and depth.

It is customary to measure all foundation and dimension stone by the cubic foot, water tables and base courses by lineal feet.

All sills and lintels or ashlars by superficial feet, and no wall less than 18 inches thick.

BRICK WORK.

Is generally measured by 1,000 bricks laid in the wall. In consequence of variatious in size of bricks, no rule for volume of laid brick can be exact. The following scale is a fair average:

7½ common bricks to a superficial foot, 4 inch wall.
15 " " " " " 9 " "
22½ " " " " " 13 " "
30 " " " " " 18 " "
37½ " " " " " 22 " "

Common bricks measure 8 by 4⅛, and 2⅛ inches thick.

Corners are not measured twice as in stone work. Openings over 2 feet square are deducted. Arches are counted from the spring. Ornamental work counted 1½ bricks for 1. Pillars are measured on their face only.

ROOFING.

Slating. A square is 100 superficial feet; thickness of slate ranges about one-quarter inch thick, and weighs $2\frac{1}{2}$ pounds per square foot. The lap of slate should be about 3 inches. The pitch of a slate roof should not be less than 1 inch height to 4 inches length.

Shingles. One bundle of 16-inch size will cover 30 square feet. One bundle of 18-inch will cover 33 square feet, when laid $5\frac{1}{2}$ inches to the weather. Five pounds of 4-penny, or $3\frac{3}{4}$ pounds of 3-penny nails will be required for each 1,000 shingles.

THE ATMOSPHERE.

100 cubic inches of atmospheric air, at the surface of the earth when the barometer is at 30 inches, and at a temperature of 60 degrees, weighs 30.5 grains, being 830.1 times lighter than water.

Specific gravity compared with water, .0012046.

The atmosphere does not extend beyond fifty miles from the earth's surface.

The mean weight of a column of air a foot square, and of an altitude equal to the height of the atmosphere, is equal to 2116.8 pounds, avoirdupois.

It consists of oxygen 20, and nitrogen 80 parts ; and in 10,000 parts there are 4.9 parts of carbonic acid gas.

The main pressure of the atmosphere is usually estimated at .14.7 pounds per square inch.

13.29 cubic feet of air weigh a pound avoirdupois, hence 1 ton of air will occupy 29769.6 cubic feet.

The rate of expansion of air, and all other elastic fluids, for all temperatures, is uniform.

From 32 degrees to 212 degrees they expand from 1000 to 1376, equal to $\frac{1}{479}$ of their bulk for every degree of heat.—*Haswell.*

WATER.

Fresh water — the constitution of it by weight and measure is,

	By Weight.	By Measure.
Oxygen	88.9	1
Hydrogen	11.1	2

One cubic inch at 62 degrees, the barometer at 30 inches, weighs 252.458 grains, and it is 830.1 times heavier than atmospheric air.

A cubic foot weighs 1000 ounces, or $62\frac{1}{2}$ pounds avoirdupois ; a column 1 inch square and 1 foot high weighs .434028 pounds.

It expands $\frac{1}{9}$ of its bulk in freezing, and averages .0002517 or $\frac{1}{395}$ for every degree of heat from 40 degrees to 212 degrees. Maximum density 39.38 degrees.

A gallon of water (U. S. standard) weighs $8\frac{1}{3}$ pounds, and contains 231 cubic inches.

A cubic foot of water weighs 62½ pounds, and contains 1,728 cubic inches, or 7½ gallons.

Doubling the diameter of a pipe increases its capacity four times.

To find the pressure in pounds per square inch of a column of water, multiply the height of a column in feet by .434. (Approximately we generally call every foot elevation equal to one-half pound pressure per square inch.)

To find the capacity of a water cylinder in gallons. Multiplying the area by the length in inches will give the total number of cubic inches; divide this amount by 231 (which is the cubical contents of a gallon in inches), and the product is the capacity in gallons.

STEAM..

Steam, arising from water at the boiling point, is equal to the pressure of the atmosphere, which is 14.706 pounds on the square inch.

Under the pressure of the atmosphere alone, water cannot be heated above the boiling point.

A cubic inch of water, evaporated under the ordinary atmospheric pressure, is converted into 1700 cubic inches of steam, or, in round numbers, 1 cubic foot, and gives a mechanical force equal to the raising of 2200 pounds 1 foot high.

The force of steam is the same at the boiling point of every fluid.

The elasticity of the vapor of spirit of wine, at all temperatures, is equal to 2.125 times that of steam.

The sum of sensible and latent heats is 1202 degrees, and that 140 degrees of sensible heat becomes latent upon the liquefaction of ice; also, that 1 pound of water converted into steam at 212 degrees will heat 25½ pounds of water at 32 degrees to 212 degrees, and that the sum is 6½ pounds of water.

The practical estimate of the velocity of steam, when flowing into a vacuum, is about 1400 feet in a second when at an expansive power equal to the atmosphere; and when at 20 atmospheres, the velocity is increased but to 1600 feet.

When flowing into the air under a similar power, about 650 feet per second, increasing to 1600 feet for a pressure of 20 atmospheres.

Specific gravity of steam at the pressure of the atmosphere .488, air being 1.

27.206 cubic feet of steam at the pressure of the atmosphere, equal 1 pound avoirdupois.

A pressure of 1 pound on a square inch will raise a mercurial steam gauge (syphon) 1.01995 inches.

A column of mercury two inches in height will counterbalance a pressure of .9804 pounds on a square inch.—*Haswell.*

TABLE OF EFFECTS UPON BODIES OF HEAT.

	Deg. Fahr.
Cast iron, thoroughly smelted	2754
Fine gold, melts	1983
Fine silver, melts	1850
Copper, melts	2160
Brass, melts	1900
Red heat, visible all day	1077
Iron, red hot in twilight	884
Zinc, melts	790
Quicksilver, boils	752
Linseed oil, boils	600
Lead, melts	594
Bismuth, melts	476
Tin, melts	421
Tin and bismuth, equal parts, melt	283
Tin three parts, bismuth five, and lead two, melt	212
Alcohol, boils	174
Ether, boils	98
Human blood (heat of)	98
Strong wines, freeze	20
Brandy, freezes	7
Mercury, melts	—39
Greatest cold ever produced	—90
Snow and salt, equal parts	0
Vinous fermentation	60 to 77
Acetous fermentation begins	78
Acetification ends	88
Phosphorous burns	43

HORSES.

A horse travels 400 yards, at a walk, in 4½ minutes; at a trot, in 2 minutes; at a gallop, in 1 minute.

He occupies in the ranks a front of 40 inches, and a depth of 10 feet; in a stall, from 3½ to 4½ feet front; and at picket, 3 feet by 9.

Average weight, 1000 pounds each.

A horse, carrying a soldier and his equipments (say 225 pounds) travels 25 miles in a day (8 hours).

A draught horse can draw 1600 pounds 22 miles a day, weight of carriage included.

The ordinary work of a horse may be stated at 22,500 pounds, raised 1 foot in a minute, for 8 hours a day.

In a horse mill, a horse moves at the rate of 3 feet in a second. The diameter of the track should not be less than 25 feet.

A horse-power in machinery is estimated at 33,000 pounds, raised 1 foot in a minute; but as a horse can exert that force but 6 hours a day, one machinery horse-power is equivalent to that of 4.4 horses.

The expense of conveying goods at 3 miles per hour per horse teams being 1, the expense at 4½ miles will be 1.33, and so on, the expense being doubled when the speed is 5½ miles per hour.

The strength of a horse is equivalent to that of 5 men.

TABLE *of the amount of labor a horse of average strength is capable of performing at different velocities, on canals, railroads, and turnpikes. Force of traction estimated at 83.3 pounds.*

Velocity in miles per hour.	Duration of the day's work.	Useful effect for one day in tons, drawn one mile.		
		On a Canal.	On a Railroad.	On a Turnpike.
$2\frac{1}{2}$	$11\frac{1}{2}$	520	114	14
3	8	243	92	12
$3\frac{1}{2}$	$5\frac{9}{10}$	153	82	10
4	$4\frac{1}{2}$	102	72	9
5	$2\frac{9}{10}$	52	57	7.2
6	2	30	48	6
7	$1\frac{1}{2}$	19	41	5.1
8	$1\frac{1}{8}$	12.8	36	4.5
9	$\frac{9}{10}$	9.0	32	4.0
10	$\frac{3}{4}$	6.6	28.8	3.6

The actual labor performed by horses is greater, but they are injured by it.

NUMBER OF NAILS AND TACKS PER POUND.

NAILS.			TACKS.		
Title.	Size.	No. per lb.	Title.	Length.	No. per lb.
3 penny fine.	$1\frac{1}{8}$ inch.	760	1 oz.	$\frac{1}{8}$ inch	16000
3 " "	$1\frac{1}{4}$ "	480	$1\frac{1}{2}$ "	$\frac{3}{16}$ "	10666
4 " "	$1\frac{1}{2}$ "	300	2 "	$\frac{1}{4}$ "	8000
5 " "	$1\frac{3}{4}$ "	200	$2\frac{1}{2}$ "	$\frac{5}{16}$ "	6400
6 " "	2 "	160	3 "	$\frac{3}{8}$ "	5333
7 " "	$2\frac{1}{4}$ "	128	4 "	$\frac{7}{16}$ "	4000
8 " "	$2\frac{1}{2}$ "	92	6 "	$\frac{9}{16}$ "	2666
9 " "	$2\frac{3}{4}$ "	72	8 "	$\frac{5}{8}$ "	2000
10 " "	3 "	60	10 "	$\frac{11}{16}$ "	1600
12 " "	$3\frac{1}{4}$ "	44	12 "	$\frac{3}{4}$ "	1333
16 " "	$3\frac{1}{2}$ "	32	14 "	$\frac{13}{16}$ "	1143
20 " "	4 "	24	16 "	$\frac{7}{8}$ "	1000
30 " "	$4\frac{1}{2}$ "	18	18 "	$\frac{15}{16}$ "	888
40 " "	5 "	14	20 "	1 "	800
50 " "	$5\frac{1}{2}$ "	12	22 "	$1\frac{1}{16}$ "	727
60 " "	6 "	10	24 "	$1\frac{1}{8}$ "	666
6 " fence	2 "	80			
8 " "	$2\frac{1}{2}$ "	50			
10 " "	3 "	34			
12 " "	$3\frac{1}{4}$ "	29			

TEMPERING STEEL.

Steel in its hardest state being too brittle for most purposes, the requisite strength and elasticity are obtained by tempering—or letting down the temper, as it is termed—which is performed by heating the hardened steel to a certain degree and cooling it quickly. The requisite heat is usually ascertained by the color which the surface of the steel assumes from the film of oxide thus formed. The degrees of heat to which these several colors correspond are as follows:

At 430, a very faint yellow At 450, a pale straw color	Suitable for hard instruments; as hammer faces, drills, etc.
At 470, a full yellow...... At 490, a brown color....	For inst'm'ts requiring hard edges without elasticity; as shears, turning tools, etc.
At 510, brown, with purple spots...............	For tools for cutting wood and soft metals; such as plane-irons, knives, etc.
At 550, dark blue........ At 560, full blue.........	For tools requiring strong edges without extreme hardness; as cold-chisels, axes, cutlery, etc.
At 600, grayish blue, verging on black...........	For spring temper, which will bend before breaking; as saws, sword-blades, etc.

If the steel is heated higher than this, the effect of the hardening process is destroyed.—*Haswell.*

UNITED STATES MEASURES AND WEIGHTS

(According to Act of 1866.)

MEASURES OF LENGTH.

Denominations and Values.		Equivalents in use.
Myriameter..	10.000 meters.	6.2137 miles.
Kilometer...	1.000 meters.	.62137 mile, 3280 feet and 10 inches.
Hectometer.	100 meters.	328 feet and 1 inch.
Dekameter..	10 meters.	393.7 inches.
Meter.......	1 meter.	39.37 inches.
Decimeter..	$\frac{1}{10}$ of a meter.	3.937 inches.
Centimeter..	$\frac{1}{100}$ of a meter.	.3937 inch.
Millimeter...	$\frac{1}{1000}$ of a meter.	.0394 inch.

MEASURES OF SURFACE.

Denominations and Values.		Equivalents in use.
Hectare...............	10 000 square meters.	2.471 acres.
Are....................	100 square meters.	119.6 square yards.
Centare...............	1 square meter.	1550 square inches.

MEASURES OF VOLUME.

Denominations and Values.			Equivalents in use.	
Names.	No. of Litters.	Cubic Measure.	Dry Measure.	Liquid or Wine Measure.
Kiloliter or Stere	1000	1 cubic meter.	1.308 cub. yds.	264.14 gallons
Hectoliter	100	$\frac{1}{10}$ cubic meter.	2 bu. & 3.35 pks.	26.417 gallons
Dekaliter.	10	10 cubic decimeters.	9.08 quarts.	2.6417 gallons
Liter	1	1 cubic decimeter.	.908 quart.	1.0567 quarts.
Deciliter..	$\frac{1}{10}$	$\frac{1}{10}$ cubic decimeter.	6.1022 cubic in.	.845 gill.
Centilliter	$\frac{1}{100}$	10 cubic centimeters.	.6102 cubic in.	.338 fluid oz.
Milliliter..	$\frac{1}{1000}$	1 cubic centimeter.	.061 cubic in.	.28 fluid drm.

WEIGHTS.

Denominations and Values.			Equiv'ts in use.
Names.	No. of Grains.	Weight of Vol. of Water at its Maximum Density.	Avoirdupois Weight.
Millier or Tonneau..	1 000 000	1 cubic meter.	2204.6 pounds.
Quintal..............	100 000	1 hectoliter.	220.46 pounds.
Myriagram	10 000	10 liters.	22.046 pounds.
Kilogram or Kilo....	1 000	1 liter.	2.2046 pounds.
Hectogram	100	1 deciliter.	3.5274 ounces.
Dekagram...........	10	10 cubic centimeters.	.3527 ounce.
Gram................	1	1 cubic centimeter.	15.432 grains.
Decigram	$\frac{1}{10}$	$\frac{1}{10}$ of a cub. centimeter.	1.5432 grains.
Centigram...........	$\frac{1}{100}$	10 cubic millimeters.	.1543 grain.
Milligram	$\frac{1}{1000}$	1 cubic millimeter.	.0154 grain.

MEASURE OF LENGTHS.

The standard of measure is a brass rod, which, at the temperature of 32°, is the standard yard.

LINEAL.

	Inches.	Feet.	Yards.	Rods.	Fur.
12 inches = 1 foot.					
3 feet = 1 yard.	36 =	3.			
5.5 yards = 1 rod.	198 =	16.5 =	5.5.		
40 rods = 1 furlong.	7929 =	660 =	220 =	40.	
8 furlongs = 1 mile.	63360 =	5280 =	1760 =	320 =	8.

The inch is sometimes divided into 3 barley corns or 12 lines.
A hair's breadth is the .02083 (48th part) of an inch.

1 yard is........................ .000568 of a mile.
1 inch is........................ .0000158 of a mile.

GUNTER'S CHAIN.

7.92 inches = 1 link.
100 links = 1 chain, 4 rods, or 22 yards.
80 chains = 1 mile.

ROPES AND CABLES.

6 feet = 1 fathom. | 120 fathoms = 1 cable's length.

GEOGRAPHICAL AND NAUTICAL

1 degree of a great circle of the earth = 69.77 statute miles.
1 mile = 2046.58 yards.

LOG LINES.

Estimating a mile at 6139.75 feet, and using a 30″ glass.
1 knot = 51.1629 feet, or 51 feet 1.95 inches.
1 fathom = 5.11629 feet, or 5 feet 1.395 inches.

If a 28″ glass is used, and 8 divisions, then
1 knot=47 feet 9.024 inches. | 1 fathom=5 feet 11.627 inches.

The line should be about 150 fathoms long, having 10 fathoms between the chip and first knot for stray line.

NOTE—Bowditch gives 6120 feet in a sea mile, which, if taken as the length, with a 28″ glass, will make the divisions 47.6 feet and 5.95 inches.

CLOTH.

1 nail = 2.25 inches = .0625 of a yard.
1 quarter = 4 nails.
5 quarters = 1 ell.

PENDULUMS.

6 points = 1 line | 12 lines = 1 inch.

SHOEMAKERS'.

No. 1 is 4.125 inches in length, and every succeeding number is .333 of an inch.

There are 28 numbers or divisions, in two series of numbers, viz., from 1 to 13, and 1 to 15.

MISCELLANEOUS.

1 palm = 3 inches. | 1 span = 9 inches.
1 hand = 4 inches. | 1 metre = 3.2809 feet.

MEASURE OF TIME.

60 seconds = 1 minute.
60 minutes = 1 degree.
360 degrees = 1 circle

$3600'' = 60' = 1^\circ$.
$1296000'' = 21600' = 360^\circ$.

Sidereal day = 23 h., 56 m., 4.092 sec., in solar or mean time.
Solar day, mean = 24 h., 3 m., 56.555 sec., in sidereal time.
Sidereal year, or revolution of the earth, 365.25635 solar days.
Solar, Equinoctial, or Calendar year, 365.24224 solar days.

1 day = .002739 of a year. | 1 minute = .000694 of a day.
30° = 1 sign.

MEASURE OF SURFACE.

144 square inches = 1 square foot.
9 square feet = 1 square yard.
100 square feet = 1 square (*Architect's measure*).

LAND.

			Yards.	Rods.	Roods.
30.25	square yards	= 1 square rod.	1210.		
40	square rods	= 1 square rood.	4840	= 160.	
4	square roods }	= 1 acre.			
10	square chains }	= 1 acre.			
640	acres	= 1 square mile.	3097600	= 102400	= 2560.

PAPER.

24 sheets = 1 quire | 20 quires = 1 ream.

DRAWING PAPER.

Cap	13 × 16 inches.		Columbia	23 × 33.75 inches.
Demy	15.5 × 18.5 "		Atlas	26 × 33 "
Medium	18 × 22 "		Theorem	28 × 34 "
Royal	19 × 24 "		Doub. Elep't	26 × 40 "
Super-royal	19 × 27 "		Antiquarian	31 × 52 "
Imperial	21.25 × 29 "		Emperor	40 × 60 "
Elephant	22.25 × 27.75 "		Uncle Sam	48 × 120 "

TRACING PAPER.

Double Crown	20×30 inches.		Grand Royal	18×24 inches.
Double D. Crown	30×40 "		Grand Aigle	27×40 "
Doub. D. D. Crown	40×60 "		Vellum Writing, 18 to 28 in. wide.	

MISCELLANEOUS.

1 sheet	= 4 pages.		1 duodecimo	= 24 pages.
1 quarto	= 8 "		1 eighteenmo	= 36 "
1 octavo	= 16 "		1 bundle	= 2 reams.

MEASURES OF VOLUME.

The standard gallon measures 231 cubic inches, and contains 8.3388822 avoirdupois pounds. or 58373 troy grains of distilled water, at the temperature of its maximum density 39°.83, the barometer at 30 inches.

The standard bushel is the Winchester, which contains 2150.42 cubic inches, or 77.627413 pounds avoirdupois of distilled water at its maximum density.

Its dimensions are 18.5 inches diameter inside, 19.5 inches outside, and 8 inches deep; and when heaped, the cone must not be less than 6 inches high, equal 2747.715 cubic inches for a true cone.

LIQUID.

	Gills.	Pints.
4 gills = 1 pint.		
2 pints = 1 quart.	8	
4 quarts = 1 gallon.	32 =	8.

DRY.

	Pints.	Qts.	Gals.
2 pints = 1 quart.			
4 quarts = 1 gallon.	8		
2 gallons = 1 peck.	16 =	8	
4 pecks = 1 bushel.	64 =	32 =	8.

CUBIC.

	Inches.
1728 cubic inches = 1 foot.	
27 cubic feet = 1 yard.	46656.

NOTE—A cubic foot contains 2200 cylindrical inches, 3300 spherical inches, or 1600 conical inches.

FLUID.

	Minims.	Drachms.	Ounces.
60 minims = 1 drachm.			
8 drachms = 1 ounce.	480		
16 ounces = 1 pint.	7680 =	128.	
8 pints = 1 gallon.	61240 =	1024 =	128.

MISCELLANEOUS.

1 cubic foot	7.4805 gallons.
1 bushel	9.30918 gallons.
1 chaldron = 36 bushels, or	57.244 cubic feet.
1 cord of wood	128 cubic feet.
1 perch of stone	24.75 cubic feet.

1 quarter = 8 bushels.	1 load hay or straw = 36 trusses.
1 sack flour = 5 "	1 M quills = 1200 quills.

	Galls.		Galls.
Butt of Sherry	108	Puncheon of Brandy	110 to 120
Pipe of Port	115	Puncheon of Rum	100 to 110
Pipe of Teneriffe	100	Hogshead of Brandy	55 to 60
Butt of Malaga	105	Pipe of Madeira	92
Puncheon Scotch Whis.	110 to 130	Hogshead of claret	46

A hogshead is one-half, a quarter cask is one-fourth, and an octave is one-eighth of a pipe, butt, or Puncheon.

MEASURES OF WEIGHT.

The Standard avoirdupois pound is the weight of 27.7015 cubic inches of distilled water weighed in air, at 39°.83, the barometer at 30 inches.

A cubic inch of such water weighs 252.6937 grains.

AVOIRDUPOIS.

		Drachms.	Ounces.	Pounds.
16 drachms	= 1 ounce.			
16 ounces	= 1 pound.	256.		
112 pounds	= 1 cwt.	28672	= 1792.	
20 cwt.	= 1 ton.	573440	= 35840	= 2240.

1 pound = 14 oz. 11 dwts. 16 grs. troy, or 7000 grains.
1 ounce = 18 dwts. 5.5 grains troy, or 437.5 grains.

TROY.

		Grains.	Dwt.
24 grains	= 1 dwt.		
20 dwt.	= 1 ounce.	480.	
12 ounces	= 1 pound.	5760	= 240.

7000	troy grains	= 1 lb. avoirdupois.
437.5	troy grains	= 1 oz. avoirdupois.
175	troy pounds	= 144 lbs. "
175	troy ounces	= 192 oz. "
1	troy pound	= .822857 lb.
1	avoirdupois pound	= 1.215278 lbs. troy.

APOTHECARIES.

		Grains.	Scrup's.	Drachms.
20 grains	= 1 scruple.			
3 scruples	= 1 drachm	60.		
8 drachms	= 1 ounce.	480	= 24.	
12 ounces	= 1 pound.	5760	= 288	= 96.

45 drops = 1 teaspoonful or a fluid drachm.
2 tablespoonful = 1 ounce.

The pound, ounce, and grain, are the same as in troy weight.

DIAMOND.

1 carat = 4 grains.	16 parts = .8 troy grains.
1 grain = 16 parts.	4 grains = 3.2 "

MISCELLANEOUS.

1 stone.. = 14 lbs.
1 cubic foot of ordinary anthracite coal from 50 to 55 lbs.
1 cubic foot of ordinary bituminous coal from 45 to 55 lbs.
1 cubic foot of Cumberland coal.... = 53 lbs.
1 cubic foot of cannel coal.......... = 50.3 "
1 cubic foot charcoal................ = 18.5 " (hard wood.)
1 cubic foot charcoal................ = 18 " (pine wood.)
1 cord Virginia pine................ = 2700 "
1 cord Southern pine................ = 3300 "

Coals are usually purchased at the conventional rate of 28 bushels (5 pecks) to a ton = 43.56 cubic feet.

A cental is 100 lbs., and an English quarter 480 lbs., or eight bushels of wheat.

Bushel.	Pounds.			
Wheat	60	Cental	$1\frac{2}{3}$	bushels.
Corn (shelled)	56	"	$1\frac{11}{14}$	"
Rye	56	"	$1\frac{11}{14}$	"
Oats	32	"	$3\frac{1}{8}$	"
Buckwheat	52	"	$1\frac{12}{13}$	"
Barley	48	"	$2\frac{1}{12}$	"

MEASURES OF VALUE.

10 mills = 1 cent.	10 dimes = 1 dollar.
10 cents = 1 dime.	10 dollars = 1 eagle.

The standard of gold and silver is 900 parts of pure metal and 100 of alloy in 1000 parts of coin.

The fineness expresses the quantity of pure metal in 1000 parts.

The Remedy of the Mint is, the allowance for deviation from the exact standard fineness and weight of coins.

The nickel cent contains 88 parts of copper and 12 of nickel.

The new bronze cent contains 95 parts of copper and 5 of tin and zinc.

Pure gold 23.22 grains = \$1.00. Hence the value of an ounce is \$20.67 183 +.

Pure silver 371.25 grains = \$1.00. Hence the value of an ounce = \$1.29 29+.

Silver coin of less value than one dollar is issued at the rate of 384 grains to the dollar.

Standard gold, \$18.60 465 + per ounce.
Standard silver, \$1.16 3636 + per ounce.

Double Eagle	= 516 troy grains.	Half Dollar	= 192 troy grains.
Eagle	= 258 "	5 Cent (nickel)	= 77.16 "
Dollar	= 25.8 "	3 Cent	= 30 "
Dollar (silver)	= 412.5 "	Cent (bronze)	= 48 "

The British standards are: Gold, $\frac{22}{24}$ of a pound, equal to 11 parts pure gold and 1 of alloy; Silver, $\frac{222}{240}$ of a pound, equal to 37 parts pure silver and 3 of alloy.

A troy ounce of standard gold is coined into £3 17*s.* 10*d.* 2*f.*, and an ounce of standard silver into 5*s.* 6*d.*

Copper is coined in the proportion of 2 shillings to the pound avoirdupois.

The Remedy of the Mint is,
Gold, 12 grains per lb. in weight; silver, 1 dwt. per lb. in weight.
" $\frac{1}{16}$ of a carat in fineness; " 1 dwt. per lb. in fineness.
Copper, $\frac{1}{40}$ of the weight, both in weight and fineness.

PART SECOND.

NEW PROCESS.

ARTICLE I.

NEW PROCESS MILLING.

There is, in what is called the new process of milling, much to be said that could not be so well introduced in the first part of this work, and hence the reason for dividing it into two parts.

There is, really, in a general way, not so much difference between the old and new process, as the latter is but an outgrowth of the former. The most that can be said is, that the new process is but an improved method, more elaborate in detail; and, consequently, dealing with the two modes in the same treatise, would entail more or less confusion. Of course, we are not now including the roller system of milling, as this mode of reducing is radically different from either of the other two; and, as it is not thoroughly developed or entirely perfected, it will be treated practically alone, and such available information given as the imperfect condition of the method will allow.

New process will here be considered to be what it is generally understood to imply, and that is, the use of all the old methods improved, and such new additions as have been found necessary, to make it a success.

Our new process mill must have its full compliment of burrs, as of old; we do not object to having one or more sets of rolls for crushing middlings or the tailings from the purifiers, or germ ends; we want to reduce or grind as you like with burrs, but with some change in the manner of doing it. Formerly the chief aim of the grinder was to have all, or nearly all, of his burrs running on wheat; he ground to make as few middlings as possible, because middlings flour was not so valuable as the first grind. But now we want to see at least as many runs on middlings as on wheat; more, really, if the greatest state of perfection and the best results are desired. There are, of course, circumstances that have a controlling influence upon this matter, that will be again spoken of; but when the circumstances and conditions are all favorable, then, in contra-distinction to the old method, there should be as many, or more, runs of burrs grinding middlings as grinding wheat. This, to the old-method millers, entirely unacquainted with the new method, is a very curious and incomprehensible part of the process. How it is possible to make middlings enough on one run of stone grinding wheat to keep another run of equal size constantly grinding middlings, is something past their comprehension; and, when it comes to making two runs on wheat keep four going on middlings, it becomes "confusion worse confounded." And, yet, just such things are done. We do not know that two runs even under the most favorable circumstances, could keep four constantly grinding middlings; but we have known it necessary to keep four runs for the purpose of taking care of the middlings made on two runs grinding wheat, and for aught we know to the contrary, they were kept grinding all the time.

It is the manner of grinding more than anything else, that distinguishes the difference between the old and the new mode; or, perhaps, it would be more proper to say, it is that that apparently distinguishes it; because, the most casual observer, if he has any knowledge of milling, can note the difference in the manner of grinding the moment he enters the mill, while few, if any, of the other necessary innovations are discernible except to the eye of the practical expert. Simply observing the new mode of grinding does not throw much light on the manner in which it is done, the effect only is observed, without an opportunity to discern the cause. The old miller might imagine that he could do the same at his own mill, just by properly manipulating the stones, while grinding, but in this he would soon find his mistake, after trial. The stones would not be in proper shape for grinding by the new method. Attention is called to this fact to show that, while apparently the mode of grinding in one case is precisely the same as in the other, actually, there is a great deal of difference. It is true, the burrs are fed in the same way; they revolve in the same way; the chop is discharged in the same way; but when the burrs are taken up and the faces examined, a very remarkable difference is noticeable, and the old style miller, if skilled in his business, will discover why he could not do it, like his new process neighbor.

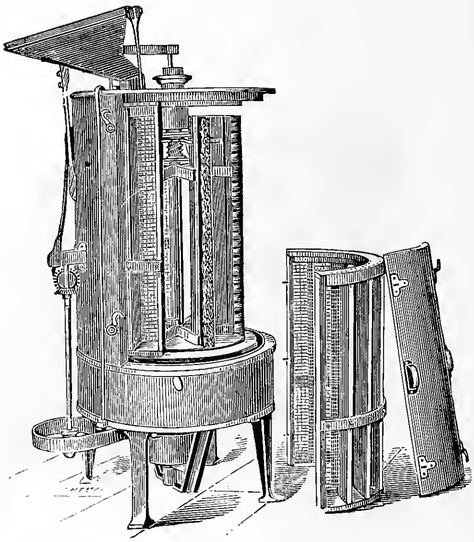
We are not now telling what the differences are, but simply calling attention to the fact that differences exist; and it is to make a study of some of the differences in the two methods, that this part of the book is written, independent of the first part.

But, as we have said, while the greatest apparent difference consists in the mode of grinding, it, after all, forms only a small part of the whole of the new process, and really ought not to be the first spoken of; nor would it be except for the fact of its prominence. It ranks next to the first part of the process, and undoubtedly ranks first in importance; for if a miss is made in grinding, it is not easy to remedy it afterward.

But, after all, the first, and a very important part of the process, is in preparing the wheat for grinding. In the days that have gone by, and not long gone either, but little attention was paid to cleaning and otherwise preparing the wheat for grinding; something in the shape of a smutter, perhaps, would be used, and sometimes a rolling-screen separator. A rolling-screen was used (described by Oliver Evans), and this we believe was the only kind of a separator used in this country, at least by him or by millers generally, to within a period within the memory of numbers of millers now living, and not very old either. Smutters or scourers were after the fashion of the separator, crude and imperfect, and perhaps not more than one of either used in any one mill. We are now speaking of mills of some pretensions—merchant mills of "ye olden time." There are to-day numbers of grist mills in the older sections of the country that are no better, if as well, supplied with cleaning machinery or with anything else, necessary to high milling; but they do not need them, or at least imagine they do not, as they but grind the farmers' grists as they are brought in; are not obliged to make an extra fine quality of flour, or to figure for large yield, and are, therefore, content to plod along in the well trodden pathway of the past, unmindful of the many changes and improvements going on around them.

But, very fortunately for the welfare of the art, merchant millers have been obliged to look at the matter through different glasses. The tastes of the people generally are constantly seeking a higher level; not only better, but the best, flour is demanded, and to meet this want, millers have to bestir themselves; and, as we have said, among the things necessary to making high grade flour, was a better system of separating and cleaning the wheat. New methods and machines have been devised, and more of them used than formerly. This was, really, and properly, too, the first step taken in the direction of a better system of milling, and was commenced some time before the new process (so-called) was introduced, but since which time the requirements of milling has required still greater perfection in the system of cleaning the grain; and, as a consequence, not only a smutter and rolling-screen separator is found in a mill, but in many of them brush machines, smutters, reciprocating separators, cockle machines and rolling-screens, in many instances, are all used in each mill, and sometimes two or more of each kind, or at least of such kinds as are the most useful. By this means millers are enabled to very thoroughly clean and grade the wheat, and get it in such condition as will give the burrs a chance to do good work.

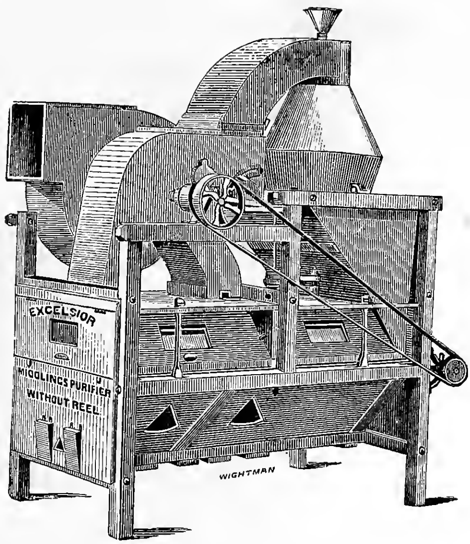
This, as we have said, is the first step, and to some extent (to the casual observer) a part of the invisible process. The difference in the working of the burrs is noticed at a



EXCELSIOR BRAN DUSTER.

Made by HUNTLEY, HOLCOMB & HEINE, Silver Creek, New York.

(See Appendix.)



EXCELSIOR MIDDLINGS PURIFIER.

Made by HUNTLEY, HOLCOMB & HEINE, Silver Creek, New York.

(See Appendix.)

glance, but the great increase in cleaning machinery is not so readily detected. And just so is it with the balance of the process, hid away, seemingly it is, so as not to be detected by the ordinary observer; and so, too, that he can scarcely tell the difference between a new process mill and an old one fairly well provided with machinery. It is more especially impossible to detect the part, although it may be in full and complete operation, which makes new process milling most valuable. The middlings are separated from the flour, handled, and nicely cleaned before the eye almost of the observer, and yet he can scarcely tell how it is all done. The machines may be seen, but further than that, nothing can be known unless it is explained. It is all simple enough, though, when once understood; there is nothing mysterious about any part of it, and hence its great practical utility.

A new process mill, such as we are now talking about, and such as we are going to describe in detail in a few articles, is very simple and very perfect in its operations; we do not say most perfect, for improvements are going on all the time, and are liable to for some time to come.

ARTICLE II.

THE BURRS—FURROW AND FACE—BALANCING—HIGH GRINDING.

As stated in the last article, the arrangement and kind of cleaning machinery to be used, is the first consideration in a new-process mill, but as the arrangement is, or ought to be, substantially the same in all mills, whether technically new process or old, the instructions for arranging, found in the first part of this work, will be found to answer all purposes, and nothing need be added here, except to repeat with greater force, if possible, the declaration that a good and well arranged system of cleaning machinery is of the highest importance, and without which, good or the best, results in milling cannot be obtained. The adhering dirt and other foreign matter injurious to the color of flour, must be removed before the wheat is ground, otherwise it must, to a greater or less extent, remain in the flour.

The burrs, to which this article will be chiefly devoted, require some changes for grinding by the new process plan; and perhaps it might be said that a change in texture, in order to more perfectly harmonize with the changed methods, would be needed. Certain it is that the purer and finer the quality, the better the results. And right here it seems well enough to say, that the difference in the price of mill-stones is, or ought not to be, an object to any miller, because there cannot be difference enough in the first cost to repay for the many serious drawbacks that necessarily follow the purchase of bad or imperfect stones. If mill-furnishers or dealers of whom the purchase is to be made, are reliable, straight-forward and honorable men, it is much better, as a rule, to risk their judgment, take their word for it, and pay them a fair price for good stones, than to compel them, as a matter of self-protection, to furnish you an inferior article on account of your own shortsightedness and desire to save on purchases. And then, too, in the purchase of millstones, it is well to select such houses as are of long standing and well-known integrity, as by so doing the liability to get poor millstones is much lessened, be the circumstances what they may. Such houses rarely handle stock that is not good.

The chief difference between burrs for old and new process milling, allowing the quality to be the same, is the manner in which they are dressed. The old method requires or seems to require, narrow furrows, wide lands, and rough or fairly rough surface. The new, on the contrary, demands wide furrows, narrow lands, and smooth surfaces and also a truer and more perfect face. Not that a more perfect face is more necessary in new process milling than in old, but rather because the motive that impels the introduction of the later and better methods of milling, also creates a desire for greater perfection in all the working parts of the mill: which accounts mainly for the fact that new process millers keep their burrs in more perfect face than do the old.

The quantity of face to furrow is not by any means fixed, but varies considerably with different millers; in order, though, to secure the best results in high grinding or reducing by burrs, about sixty-five per cent. of the entire face surface should be reduced to furrow. The furrows should be comparatively shallow, a little deeper at the eye than at the skirt; and, being deeper at the eye, would necessarily require them to be a little wider also at the eye; the bottom of furrow must be straight and out of wind, and hence the reason for being widest where the furrow is deepest. The furrows should be drawn out to a nice feather edge, the bottom forming a gentle but perfect incline, as it is on these inclines much of the grinding or granulating is done, and there should, therefore, be no abrupt shoulders of any kind, as used to be the case, and is even now so, in some instances.

Occasionally, for some unaccountable reason, millers seem to have a desire for small shoulders on the feather edge of the furrow. The only apparent value of such an obstruction is to irregularly murder the grain without producing valuable or useful results. It is now universally conceded that the bottom of the furrow should be made as smooth as it is possible to make it, and many votaries of smooth surface claim that the face of the stone should be just as smooth as the furrow; but this claim is disputed by others. It is, though, we believe, conceded by all of the more advanced millers that the face should be fairly smooth, and that when cracked by a pick at all, the cracking should be very light. But the admission of those in favor of cracking, that the stones grind best after running long enough to wear off the wire edges of crack, goes a long way in proving that smooth surfaces are the most valuable; else why do the stones do better work, after running long enough to wear smooth, than before.

The chief value of the pick, or other stone dressing instrument, is to dress off the high places and keep the burrs in as good face as possible. If this is done, the natural grit of good burrs will produce the best results, without the aid of cutting edges made by picks. Smooth surfaces, both of face and furrow, with perfect face, may be considered the most useful, and what every miller should strive to get on his burrs.

It is unnecessary to say anything here about the draft or number of furrows. It is, as has been before intimated, an unsettled question, and probably cannot be positively settled. The author is of the opinion that it makes but little difference about either, so that both are kept within reasonable bounds; that is to say, keep the draft of leading furrow about an inch for each foot in diameter of stone, and the number not exceeding three to the quarter; two to the quarter make it nearer equal, and, if an equalized dress is the best, then the legitimate conclusion would be that two furrows to the quarter would be the most valuable; but as both are working to apparently equal advantage, there seems to be no good ground for establishing an arbitrary rule in reference to the matter.

The really important part of the matter is that, no matter whether two or three furrows to the quarter, they should be put in right, dressed right, and kept dressed right; which means, simply, that they should be smooth, straight and wide; with a gentle but regular incline from the back of furrow up to feather edge or face of stone.

Sometimes numbers of other short furrows have been cut at sharp angles across the lands for the purpose, as claimed, of making more middlings; but whether this was the result of having more furrows, and, consequently, more reducing edges, or of the necessary reduction of the face, is a question. It is believed that a corresponding reduction of face surface, by widening existing furrows, would produce the same result, and would be less troublesome and more easily kept in order.

Bosoming for new process grinding is much the same as for other grinding; one third, at least, of the diameter of the stone should be allowed for bosom; and, if it were possible to have a perfectly graduated bosom from the eye to the skirt of the stone, it would probably be better; but as such cannot be well obtained, it is perhaps, practically, best not to attempt anything more than a feed distributing bosom, about the size indicated, leaving the balance of the surface straight.

Considerable attention was paid to balancing in a previous article, and, it is therefore useless to add anything here, further than to say, or rather repeat, that this part of the preparation should not be overlooked nor its value underestimated. The modes of balancing therein described were not intended to be arbitrary. The object aimed at, as was then stated, was to illustrate the principle, the manner, or means, that could be devised by the operator.

When a pair of burrs is put substantially in the shape herein described, they may be considered ready for high grinding or new process milling. The object of this mode of grinding is to make middlings, as little first flour as possible, not to deteriorate it too much; and all the middlings possible, is the aim. By the after treatment of the middlings thus made, will be found the principle secret of making patent flour, so called.

ARTICLE III.

THE PURIFIER.

After the wheat is ground or granulated (the latter term being really the most applicable in the new method, because the design is to reduce it to granular particles of various grades of fineness, but the coarser the better, so long as free from the bran) the product is conveyed to a reel, and the bran, middlings, and flour, separated from each other. The flour is finished ready for market, but the bran and middlings have to each be subjected to still further treatment; but, as it is the middlings we are interested in now, we will let the bran have a rest and give it a lively scouring up after awhile.

After the middlings have been separated from the balance of the stuff, it is necessary that it should pass through another reel, clothed with fine cloth, no coarser than 12, and finer, according to circumstances. This is called the dusting reel, and is intended to remove all the fine flour, not taken out by the first bolting process. This last operation, if complete, leaves the middlings sharp and distinct and in good shape for the purifying process. But first it is necessary to grade the middlings; we say necessary, but it would, perhaps, be as well to modify, by saying that it ought to be done, as, we think, the best results depend upon it, and the best flour-makers do it, although very good results follow without it. The reason for grading before purifying is that very coarse and very fine middlings require a different manipulation for purifying thoroughly. The same kind of a machine will purify both, as a rule, equally well, but each grade, as a matter of course, requires different cloth. But to get back to the grading process. For this purpose a reel has to be provided, clothed with cloth of different degrees of fineness. We will say, as an example, one reel eighteen feet long, clothed with nine feet of No. 6 at the head, followed by five feet No. 4, and the balance No. 1. This arrangement would make three different sizes of middlings, or three grades. This must be looked upon simply as an illustration of the method, and not an arbitrary arrangement of cloth, because the numbers and quantity of cloth has to be adapted to the kind of milling that is done. Hard wheat and high milling requires coarser cloth, while soft wheat and low milling may require finer cloth. The chief object here sought for is to impress the importance of making two or more grades of middlings. After the middlings have been thoroughly dusted and graded, and right here, without again repeating it, perhaps it may be considered by some of no very great importance to dust the middlings, but it is, though. The middlings must be separated from the fine flour before undergoing any kind of a purifying process, otherwise, by the process, the fine flour is very liable to be wasted by being blown into the dust room along with the dust and dirt of various kinds removed during the process. Therefore, to insure yield, save waste, and to make the business the more profitable, it is absolutely necessary that the middlings should be well dusted before being purified. The dustings can be run into low or such grades of flour as will not be injured thereby; circumstances must determine that question.

The method of purifying middlings, or rather, perhaps, it would be better to say, that the principles involved are much the same, no matter what the method. The impurities to be removed have to be either floated off, or drawn out by air suction, or driven out by blasts; in some instances all of these means are used in the same operation. To do it properly, the middlings must first be spread out in a very thin stratum on a sheet of bolting cloth, the bolting cloth being attached to a frame, having a reciprocating motion. This motion keeps the middlings constantly, but slowly, on the move, while there is playing through the meshes of the cloth a gentle current of air, drawn up through it by a suction fan above, or forced up through it by a blast fan below, or both combined. This current of air carries along with it the light, fuzzy matter that darkens the flour, and that cannot be effectually removed in any other known way. At the same time this current of air buoys up the fine bran and other stuff too heavy to be carried off by the air currents, and causes it to float on top and over the tail end of the apparatus, while the cleansed middlings are sifted through the cloth down into a conveyor or hopper below, where it is gathered, and, if completed, sent to the stock-hopper, or wherever else it is required to be sent.

The whole process is very simple when understood, and requires only that all the conditions be fulfilled and the arrangements made complete. To but half do it is almost as valueless as not doing it at all; and, hence, we would advise all flour-makers who contemplate making a change and adopting the new process of milling, to do it with sufficient thoroughness to insure at least a partial success; and the more thorough they make it, the nearer they come to making it a complete success, the more satisfactory in every respect will be the outcome.

ARTICLE IV.

ARRANGEMENT OF PURIFIERS.

Having said all, perhaps, that is necessary, in reference to the principle and the importance of purifying the middlings, we will now turn our attention to the application of the same, and to the arrangement of machines.

When machines are spoken of, we do not mean any particular machines, for there are now a legion of purifiers, many of which are good; and, so far as the object to be attained is concerned, it does not matter whether the miller buys one of the many made by different manufacturers, or whether he makes one of his own; but this much must be said in reference to his being his own manufacturer: he must understand what he is doing before commencing, otherwise he stands a most excellent chance of paying very dear for his whistle. Purifying middlings is a very delicate operation and requires a delicate working machine and a delicate manipulation; and a miller, by being his own manufacturer, is liable before he gets what he really needs, to spend much more than it is worth, unless he does know before hand just what he wants and just how to provide it; and, in consequence, we think we are safe in advising, as a rule, millers to apply to some manufacturer of machines, in whom they have confidence, to provide them with purifiers; and, although, after purchasing the most standard machines and of the most reliable dealer or manufacturer, there may sometimes be a failure; that is, the purchaser may not be able to make the machine work satisfactorily. But in such case he is relieved of the expense, the burden and care of experimenting with the machine, as the manufacturer is only too willing to attend to it in order to save the reputation of his machine, and will make it work or replace it with something that will work.

The author is or has been acquainted with a number of instances where the purifiers were built in and along with the mill, but the parties so doing had an intimate knowledge of what they were doing, and hence had no trouble in making it a success.

In arranging purifiers in old mills already well filled with machinery, the location has to be fixed according to circumstances. It may be, and mostly is, impossible to get such machines just where it is most convenient to have them, and where they could be placed and worked to the best advantage, and at the least expense. In such cases, as a matter of course, the best arrangement that can must be made. The further away from where they are needed, the greater the expense of getting them in, on account of the addition of conveyors, elevators, spouts, etc.

The most convenient place for purifiers, provided the other conditions are as they should be, is directly above the stock-hoppers, so that the purified middlings can run directly from the machines into these hoppers. When the middlings are graded, as has been recommended, each grade should have its own hopper and be ground on a separate run of stones. This mode of doing it is, as has already been said, necessary in order to make the change a complete success; but great benefits can be derived by cleaning the different grades separately, and afterwards grinding them all together. It is, at least, better to do it in this way than not to do it at all, as we believe it is of the highest importance that the middlings should be purified before re-grinding, and the more complete the system of grinding, the more perfect the work; but if imperfections in the plan exist, it had better be in the grinding than in the purifying part of the arrangement; all the grades had better be ground on one run of stone than not to have purifying surface enough, because it is possible to make good, clear flour out of well purified middlings, all of the grades ground together; but it is not possible to do it with as many runs as there are grades, if the middlings are but half cleansed. We do not here wish to be understood as in any way trying to back down from our original position—that the best results can only be obtained by having a complete outfit in every way—we still adhere to that and deviate only to accommodate ourselves to circumstances. There are some old mills, we may safely say a great many old mills, that can be greatly benefitted by making but a partial change, and as the owners of these mills, many of them, are not prepared to make all the changes necessary for a complete new process mill, it is best that they should know what is of the most importance in making any change, and what is likely to benefit them the most; and, in answer to that we say emphatically, if they have already paid attention to the dress of their burrs, as already directed, then prepare for purifying the middlings. But to go back to the arrangement of the purifying machines. As we said, the machines, if possible, should be so arranged as to deposit direct into its own stock-hopper each grade of middlings. But if but one run of stone only, or in other words, if all the grades have to be ground together, then the finished products of all machines should be run together in one hopper by the use of spouts, if available; if not, a common conveyor.

In small mills, where it is not convenient to put in more than one purifier, it is better even to do that than to have none. It is impossible to make a thorough purification on one machine, but with a good machine, great improvement can be made. Still, we would invariably recommend the use of at least two purifiers: two small ones instead of one large one. There is a prevailing idea among millers owning small mills that if they can get one machine large enough to do their work, they are fixed; but this is not true, for not only cannot the middlings be so well purified, but it cannot be done so economically with one machine as it can be with two. With one machine only, more or less of the coarse middlings are liable to be floated off over the tail along with the fine bran and be wasted. With two machines, both clothed to suit, this waste can be avoided.

If it be not convenient to place the purifier in direct connection with the stock-hoppers, then, of course, the next most convenient locality must be selected. In doing this, it must be kept in view, as much as possible, the task of getting the middlings both to and from the machine or machines, and also for convenience in driving all of these things must be looked after, and for the purpose skilled mechanics should be employed, and men of judgment, as by that means only can economy in expenditure and a good job be secured.

Purifiers, like all other machines, must be set level and in line with driving shafting, and then well braced to insure a steady motion. It should have been remarked, in seeking a location for the purifiers, that a convenient place for a dust house should be secured, and this should be as close to the machines as is practical, because the air currents used in purifiers are not strong enough to carry the waste a great distance without filling and choking up the channels, which, in a little while, prevents the machine from working properly; nor should there be any abrupt turns in the air-conducting spout from a purifier, where it is possible to avoid it. If any at all, they should be on a full and complete circle, with no chance for a break or a clog.

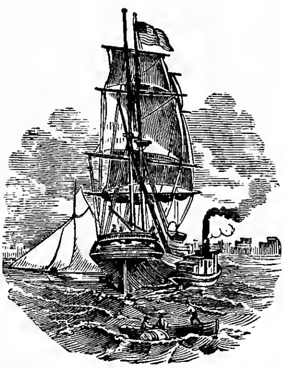
It is usual to provide for returning a part of the product back to the head of the machine. This is especially so where more than one is used; a part of the coarsest product should be sent to the second machine. This must, however, be arranged according to circumstances and existing conditions; as no set of rules will apply with absolute certainty to all, there must be variations to suit. It might be said that these technical questions are settled by the manufacturer of machines, and in purchasing machines, the manufacturer's instructions are to be followed. But when parties build their own machines, then, of course, they must find out how to run it; and, therefore, in using single machines, provision must be made for returning back to the head of the machine, and as much or as little of the product sent back, as may be necessary to obtain the best results. Single machines must be provided with graded cloth, commencing at the head with the finest and ending at the tail with the coarsest. The number of cloth used must be determined by the mode of grinding, and the coarseness of the middlings. High grinding demands coarse cloth at the head; low grinding relatively finer cloth. In ordinary milling, No. 6 is used at the head and then graded down to 1, at the tail; but when higher grinding is adopted, coarser cloth accordingly must be used.

It is of no real advantage to send the product or any part of it, coming through the coarser cloth at the tail of machine, back to the head. If there is no other provision for repurifying it, it had better be cut off and used for a lower grade of flour.

After purifiers have been placed and in good running order, it is easy enough to learn how to manipulate the returns and regulate the other cut-offs, so as to get the best out of it all. The tailings, or that portion of the stuff which floats over the tail end of shaker or sieve, is generally supposed to be of no value except for feed. This, however, is not always the case where full provision is made for new process milling; the tailing of purifiers are sent to crushing rolls, and from thence to other purifiers, and re-cleaned.

It must be borne in mind that no effort is here made to give instructions for the arrangement of purifiers in a forty-run mill, or even in mills much less in size and capacity, where many machines are used and a large business done. Parties controlling operations on so large a scale need no instructions, or at least they ought not, although it often happens that they do, but are in blissful ignorance of the fact.

The chief object aimed at in the instructions here given, in reference to the arrangement and working of purifiers, is intended, as the work entire, in fact, is intended, for the benefit and instruction of those that have not had the advantages of a high mechanical education—men of about the same calibre as the author, who claims to stand on no very exalted plain, and for the benefit of the rising generation of young millwrights and millers who are eager to take advantage of every opportunity afforded them for learning something of their future business.



ARTICLE V.

BOLTING.

It might be supposed that bolting, under the new process of milling, would be much the same as under the old, and so it is, really; except by adding more cloth, no important changes are made in the manner of bolting by many who have adopted the later methods of milling. But while a change in the manner of bolting may not follow, necessarily, we still think that very good results follow a radical change from the old system. But not to anticipate; we will confine ourselves to the subject in a general way, without reference to the manner, especially, in which it is done.

We have been talking about and trying to learn how best to purify and re-grind the middlings, and will now inquire how best to bolt them after being ground.

Substantially the same rules for making chests, close, tight, and secure, as has been previously given should be adopted.

And here we will briefly describe how to make a reel; this should have been done in our first lesson, but was neglected. The shaft of a reel may be made of wood, as has been described; or gas pipe, as is frequently done, may be used for the purpose. In the latter case, iron spiders have to be fastened to the gas pipe, three or four, according to length of reel, with set screws. Then, for stiffening the shaft, iron stay rods must be run from the center or hub of the two end spiders, and over the middle spider or spiders, one stay rod for each set of arms. These stay rods are to be made reasonably taut, after which the ribs can be fitted to the arms of the spiders, and the construction of the reel proceeded with in the ordinary way, or in the way we are now about to describe, for making entirely wooden reels. After the shaft has been completed, including the fitting in of the gudgeon, mortises must be cut or round holes bored in the shaft for the arms. It is more common now to use round than square arms in reels. These arms may be dressed out by hand, or what is better, they can be turned up in a lathe, where it is available; they should be made full in the center, and of equal size where they go through the shaft, and tapering slightly from the shaft to either end, with about a half inch round tenon turned on the ends; the body of the arm should be about one and a quarter inches thick. Some millwrights make reel shafts six-square, but it makes a better looking shaft and one easier handled, to make it twelve-square. On a twelve-square shaft a line should be made along the center of every other square, then commencing sixteen or eighteen inches from either end and ending about the same distance from the other end, the same must be spaced at an equal distance apart; the holes should then be bored from both sides, care being taken to have the starting points exactly opposite each other, so as to have the arm stand at right angles with the shaft when it is in; when the arms have been fitted in, the ribs must be fitted to the arms, and we will explain that among the innovations made in the old system, is that flat, or comparatively flat ribs, are now used instead of the deep rib, as formerly; the ribs should not be made more than an inch in depth, anywhere, and they can be made less by using more arms and making the intervals shorter; on the lifting side the rib should be beveled off to a thin edge between the arms, this will allow the meal to slide over gently without being lifted up and dashed down in the cloth repeatedly, and thereby insure better bolting; the outside of ribs should be dressed to a circle corresponding to circle of reel, or perhaps they should be rounded a little more, so as not to have the cloth bearing too hard on the corners. After the ribs have been fitted in, the head must be attached in any convenient manner that may be suggested or liked; when heads are made double, as is done by some, mortises corresponding with the size and shape of the ends of the ribs are made in the head, which allows it to slip on the ribs and into place; common screws are then used through the outside of head and into the ends of ribs, for securing the head to its place. The inside portion of a double head should be made the size and shape of the six-square reel; it then answers for fastening the cloth to; if, though, the shoulder or bearing thus formed does not furnish surface enough for attaching the head of the cloth to, it can be increased by fitting strips between the ribs and against the head.

When the head has been finished the tail strips must be fitted in; these should be not less than three inches wide, nor more than a half inch thick, and should be let down in the ribs so as to make the outside surface flush; the ends of strips should be mitred on each rib, and the sharp corner thus made rounded off to correspond with the rib.

After the tail strips have been fastened on, the inside corner should be beveled off so as to form as little obstruction as possible to the outward passage of the bran.

As has been said, reels of thirty-two inches in diameter, or less, are made six-square. The cloth for reels of this kind is made by stripping the bolting cloth, whatever kinds are to be used, into three pieces, two widths of bolting cloth being sufficient to go around a reel; between each strip of bolting cloth there is sewed a strip of ticking wide enough to cover the rib of the reel, and at the head of the reel there should be about six inches of ticking all around, or enough to allow the feed to drop on it, instead of the bolting cloths. At the tail, also, there should be enough ticking all around to cover the tail strips. This mode of making and putting on a bolting cloth keeps the silk from coming in contact with any part of the wood work of the reel, prevents insect harbors, and is generally an excellent plan for clothing a reel.

This, we think, is about all that need be said about the practical part of making and clothing a reel, and more than should have been said here, except, as we have said, for the reason that it was overlooked in another part of the work, where it ought to have come in.

A few things about the general principle, in harmony with present methods of bolting, is what we want to say here. We want to say that, as it is important that the middlings should be ground alone, so also should the flour be bolted alone. We do not mean that each grade of middlings must (although it is best that each should) have a separate reel, unless it should be a grade of quality. All of the middlings flour of the same quality can be bolted together, but not in a cramped way. There should be enough of cloth to insure a good job, and fine enough also. The flour should not be lifted up by the ribs and banged around in the reels, but allowed, as we have said, to have a gentle, sliding motion around the reel. The motion of the reel should not be too rapid nor the pitch too great; a quarter of an inch to the foot is sufficient pitch, and twenty-eight to thirty revolutions per minute, is fast enough to run the reel, that is, a reel thirty-two inches in diameter. Larger reels must run relatively slower, and smaller reels faster. The smoother the motion of the chops in the passage through the reels, the more certainty there is of having the flour clear and pretty; and, as the great aim of high art milling is to get the flour as white, as pure, and as clear as possible, the more attention there is paid to having the bolting reels all that is needed for the purpose, the greater surety there is of obtaining desired results. Abundance of cloth, and that of the right grade of fineness, reels so constructed and run as to give the meal a slow, easy motion, keeping it at the same time in constant contact with the bolting cloth, is what is most needed to insure good results in bolting.

ARTICLE VI.

BOLTING (CONTINUED).

To avoid the returning process in bolting, as done by the old method, it is necessary to make flour at every stage. To illustrate, we will take three reels, one above the other; the upper one will be clothed with No. 12 cloth the entire length, the next No. 13, and the third with No. 14. The chop meal is sent first, as usual, to the upper reel, from which flour is drawn as far as it will make it good enough, the balance is cut off and sent to the head of the next reel; so, also, is all that passes over the tail of the upper reel, just the same, in fact, as is usually done. Both the cut-offs and tailings of the upper reel, are sent to the next reel below, and by the old method, from thence back to the upper reel again; but that part of the mode we propose to do away with. We believe that after the flour has been bolted it should remain free and not be again mixed with the offal, as is the case whenever well bolted returns are sent back to the head of the first reel. In the second reel flour is made as far as it can be good enough, the balance is cut off; and it, together with the tailings, are sent to the head of the third reel, and again flour is made, so far as it can be, the same as in the two upper reels. It is now presumed, though, that the flour is all taken out and the tailings of the third reel are ready to go to a dusting reel, they being the middlings. It must be understood, though, that all the flour has not been saved yet. There is a cut-off from the third reel that has to be taken care of, but that we will leave for the present, and go over the ground again; and, as nothing has been said about bran, we will suppose we have been dressing middlings flour, and, although, it is a kind of backward way of doing business, it will serve just as well for illustrating the method.

We will now provide another three-reel chest, and clothe it in this case in the same way as previously; but before introducing the chop to the upper reel in this chest, it must undergo some kind of a scalping process, by which the bran and shorts are removed. This may be done by the use of a separate reel covered with very coarse cloth or wire, or it may be done with disintegrating, cooling, or agitating machines, made for the purpose. Some of these machines seem to be working very well and are apparently more satisfactory than the ordinary reels, but the mode of scalping must be determined by those interested; all that is now to be said, is to scalp or remove the bran before sending the flour to the bolting chest.

After it has been sent to the first reel of the chest, all that will make the grade of flour that is desired is gathered for that purpose, the balance is cut off, and together with the tailings of the reel, is sent to the head of the next reel below, where the same operation is repeated, and cut-off and tailings go to the third reel, where all that can be used for flour is saved, and the balance cut off, and that brings us where we left off with the other chest. To take care of what has been cut off the lower reels, two other reels will have to be provided, covered with cloth at least as fine as that used on the lower reel in the chests named, the lower reel of the two the finer, if possible. To the upper of these two reels last provided, must be sent the product that was cut off and unprovided for in the bottom reels of the two first named chests. If there should be any product of the two reels good enough for the first grade flour, it may be run along with it; if not, the whole of it must be run into second and third grade flour, or into one grade only, as may be desired. These two reels are operated in the same manner as the others; the flour is spouted into the head of the upper reel, and the best of the results taken care of, while the balance, including the tailings, are sent to the lower reel, where the presumption is all is finished up.

It must be distinctly remembered that the arrangement spoken of here is not intended to be arbitrary; it is intended to be illustrative only. We do not pretend to confine the miller to a fixed number of reels, nor to a fixed kind of cloth; both may be varied to suit. There may be four reels and four operations in each of the two first named chests; and, instead of using the numbers of cloth as named, Nos. 12, 14 and 16, may be used in succession, or any other set of numbers that may seem best adapted to the end in view. Nor do we say that even then the flour will be sufficiently well bolted; on the contrary, we believe the entire mass can be made better in color, at least, by rebolting. In fact, we are not in the least afraid of bolting; the more of it in reason, the better. What we want most to impress upon the mind of the reader, is that when flour has once been separated from the offal, keep it separated; and what we have attempted to do is simply to show how it may be done without confining the miller to a fixed set of apparatus.

This mode of bolting is not general by any means; in fact, we think, but comparatively few of the millers of this or any other country, have ever tried it, but such as have, appear to have uniformly good results. But a simple changing of the mode of bolting, without making such other changes in old mills as have been spoken of, and as are necessary to insure good results, although improvement may be made, entire satisfaction cannot be expected.

The whole system of new process milling is just such as has been repeatedly said, that, while a change for the better, made in any one stage of the operation, may benefit, entire satisfaction and the best results cannot be secured without an entire remodeling of the old mill and system.

ARTICLE VII.

A BRIEF DESCRIPTION OF A NEW PROCESS MILL.

We think, perhaps, a quicker and more comprehensive knowledge of how a new process mill should be arranged can be obtained by a brief description of, say, a ten-run mill.

Our imaginary mill must be a firm, handsome structure of either brick or stone (this, however, need not prevent those who desire it to put up wooden or frame buildings), sixty by seventy feet, and should be, though not necessarily, four stories high above the basement. The basement should form a complete, well-ventilated and well-lighted story, with a grouted or other kind of a firm, hard floor, and should be at least twelve feet in height from floor to ceiling. The first story above the basement should, also, be well-lighted, and at least fourteen feet high. The two next stories eighteen feet in height, and the top story eighteen feet or more, as the case may be, and according to the style of roof used.

Along one end of the building, in the basement, there should be mounted on a firm foundation of solid masonry an equally firm and neatly finished husk-frame, made either of wood or iron (we prefer iron). Measuring from center of husk-frame back into the building a distance of sixteen feet, or such a matter, there should be stretched across the building, parallel with the husk-frame, a line of three to three-and-a-half inch shafting. This line of shafting, to be lastingly firm, should, like the husk-frame, be mounted on pillars of solid masonry, although it is quite common to use heavy wooden posts or wooden frames for supporting this shaft. This line-shaft is supposed to run through from the outside of the main building, where it is connected with a steam engine or other motive power. Its speed should not be much less than one hundred revolutions per minute if it can be avoided. From this shaft, and over pulleys on the same of a size suitable to make the speed of burrs right, must run quarter-twist or reel-belts, one for each run ot stone, and each nine inches in width, and connecting the stone spindles with the line-shaft. With suitable guides and tightening pulleys for the belts, we have an excellent driving apparatus for the burrs, and although as good as is generally made, still imperfect.

We have in the past thought and frequently asserted that burrs driven in this way needed no other device to insure a steady, regular motion; but after observing some experiments in a small way, have come to the conclusion that, while so much irregularity in motion is not observable as when gearing is used, still there is some under the most favorable circumstances where reciprocating steam engines are used as motors; hence, in order to be sure of a steady motion it is best to put springs of some kind on the spindles. This done, one more innovation is necessary to make it all a good and easily managed arrangement. Instead of the ordinary pulleys on the line-shaft, friction pulleys, much the same as are used by paper makers on their super-calenders, and for other purposes, should be substituted. These friction pulleys should be managed from above by hand-wheel connections, the same as the hand-wheels for raising and lowering the stones. Then, whenever it becomes necessary for the miller to stop any of his burrs, all that is necessary is to give the friction hand-wheel a few turns and it is done. This is a convenience that can never be thoroughly appreciated by millers until it is tried.

We must not forget to here observe that the spindles should be at least eleven feet in length because we want everything to work well. The pulleys on spindles must be in accordance with size of stone, and as we in this case intend to use four feet burrs, our pulleys will not be less than forty-five inches in diameter.

Passing from the basement into the story above, we observe ten runs of burrs in a line on a raised platform extending entirely across the building. On one side of the building, and running at right angles with the line of burrs, is a run of flour packers; aside from these nothing else of note is observable, except the various stands of elevators and the numerous spouts, all of which are arranged so as to be as little in the way as possible. The principal features on the third floor are the two six-reel bolting chests. One of these is for the first flour, and the other for middlings flour; one side for coarse and the other for fine middlings; both sides are operated as described in the last chapter. It will be understood that these chests will extend up through the floor of the next story. In addition to the chests on the third floor there will be found extending across the mill, and over the burrs, a line of stock-hoppers for both wheat and middlings.

On the fourth floor, and directly over the middlings stock hoppers, or as nearly so as possible, will be found arranged the purifiers, six of them at least; and for the purpose of making all as convenient as possible, these purifiers are set in two lines, one line over the other. The middlings that are not well enough finished on the upper machine are dropped into the one below instead of being returned back to the head of the first machine. These purifiers are classified and clothed suitably for handling the fine and coarse middlings, each machine, or set of machines, taking care of its own. We have said "at least six purifiers," and we mean the largest size; if small machines, more will have to be used; and it might be that more would be needed anyway. That will depend on the manner of milling, location, etc. We place the purifiers one line over the other in this case because we have an eighteen feet story, and can do so unless the machines are exceptionally high.

In the upper story the scalping reels or agitators, or whatever other devices we may use for taking the bran out of the flour, are located; so, also, we have a four-reel chest for the purpose of handling the last cut-off from the main chests, as previously described, and any and all other stuff of a lower grade that may be necessary to send to it. So, also, on this floor, will be the middlings dusting reels, and perhaps the crushing rolls, two or three sets of which must be used for germ flatteners, and for partially reducing the middlings. In this mill it must be remembered we depend mainly on the stones for reduction; reduction by other processes will be elsewhere described in the book. However, as this is only an imaginery mill, we do not wish to be arbitrary about the location of the crushing rolls, but will state that the object is to save elevators and spouting. If they are on the upper floor their product can be spouted away into purifiers or bolting reels without being re-elevated, as would have to be done if they were on a lower floor. The same is true of the dusting reels; we want to make one elevating do; elevate into the reels and spout out into the purifiers.

In the top story we will begin with the cleaning machinery. It will be assumed that the wheat has already passed through a receiving separator of some kind in an adjoining warehouse (we do not want to handle or store any wheat in the mill), and we will commence the cleaning system by planting a fine separator on the top floor; on the next floor below, and under the separator, will be placed a mild scouring-iron smutter, and below that again on the next floor a brush or finishing machine. The wheat will pass then uninterruptedly from one machine to the other, and after passing through the last machine, can be elevated and deposited in the stock-hoppers. One set of cleaning machines may not be sufficient, and if not, another smutter and brush machine should be added, or two brush machines, leaving the second smutter out. This can be determined only by circumstances; in some localities the wheat needs more cleaning than in others. The best manner for driving these smutters and brushes is to drop an upright shaft from above, and drive all from the same shaft. We object, though, to having what is known as a main upright shaft for driving all the machinery on the upper floors. A belt running from the main line in the basement up to the fourth story is preferable. A main line in the fourth story, to which all the machinery on that floor, and above and below it can be attached, is a much better arrangement than to have a heavy, lumbering upright shaft running all the way up through the mill.

As of course will have been noticed, this has not been intended as a detailed plan of a mill, but only a general plan, leaving the details to be arranged by a skilled mechanic to suit the taste, inclination and circumstances of those interested in the construction of any such mill. We have this to say to all engaged in the construction of mills, that the more simple the arrangement of the machinery the better. Never put in a conveyor when a spout can be used, nor a stand of elevators if it can be avoided; do not put in a foot more shafting than is needed, nor any heavier than is required to do the work; neither put in an unnecessary wheel or pulley, because, besides the first cost, all this surplus machinery requires power to run it, and power costs money. Study the art of doing the work with as little machinery as possible; but do not get to the other extreme of having driving machinery too light. A careful study of tables on gearing, belting, and shafting, in the first part of this book, will be of great value in this respect.

We have noticed that some mechanics use a great deal more shafting and gearing, and heavier on the same kind of jobs, than others. Whether they were interested in the sale of such material or not, we do not know; but whether or not owners, or those who have to spend the money, ought to see to it that they are not imposed upon in this way, because it does not end with the first cost; it is ever after a cost for power and keeping up wear and tear.

ARTICLE VIII.

IMPROVED METHOD OF GRADUAL REDUCTION — JONATHAN MILLS' SYSTEM.

Until within a few years ago, all progress in milling was limited to the perfecting of mechanical appliances for the different operations which constituted the art. While this must always remain the case, to a large extent, the past few years have witnessed advances along another line, in the devising of new processes for reducing the wheat berry to flour and the invention of new machinery for carrying out these processes into practical results. So long as the old system of milling was in vogue, progress in the grinding of the wheat was barred after a certain limit was reached. Imperfections in the grinding machinery could be largely remedied, but the nature of the wheat-berry itself presented insurmountable obstacles to the improving of the flour beyond the limit that had already been attained. A knowledge of this fact led millers to adopt the new process; but one great difficulty in the way of success in this new departure was the employment of the *means* of the old system to bring out the *methods* of a new one. Besides, the new process is only a partial adoption of gradual reduction, this adoption being partial simply because the means of carrying out a complete system of gradual reduction, which would meet the commercial demands of the American miller, were wanting. It would not answer to adopt the Hungarian system for the reason that the low grade flours would be unsalable in the markets open to the millers of this country; and therefore our millers were compelled to be content with a relatively low per centage of high grade flours, or else sacrifice their profits in rich bran and cheap low grade flours. Mr. Jonathan Mills, inventor of the system of milling which bears his name, believing that the means employed would forever be inadequate to meet the requirements of gradual reduction milling which could be profitably adopted by our mills, determined to perfect a series of machines that would enable the miller to carry out in practice what science shows to be desirable.

Before entering upon an account of these machines, a view of the wheat-berry may throw some light upon the ends held in view by Mr. Mills' system. The accompanying engraving (Fig. 1) shows a portion of the cross section of a grain of wheat. Letters A, C, D and E show the different bran coatings. Letter F shows the outer layer of albumen in large cells, and letter G the regular starch cells in the interior of the berry. At the lower end of the wheat-grain is the germ, chit or embryo, as it is variously called. These are the elements with which one has to deal in the reduction of wheat to flour. The object of scientific milling is to exclude the bran and germ from the product of the grinding or reduction, and to incorporate in the flour the albumen and starch cells. A process which accomplishes this, therefore, must be far different from grinding, and employ more accurate and delicate means. While it is easy to produce, by ordinary appliances, a flour which meets the requirements above named, only a small per centage can be so obtained, while the demands of economy are that the yield of scientific milling be larger, so that it may be profitable. It is here where the principal obstacle occurred. To gradually disintegrate the wheat would necessarily leave the bran richer than the miller could

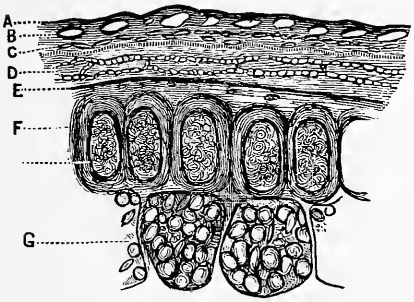


Fig. 1. *Cross Section of Wheat. Drawn with Camera Lucida. X 200 Diameters.*

afford to have it, while re-grinding the bran would produce a flour of very low grade. Faced by all these problems, Mr. Mills saw that in the first place a succession of operations must be resorted to in order to reduce the wheat and obtain a large per centage of middlings (the albumen and starch cells), without any violent or tearing action which would comminute the bran. Then it was apparent that, as these successive reductions would leave the offal rich in nutritious materials, some device must be contrived to remove these valuable elements in such shape that they might be largely saved in the form of middlings, and re-ground into high grade flour. Finally, a perfected mill for re-grinding the middlings seemed a fitting cap-stone for the system. In a word, the inventor's aim was: 1. To produce a large per centage of middlings without comminuting the bran, as is done more or less in ordinary new process milling, and the Hungarian system with corrugated rolls. 2. To produce a wheat flour and a low grade flour that would be readily salable, since the corresponding flours made by the Hungarian system would find no market in this country. 3. To save from the offal the large per centage of middlings wasted entirely with the bran as feed, or made into low grade flour where the millstone is used to re-grind the bran. For the successful accomplishment of these aims he designed, after much patient thought and experiment, a degerminator-gradual-reduction machine, a bran machine and an improved rigid under-runner middlings mill. The construction and operation of these several machines will appear more clearly in the following descriptions and illustrations.

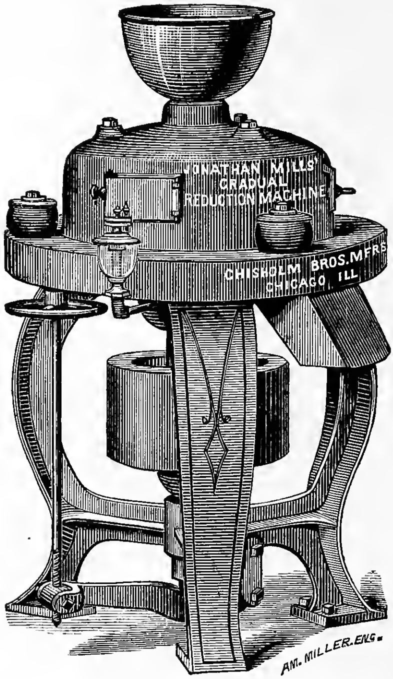
It may, however, be proper to remark here, by way of preface, that this system produces from winter wheat about sixty-five per cent. of patent flour, thirty per cent. of wheat flour of superior quality, and only about five per cent. of low grade, while from hard spring wheat it produces from seventy-five to eighty per cent. of patent, fifteen to twenty of superior wheat or clear flour, and five per cent. low grade.

A view of the process as a whole will materially aid in understanding the parts taken in the system by the several machines. For this purpose it is necessary to take account only of the gradual reduction and bran machines, as the remaining steps in the operation could be performed by mill-stones, porcelain rolls, or smooth-chilled iron rolls. A complete set of reduction machines comprises six, for which one double bran machine suffices to clean the offal. The system comprises five successive reductions or breakings on the reduction machines, and two other reductions or cleanings on the bran machine. The wheat is first separated and smutted in the usual way, and then sized by means of a rolling wire screen.

First reduction: The large wheat is sent to one reduction machine, and the small wheat to another, in which the kernels are split longitudinally through the crease. The split wheat from both machines is sent to a wire scalping reel, in order to take out the flour middlings and germ obtained by this operation. This is called the degerminating process, or first reduction. *Second reduction:* The split wheat is spouted from the tail of the first wire reel to the second reduction machine which reduces the split wheat lightly, and loosens the germ from any kernals not removed by the first operation. This material is then scalped on another wire reel the same as the first, in order to take out the flour middlings and germ obtained by second reduction. *Third reduction:* The broken wheat from the second wire reel, goes to the third reduction machine and is scalped on a third wire reel as before, taking out the flour and middlings. *Fourth reduction:* The broken wheat then passes from the third wire reel to the fourth reduction machine and is reduced still more, and the chop is sent to a fourth wire reel to bolt out the flour and middlings as in the third. *Fifth reduction:* The broken wheat from the fourth wire reel, now nearly reduced to bran, is next sent to the fifth and last reduction machine where it is finished, the chop being sent to another scalping reel, and the flour and middlings made on this reduction taken out.

The bran is then sent to one of the Jonathan Mills' bran machines (shown in the engraving) first to one side, where it undergoes the first operation of cleaning. The flour and

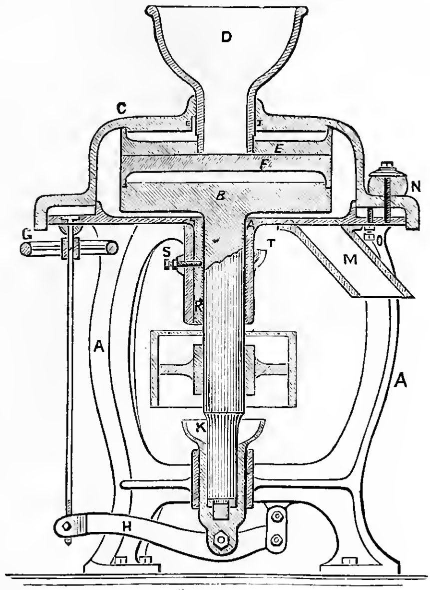
Fig. 2.



middlings loosened from the bran are scalped off. The bran is then sent to the other side of the bran machine, and the flour and middlings scalped out. The bran being thus finished is sent to the bran room. The wheat has now been reduced to flour middlings and clean bran.

The flour middlings and germ from the scalping reels of the first and second reductions are sent to a bolting reel to be dressed, the flour here obtained being a *low grade*, while the middlings and germ are separated in the usual manner. The flour and middlings from the third, fourth and fifth reductions are sent to a different chest of reels to be dressed. The flour obtained is the first or wheat flour, and is pronounced by competent judges and experts to be of the very

Fig. 3.

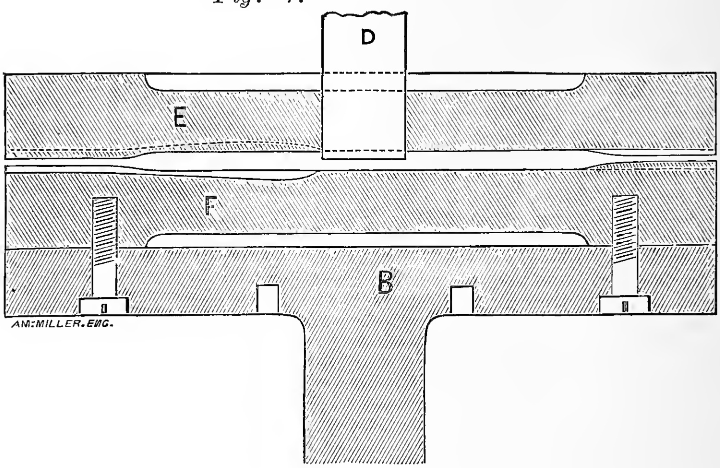


best quality as to color and strength. The flour and middlings from the bran goes to a bolting reel where the flour is taken off and sent to the packer with the low grade of the first and second reductions, while the middlings are sent with those made by the various reductions.

The first machine used in this system has the double purpose of removing the germ and reducing the interior of the wheat-berry to middlings preparatory to grinding them. The same apparatus essentially is used for all of the five reductions, the only difference being that the disks E and F are adjusted more closely in each successive operation, and that in the machines used after the first reduction the disk-faces (V, W, X, Fig. 5) are modified by extending the skirt corrugations for about an inch down into the depressed bosom.

The machine consists essentially of two disks of chilled iron, each 16 inches in diameter, with marginal rounded corrugations and smooth surfaces, and a depressed bosom in both disks. The lower disk is the runner and the upper is stationary, and provided with a central feed opening. The

Fig. 4.

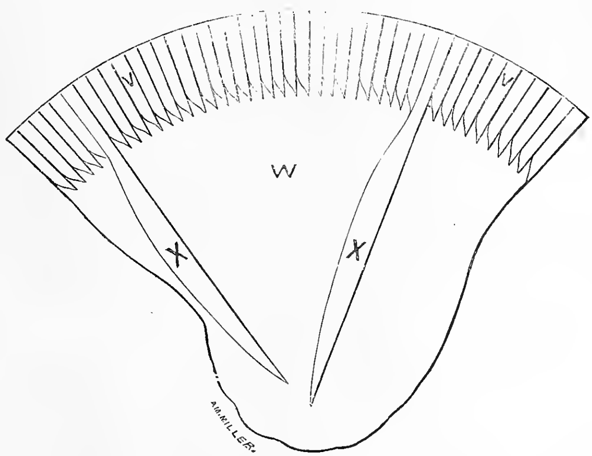


whole machine is constructed of iron (see perspective, Fig. 2) and all the parts which act upon the grain are smoothly polished.

Referring to the sectional view of the machine (Fig. 3) its general construction is readily understood. A, A, is the frame, B is the spindle-head, the foot of which rests in the oil-pot, K; to this spindle-head is fitted the lower or revolving disk, F (see enlarged view, Fig. 4), which is raised and lowered by the lighter-bar, H, operated by the hand-wheel G. C is the cap-plate, into which the stationary disk, E, is fitted, and by which it is trammed to the revolving disk, F. The hopper, D, is so arranged that it can be raised or lowered at will, in order to increase or diminish the feed. M is the delivery spout; T is the tallow-pot; S is the set-screw to operate the gib, R.

The relative position of the two disks, E and F, is shown in Fig. 4. Both disks are depressed in the face from the center to within a few inches of the periphery so as to leave space for the free passage of the grain in a horizontal position or upon its side, but not otherwise. The skirt of the disk, as shown in Fig. 5, is divided into furrows by corruga-

Fig. 5.

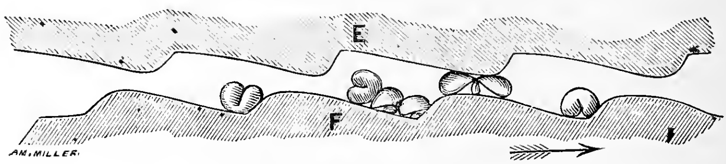


tions, V, V, having a draft of about three inches. The leading furrows, X, X, extend from the corrugations to the draft circle. The entire surface of both discs are polished as smoothly as possible, and all the edges carefully rounded off.

The machine is operated at a speed of from 500 to 700 revolutions per minute. The centrifugal force leads the grain along the furrows, X, X, in a horizontal position, and feeds it over the bosom, W, to the depressions between the corrugations, V, V. The speed of the surface on which it rests causes it to travel up the incline of the corrugations or ridges, V, V, and in its ascent it is rotated until its creased side bears on one or the other of the disc surfaces and the pressure of the smooth surface splits the berry open and releases the germ. It is obvious that the smooth surfaces of the disks and the rounded edges of the ridges are necessary in order that the berry may not be broken at once, and the bran rasped off and mingled with the interior parts of the wheat. The action of the disks upon the wheat-berry is accurately shown in Fig. 6. The small amount of flour detached in the degerminating process is low grade as above stated.

The succeeding reductions are made upon the same principle, the chief difference being that the disks are adjusted more closely together at each succeeding operation, so that

Fig. 6.

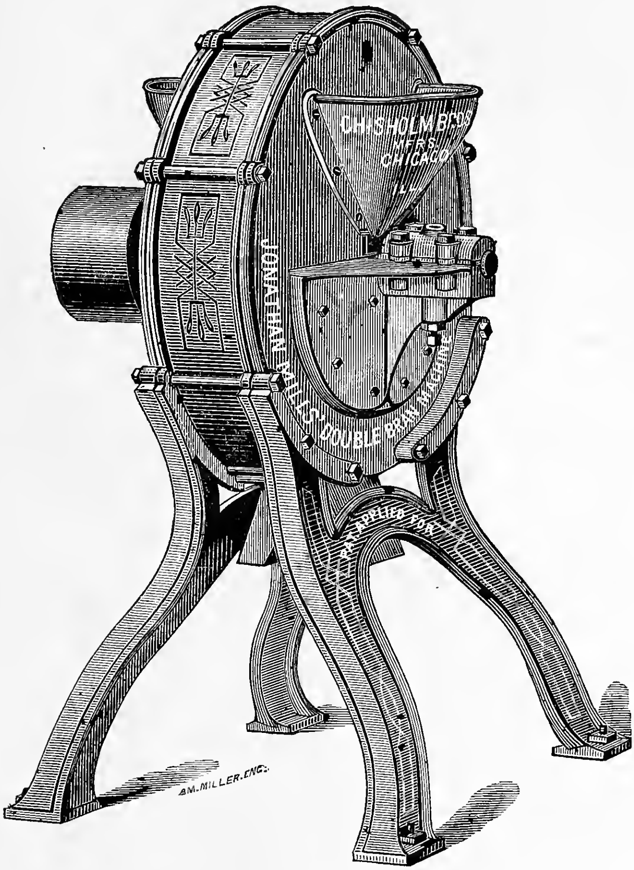


the rounded edges of the ridges or corrugations are nearer and nearer to each other as the reduction of the wheat proceeds. The essential difference between such a reduction and the reduction by rolls, or millstones, is, while with smooth rolls the berry would be squeezed, and with corrugated rolls, or millstones, it would be cut or rasped, with the disks in question the berry is rolled out, or granulated, the result being the large production of middlings above stated, while the bran is kept intact and the gluey coating not disturbed.

The utility of the bran machine, and the novel principle upon which it is based, entitle it to a full description. The machine is made entirely of metal, and occupies a floor space of 37x37 inches, and 46 inches high.

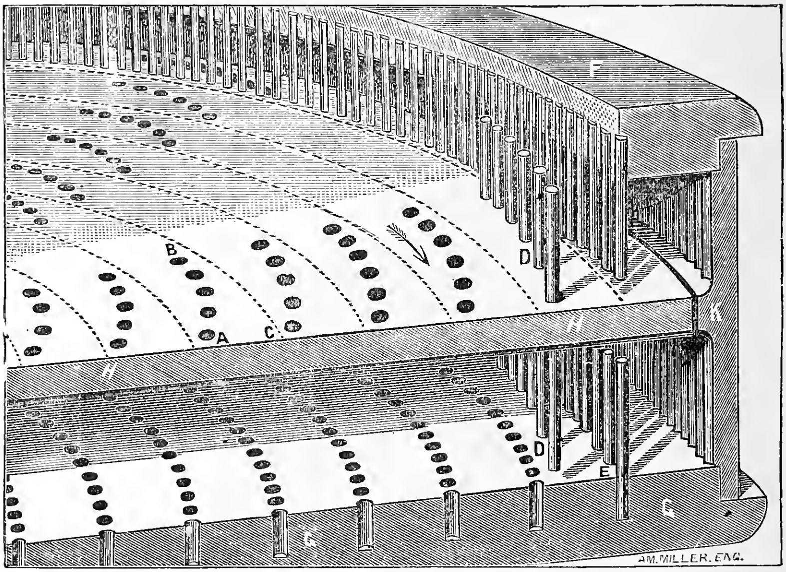
The sectional view of the bran machine (Fig. 8) has one plate, F, cut away, showing part of one side of the disk or sweep, H, H; also part of one circle of stationary pins fixed in plate, F. D, D, shows one of the curved oblique wings of pins in the sweep or disk, and the holes in the sweep show where the other wings are. The dotted lines on the sweep

Fig. 7.



show the position of the circles of stationary pins that are fixed in plate, F, while the holes shown in plate, G, G, show the position of the circle of stationary pins in it. K is a section of the curb showing the inner corrugated surface. The arrow shows the direction of the revolving disk or sweep. The curved triangle, A, C, B, shows how the bran is gathered by the oblique wings represented by A, B, or D, and pressed and rubbed against and through the circles of stationary pins represented by C, or E. The sides are formed by two parallel circular plates of cast iron, separated by a cylindrical iron curb, upon which they are clamped by bolts

Fig. 8.



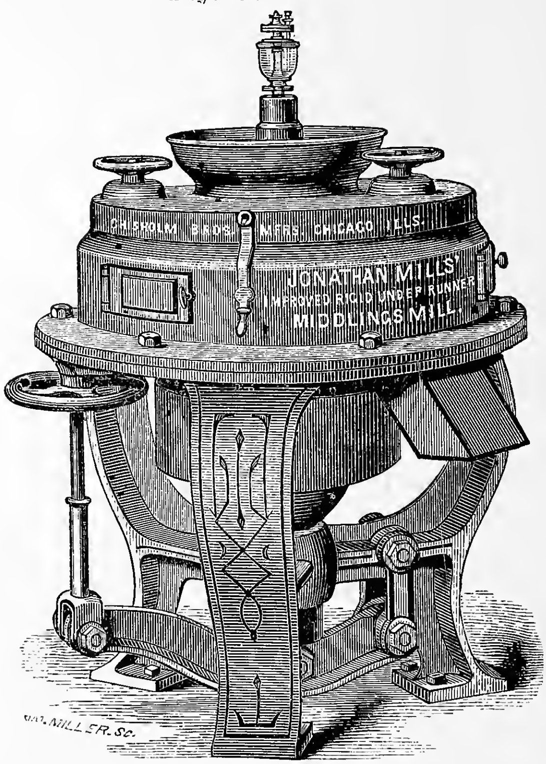
passing through the marginal flanges outside the curb. This forms a shallow cylindrical chamber, about thirty-two inches in diameter and five inches deep, communicating by a central opening to a hopper on each side, and provided with marginal delivery-spouts at the bottom, one for each side. This cylindrical chamber is divided perpendicularly by a solid circular iron plate or revolving disk or sweep. This disk or sweep is keyed on to a horizontal two-and-a-half inch shaft, that has long, substantial journals on either side, and upon one end of which the driving pulley is placed. The bearings are long, and substantially supported by brackets, cast or secured upon the plates forming the sides of the machine.

On the inner face of each of the stationary side plates, eight rows of steel pins are fixed in concentric circles, the circles being about one-and-one-half inch apart, and each circle of pins in one plate being directly opposite the corresponding circle in the other plate. These steel pins are from one-fourth to three-eighths of an inch in diameter, and are set from one-sixteenth of an inch apart in the outer circle to say four-sixteenths of an inch apart in the inner circle. These pins are about two inches in length, and extend inward toward the revolving sweep or disk already described, only allowing sufficient space for the circular sweep or disk to revolve. These circles of pins form stationary concentric, annular, slotted partitions, through each of which the bran, fed in at the centre, must pass.

The revolving sweep or disk is laid off into twelve or more radial sections. In every alternate section, curved, oblique, transverse rows of steel pins are securely fixed, extending an equal distance on each side (see D), about two inches, or so as nearly to touch the inner face of the stationary side plates. These pins are set about one-eighth of an inch apart, in each row. The rows themselves form oblique, curved, slotted wings, upon each side of the sweep or disk. The slotted wings move around in the circular spaces formed by the adjacent circles of fixed pins in the stationary side plates. As the sweep or disk revolves, these curved wings gather the bran and rub and force it outward, through the stationary circles of pins. The inner surface of the curb has transverse ribs or corrugations, near which pass the outer curved rows of pins at the circumference of the sweep or disk.

From the foregoing description, the operation of the machine will be readily understood. The sweep or disk is made to revolve rapidly, by means of a belt on the driving pulley. The bran is fed into the hopper, on each side, and passes into the machine at the centre. The hub of the sweep or disk is provided with solid wings, which sweep the bran outward, and force or rub it through the first or inner circle of pins. The pins in this circle are made heavy, for the purpose of arresting any hard substances, and of breaking up any dough-balls that may have formed in the bran. Having passed the first circle of stationary pins, the bran is gathered by the first or inner series of oblique rows of pins (or curved wings) in the revolving disk and crowded, rubbed

Fig. 9.



and forced outward, through the second fixed circle of pins. The next series of curved wings then gather and rub the bran outward, through the third fixed circle of pins, and so on, until the outer fixed circle of pins is passed. Here the corrugations on the inner face of the curb operate to restrain the bran against the action of the outer curved rows of moving pins or wings, and continue the attrition or rubbing, until it is discharged through the spouts below. It will thus be seen that the violent rubbing of the bran upon bran and against the smooth steel pins is very effective, while, in a mass so yielding, the pressure cannot be at any point so violent as to destroy the granular form of the middlings detached, nor can it comminute or pulverize the bran. Each side of this machine is a duplicate of the other, and yet quite separate, distinct and independent. Each side may act on different qualities or conditions of bran, simultaneously, and at the same time keep them separate.

The bran from high grinding requires two operations, in order to clean thoroughly. It is spouted into the hopper on one side of the machine, as it comes from the bolting chest, passes through the machine and out of the discharge spout at the bottom, on the same side. It is then sent to a scalper, to take out the flour and middlings that have been scoured off. From the tail of this scalper, the bran is spouted into the hopper on the other side of the machine and undergoes a second operation. From there it is sent to another scalper which takes out the flour and middlings scoured off by the second operation. All bran from hard wheats treated in this way will be perfectly clean, but bran from soft wheats should, in most cases, be afterward sent to a brush bran duster. The capacity of this machine is from twelve to fifteen tons of bran in twenty-four hours, and is driven by a four to six-inch belt.

*The last of these machines used in this system is the "Chicago Middlings Mill," which is the result of Mr. Mills'

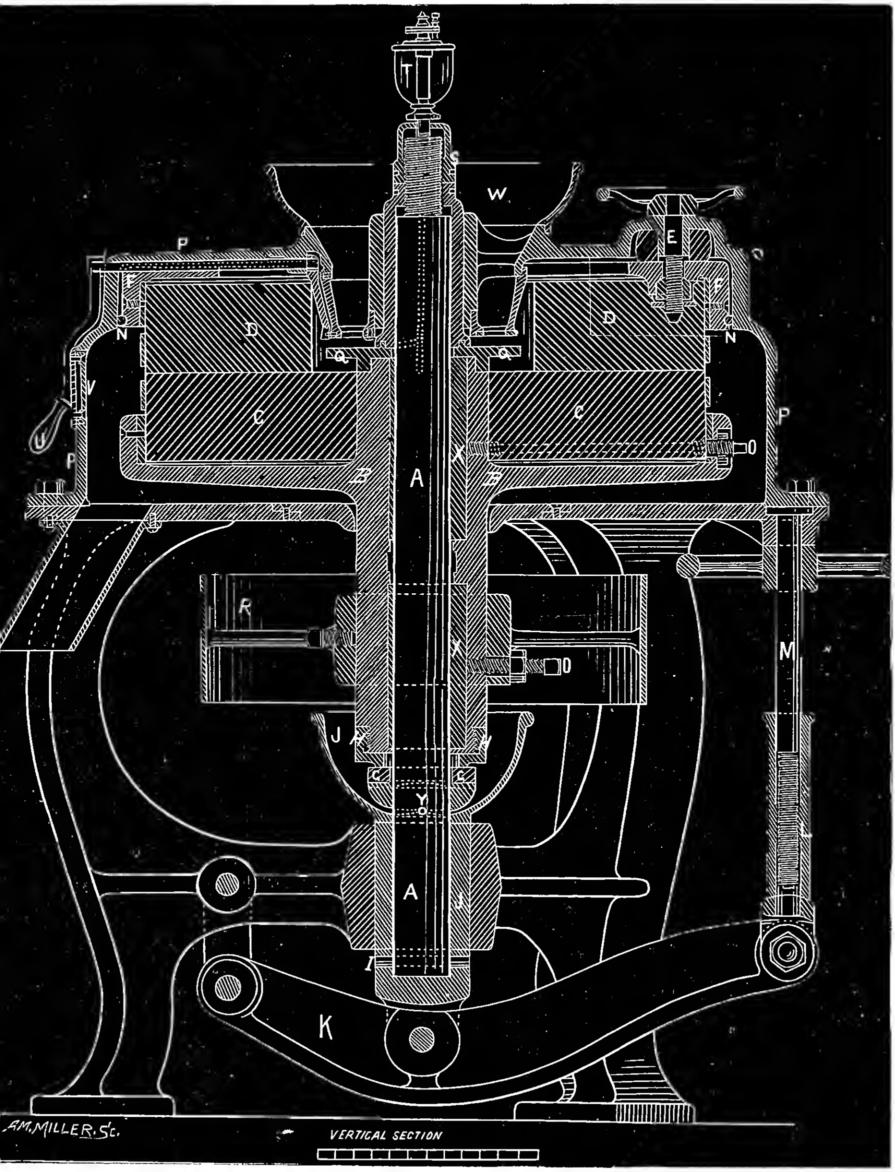
*The author of this work disclaims any intention of indicating a preference for any particular make of middlings mill, or other special machine. The above mentioned mill, and other machines referred to and described in this article, are so described because of the fact of their being new, and their association and connection with the system presented. After a careful examination and investigation of the system as a whole, I am satisfied that it is valuable, but do not wish to be understood as assuming that other middlings mills, or other bran machines, will not work just as well, even in that system.

experiments for a number of years with rigid under-runner mills. Mr. Mills' theory is (and he claims to have fully demonstrated it in practice), that rollers and oscillating millstones are incapable of producing the perfectly fine, round, even granulation necessary for the production of the highest possible grade of flour, on account of defects of principle and operation. He therefore began a series of experiments, in order to remedy the defects of ordinary under-runner mills, and with such success that he is enabled to use thirty and thirty-six inch stones in the Chicago middlings, without end-shake or oscillation of any kind, the two things antagonistic to even and perfect granulation with millstones.

One of the first peculiarities of the machine is that it reverses the ordinary relation of the spindle to the mill stone, for the former remains fixed while the latter revolves around it. In the sectional view, (Fig. 10), A, A, is a stationary steel spindle, firmly supported at the bottom and top, so that no lateral movement, or "spring," is possible. The runner, C, C, revolves around this spindle, being secured in the bed plate, B, B. A long hub or sleeve is cast solid with the bed plate. This hub or sleeve is bored out and provided with an extended bearing accurately fitting the steel spindle, A, A. This bearing is furnished with broad keys or gibs, X, X, which can be tightened by the set-screws, O, O, in order to take up any wear. By this means, the amount of friction is reduced to the lowest possible amount, all "side-shake" is avoided, and the greatest possible accuracy in running is secured.

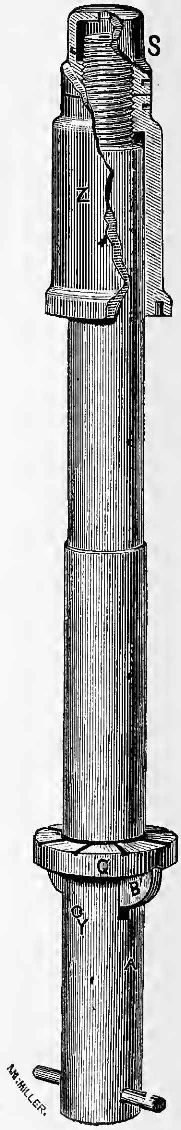
The combination for preventing end-shake is both ingenious and effective. Upon the upper end of the hub or sleeve of the bed-plate, B, B, is secured a cap-plate, Q, Q, and bearing upon this is a long sleeve, Z, (Fig. 11), accurately bored out to fit the upper end of the spindle. The bore of the upper part of this sleeve is smaller than that of the balance of the sleeve, and is threaded to fit a screw cut upon the upper end of the spindle. Above this is a cap or check-nut, S. This nut, as well as the sleeve, is tightened or loosened

Fig. 10.



by means of a spanner-wrench, and by adjusting them to the cap-plate, Q, Q, which is fastened to the sleeve of the bed-plate, all "end-shake" is positively done away with, while, at the same time, the freedom of the running stone is not interfered with, allowing, or rather causing it to run in a perfect plane.

Fig. 11.



The stationary spindle, A, A, is firmly keyed in the bridge-pot, J, J, by the pin, I. The bridge-pot has a vertical movement through the cross-tree, but is so accurately fitted that no lateral movement is possible. The upper end of the bridge-pot is flared out to form a large oil-cup, which catches all the oil and prevents its being thrown out and wasted. An adjustable annular step, G, G, is fixed to the stationary steel spindle, and upon the lower end of the hub or sleeve of the bed-plate is fixed a foot-piece, making a very easy running and a lasting step for the support of the running stone. The upper end of the spindle, A, A, is supported against lateral vibration by a cross-tree in the upper or cap plate of the machine, P, P, which forms the curb and supports the stationary, or bed stone. The bridge-tree in this cap-plate is bored out to fit the sleeve which fits over the upper end of the spindle, leaving it free to move vertically, while fitting so accurately as to prevent any side play.

The upper, or stationary stone, D, D, is securely fastened in a strong flanged ring, F. Three equidistant screws, E, operated by hand-wheels, pass through the top plate and through the flanged ring, F, and work into nuts placed in recesses on the under side of the flange. The hand-wheels bear upon the top-plate, and between the plate and the flanged ring are heavy rubber cushions, placed in suitable recesses in the top-plate. By means of the screws, E, the upper stone may be accurately trammed, and the rubber cushions will yield sufficiently to allow the passage of any hard foreign substances which may happen to get between the stones.

A neat feeding device placed at the bottom of the hopper, W, operated by the lever, U, feeds the middlings uniformly upon the revolving plate, Q, Q, from which they pass between the stones. The lower, or running stone, is driven by a pulley, R, placed on the extended hub of the bed-plate, B. The bridge-pot, carrying with it the stationary spindle, the running stone and the nut and sleeve to prevent end-shake, is raised or lowered as required by means of the lighter-bar, K, hand-wheel and lighter-screw, M, L. An automatic oiler, T, is placed upon the upper end of the stationary spindle, and through the hole, shown by the dotted lines in the spindle, supplies oil to all the running parts of the mill.

The points of superiority of this system may be briefly summarized in conclusion, as follows: In the process of gradual reduction the germ is removed from the wheat without being broken, and therefore the discoloration of the flour caused by incorporating the germ in it is avoided. In a similar manner the bluish dirt in the crease of the berry is taken out before the wheat is reduced to flour and therefore the first and second reductions constitute a cleaning operation as well as a step towards flouring the wheat. The importance of this can readily be appreciated when it is remembered that the germ and bluish dirt once mingled with the flour cannot be removed by any system of bolting. Another important point is the fact that comminution of the bran is avoided, and the small particles of bran which are necessarily pulverized when millstones, or corrugated rolls, are used on the wheat, are not produced by these reduction machines, and are consequently not found in the flour. This, with the foregoing facts, account for the extreme whiteness and clearness of the flour made by this system of milling. The use of the bran machine effects a large saving in material, which can be utilized in the high grade flour, while the improved middlings mill secures an even and perfect granulation of the middlings produced by the reduction machines.

ARTICLE IX.

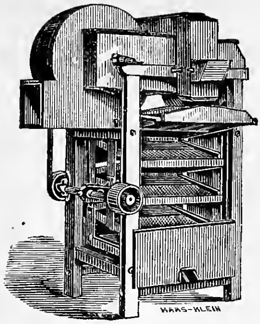
THE HUNGARIAN SYSTEM OF MILLING WITH ROLLERS.

The following description of the Hungarian system of roller milling, which is taken from a paper read by J. Ingleby, before a mechanical association in Manchester, England, is not as complete as we would desire, but covered as these things all are by patents, and the great show of secrecy in relation to the matter in this country, especially, prevents the obtaining of all the information we would desire; but trust there is sufficient to enable the reader to get a fair insight into the matter:

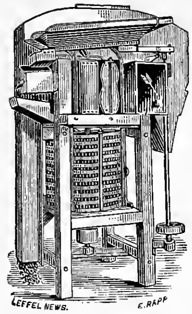
"I have undertaken, at the request of your worthy President, to direct your attention—in the short time at my disposal I cannot do more—to a subject connected with a very important, if not *the most* important branch of manufacture, viz: that which provides us all, from noble to artisan alike, with our daily bread. However unworthily I may describe it, a process which claims to produce the "staff of life" of a better quality and at a less cost than heretofore, cannot fail to be of some interest to you. Moreover, this question of milling with rollers instead of stones is just now agitating the whole milling interest in this country; for, the British miller has just awoke to the conviction that to meet the competition of cousin Jonathan in *price*, and of the Hungarian in *quality*, demands a radical change in his mode of manufacture. *America*—with always an enormous surplus of cheap grain, and with numerous and immense milling establishments specially adapted for the unvarying material close at hand, directed by most shrewd and energetic minds, and favored by cheap freights and the natural preponderance in favor of the shipment of flour instead of grain—America is formidable in *price*, but *Hungary*—with twelve giant mills in one town alone producing nine million hundredweights of flour per annum, selling their low qualities at home and sending to England one-and-one-half million hundredweights per annum of the very finest flour, such as no English miller *can* produce, but *must* buy in order to mix with and render salable his own product—Hungary is still more formidable in *quality*. When our native millers' ordinary article is selling at 40s. per sack, America can afford to send quite as good flour at 26s. to 30s., and yet Hungary can tempt us to buy her unapproachable brands at 50s. to 60s. per sack. The difference on either side represents a very considerable disadvantage to the English miller.

"In addition to the above considerations, I hope my subject will specially commend itself to those present insomuch as the introduction of roller milling means a greatly increased employment of machinery in our mills, and the addition of another branch to the science of mechanical engineering in this country.

"It will first be necessary to devote a little attention to the object and usual mode of grinding corn. The object is, broadly speaking, to reduce the grain by bruising, grinding, or pulverizing into such a state of fineness as is required for the purpose of making bread of the quality demanded by the public at large. In the earliest ages it was natural to use the friction of two stones, one upon the other, for this purpose; all savage nations are found doing so to this day; but whilst civilized man has long since discarded all other implements of the "stone age," such as stone hammers, axes, weapons, etc.—and has successively advanced through an age of bronze into one of iron, out of which he now seems emerging into an age of steel—no other implement but the millstone has ever, until our own times, been generally employed for grinding corn for bread. Its antiquity and unchangeable construction are truly marvellous. In the time of Job the hardness of the nether millstone—the bot-

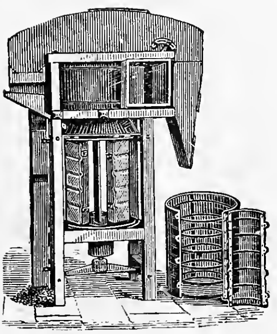


No. 1. Eureka Separator

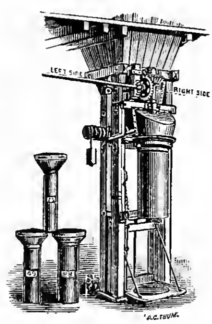


No. 2. Eureka Smut and Separating Machine.

No. 5.



No. 3. Eureka Brush Finishing Machine.



No. 4. Silver Creek Flour Packer.

SEPARATING, BRUSHING AND PACKING MACHINES.

Made by HOWES, BABCOCK & CO., Silver Creek, N. Y.

(See Appendix, page xxiv.)

tom fixed one—was proverbial, and when the doom of the first-born of Egypt was pronounced, not even the son of the "maidservant that is behind the mill," whirling round the upper stone, could escape. And still the chant of the women at the mill is to be heard in the East, and though in the West we have altered the mode of application and the character of the motive power, we cling to the use of the upper and nether millstones, and almost regard the substitution of any other means of grinding corn as sacrilege. And as long as the bread eater was satisfied with "whole meal" bread, and flour meant nothing but ground grain, more or less fine, no better implement than the millstone was required; but this is not now the case. We began by desiring closer grinding and "fine wheaten flour;" then we thought it better without the bran and invented wire sieves to dress this off, and having thus embarked on a course of dressing and sieving we next took out the fine bran and the coarse sharps; then, when silk dressing cloth appeared, the fine sharps; and eventually we insist upon having our bread of the finest and whitest, sweetest and strongest flour that can be made. It is this demand for what is called 'color,' 'strength,' and 'flavor' in flour that has doomed the millstone and called up the roller mill.

"The change that has taken place in flour milling is both curious and instructive. The ordinary miller in this country endeavors by the shape of the surface or 'dress' of his millstones, and by bringing his stones almost close together, *i. e. grinding low*, to reduce as much of the grain to flour at one passage as is possible. This endeavor is limited on the one hand by the whiteness of the flour required, because with stones too low a large quantity of bran would be ground up fine with the flour and discolor it, and on the other hand by the fact that the heat developed in grinding with the stones close together would certainly spoil and often fire the flour. Nevertheless, he manages generally to get some eighty per cent. of best flour out of wheat which only contains seventy to seventy-five per cent. at the first—or rather he grinds up five to ten per cent. of bran so fine that it is obliged to go with his flour.

"Besides flour and bran the miller obtains a small proportion of unground kernel of wheat, in a granular state, of about the fineness of fine sand, and of course mixed up with bran of the same size, so that any attempts to regrind it, as it is, result in flour so 'dark' as to be unsalable, except as food for cattle. This granular product is known as 'sharps' or 'middlings,' and of late years a machine, called a 'middlings purifier,' has been invented and brought to great perfection by which these sharps are exposed, in various ways, to the action of a current of air, which carries away the light bran and dust and leaves the middlings or particles of kernel pure and white, in a suitable state for regrinding. It was then a considerable revelation to many a miller to find that what he had been selling as pig food, and endeavoring to produce as little of as possible, *made the very best of flour* when purified and reground by itself. This revelation produced a revolution, for ere long millers became convinced that the true method of milling would be to reverse the old practice, and instead of producing at once much flour and little middlings, to make much middlings and little flour. The first step in this direction was naturally to set the millstones further apart, or 'grind higher,' also, to hollow them out in the center and thus grind less closely, but then there came the difficulty that by doing so the bran was not cleaned, but had a deal of flour adhering to it. This necessitated a regrinding of the bran, and the flour resulting therefrom was of very poor quality, unsuitable for the English market, and representing a loss of yield which simply prohibited the 'high grinding' system to the average English miller. In Hungary, on the contrary, it was generally adopted. The stones were set and dressed to produce much semolina and middlings; the best of these when purified very carefully and thoroughly, were ground on special stones, and the beautiful white flour resulting shipped off for sale at high prices to fastidious John Bull, whilst the residue of dark flour found a ready buyer in the numerous peasantry on the spot, so that, what to the English miller was loss suited the Hungarian from sky to ground.

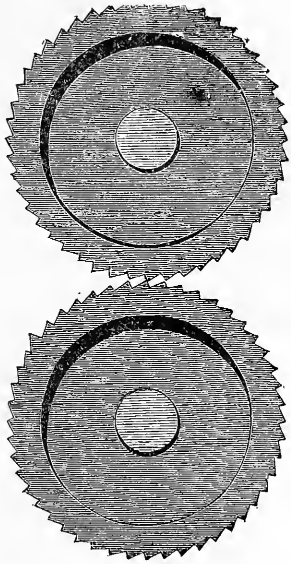
"The employment of stones as the grinding agent still entailed a considerable loss in color and quality. However high the stones could be advantageously set *some* bran is ground down with the flour; however carefully and expensively purified, the middlings contain *some* branny particles still, and the heat evolved in stone grinding always remains a troublesome and injurious element. Therefore the Hungarian millers sought a substitute for the stones which should produce more middlings, and also reduce these to flour without pulverizing the bran, which should do this without heat, and, if possible, with economy in power. It was natural to have recourse to the gentle roller friction and pressure of two cylinders in place of the more acute grinding action of two flat stones. A moment's consideration of the lengthened stay and travel of a grain of wheat between and across the sharp stones before it escapes at the periphery as flour, compared with the short momentaneous nip between two rollers will convince that the latter method will grind cooler, attack the bran much less, and require less power, although the total reduction of the wheat will be more gradual, and take a longer time. The flour will, however, retain all its natural flavor and properties.

"Of course the first attempts at the application of rollers were failures in many places, but the principle was recognixed as right and practical; especially in grinding semolina or middlings, a great advantage is on the side of the rollers, which crush into powder the grains of unground kernel, but only flatten the tougher particles of bran, thus rendering them easy to dress out of the flour, and removing the necessity for such excessive purification as is required for stone grinding. The roller mill therefore soon became an established fact, and a large mill was established in Pesth, which worked entirely with rollers, and notwithstanding the great improvements since made, still holds its own, supplies flour which obtains top prices and thus proves the superiority, even of defective roller mills, over stones.

"I cannot now do more than indicate some of the improvements successively made in these mills until the present types were reached, and then conclude by a rather more detailed explanation of the construction and application of the one with which I am more intimately acquainted.

"The first rollers were made of ordinary cast iron, placed in pairs side by side, pair above pair, and with rigid bearings: generally only one roll was driven, the other being turned by the friction of the wheat passing between the two rolls. It was soon discovered that ordinary iron wore away very fast under the action of the silica accompanying the husk of wheat, and chilled iron of the hardest and toughest quality, has, after much experiment, been found to be the only material which gives a really satisfactory result. Then the pressure was found insufficient and too rigid, so that the rolls have now been provided with increased and elastic pressure; also the piles of rolls one above the other proved too cumbrous and expensive, so that smaller mills containing but two or four rolls were generally adopted. Then the relative velocity of the rollers was discovered to be of great importance. At first the rollers had the same circumferential velocity, but experience taught that conspicuously better results were obtained by employing what is known as differential speed, and making one roller run considerably faster than the other. It stands indeed to reason that the smooth rollers working by mere direct dead pressure press the flour, so to say, forcibly into the bran, and consolidate it into cakes or flakes, whereas with differential speed a kind of abrasive action, scraping or pushing the flour off the bran is produced. Carefully conducted experiments have proved that direct pressure without differential speed produces one-third less result than the same pressure with it. Smooth rollers also soon gave place to fluted or grooved ones for reducing or granulating the wheat, the result being a great saving of power, for the power consumed in crushing grain by direct pressure of *smooth* rollers *without* differential speed is exactly *double* that required to reduce grain between *fluted* rollers *with* differential motion. The section of rollers ordinarily used for this purpose is shown in Fig. 1. The grooves or flutings are put on with a twist, like the grooves in a gun. 'Rifled' rollers might therefore be an appropriate name for them. The twist has the effect of preventing the grooves of one roller from catching within those of the other, even when close together, for those of the quicker speeded roller continually overtake those of the slower one, producing an action which would be a kind of shearing if the rollers really touched each other. But this not being the case, it really consists in twisting the parts of the grain against each other, the sharp corners of the flutings holding the outside of the grains fast, and, as it were, pushing the opposite sides of each grain in opposite directions, thus opening them, and disintegrating their contents. Such rifled rollers can now be produced by special machinery in the very hardest chilled iron, and last for years without sharpening or grinding.

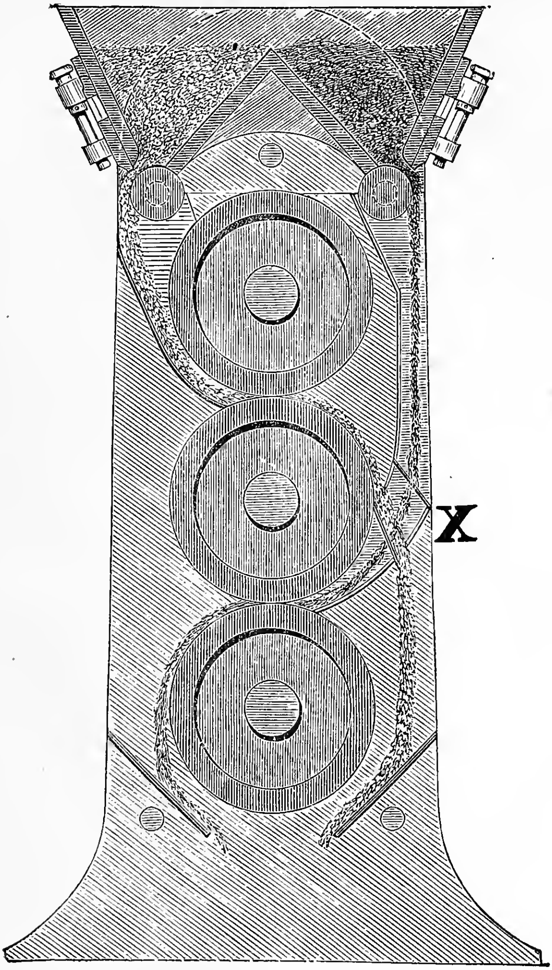
Fig. 1.



"A great impetus was given to the introduction of roller mills in 1874, by the invention by Mr. Frederick Wegmann, of the *Porcelain Roller Mill*, in which an entirely new material, viz.: porcelain or biscuit China was used for the rollers, and the whole mechanism was very much improved between 1874 and 1876, and converted into a much more serviceable and sensible tool than had hitherto been made. The effect produced by the introduction of porcelain rollers was very great, in fact unreasonably so. Their attractive appearance, their dull fine granular surface, the very beau-ideal of what a miller's stones should be, the novelty of the thing, and the really splendid work they perform whilst new upon middlings, created quite a strong prejudice in their favor, and certainly greatly facilitated the adoption of the roller system.

"Many mills also with iron rollers are made upon the same principle, but Mr. Gustave Daverio, of Zurich, who had considerable experience in the construction and manufacture of Mr. Wegmann's mill, invented a new form of roller mill, in which I think you will recognize some great improvements. He had the happy idea of using three rollers only, instead of four, placing them vertically one upon the other, and thus obtain with three rollers (consequently with six journals only) the *same effect* as the horizontal mills with four rollers and eight journals. To effect this, an apparatus had to be contrived to direct the material from the hopper in two different streams, one of which to pass between the top and center roller, and the other between the center and bottom roller. Several devices were tried ineffectually, until Mr. Daverio hit upon the idea of employing what may be called a cross channel piece, see X, Fig. 2, which allows the material ground between the top and center rollers to fall down past the two lower rollers, and conducts the material to be ground between the center and bottom rollers, right across or through the first named stream of ground material, into the desired place between the two lower rollers, without the two streams mingling in any way. With the application of this beautiful device, the use of the three-high-roller mill became possible and successful. The saving of one quarter in power by the elimination of one roller out of four is self evident. But it is even much larger than appears at first thought, for the top and bottom rollers being made to press equally from opposite sides against the *middle* roller, it follows that the friction of the two journals of this roller is almost entirely annihilated or counterbalanced. There remains, therefore, virtually only the friction of the top and bottom journals, *i. e.* other things being equal, the friction in good three roller mills, is by these circumstances, bound to be

Fig. 2.



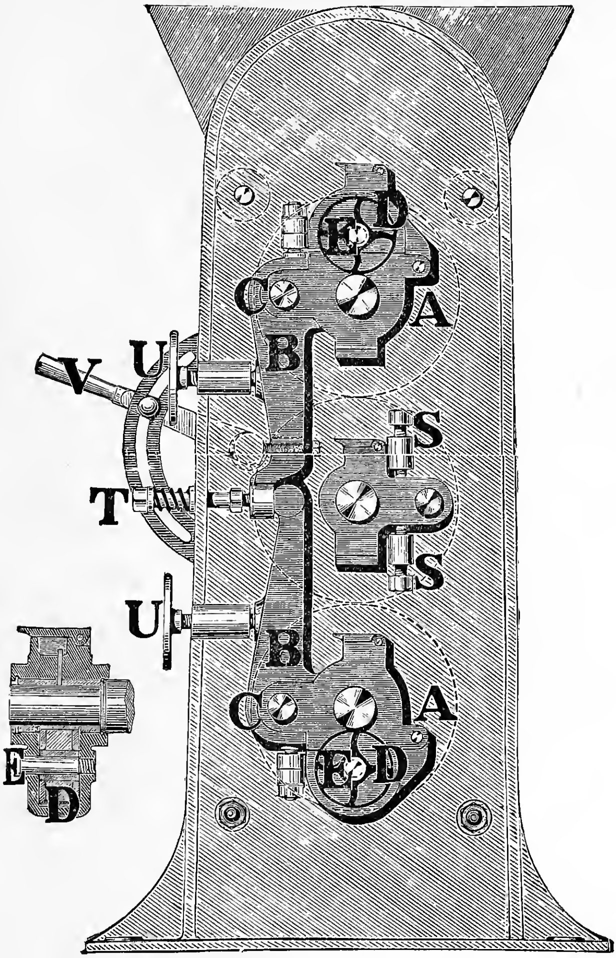
only about half that of the four roller horizontal mills.

"But a further step remained to be achieved, viz.: the further reduction of friction or power consumed for driving these mills. For this purpose a very ingenious contrivance is used by a firm called Ganz & Co. It consists of placing upon each of the outer ends of the shafts of the top and bottom rollers, on either side of the frame, a small ring, and on these rings a large steel hoop is sprung, so as to embrace the two roll shafts with the requisite pressure, whilst they in turn cause the hoop to revolve by their rotation and thus relieve the friction of the bearings. To regulate the tension of the hoop, a small roller is brought to bear on a third point on its internal circumference, which roller can be moved in or out to tighten or slacken the anti-friction hoop. This way of effecting the object is hardly of much practical use. The hoops in question, owing to their great diameter, must have an undesirable degree of elasticity, and they are themselves continually subjected to a regular cold-rolling process, combined with a tendency to take a triangular shape, which must cause them in a very short time to deteriorate and become practically useless. Mr. Daverio has solved this problem in an entirely different and very ingenious way, as shown in Fig. 3. He carries the journals ot the upper and lower rollers in bearings, A, A, forming part of the bell-crank levers, B, B, which have their fulcra at C, C. The pressure of the swing rollers in these bearings is taken up by the friction rollers, D, D, and transferred to the small steel pins, E, E, upon which they revolve. Supposing for instance the diameter of the rollers, D, D, to be six times as large as the diameter of the pins, E, E, then the power required to overcome the frictional resistance between the said roller and its pin will be only the sixth part of the power that would otherwise be necessary for overcoming the friction between the journal and its brasses. The brasses shown in the sectional view serve only to prevent lateral play of the journals, and are cut away to allow the friction rollers to come in contact with the journals.

"In this manner the friction is really and practically reduced to a very considerable extent, as is proved by the extraordinarily low amount of power required for driving

Daverio's mills, viz.: one-half to one horse power per mill. In a mill in Manchester a ten-inch strap drives nine roller

Fig. 3.



mills, and all the accompanying dressing machinery, leaving still margin for one or two more mills, although as it is, this ten-inch strap drives the complete plant necessary for grinding seven hundred sacks of wheat per week. Compared with millstones, such well constructed rollers are proved to effect both in theory and practice, a saving in this direction of fifty per cent., *i. e.* to do the same work with only half the power. Mr. Daverio's lever arrangement has other great practical advantages: the center roller is fixed by set-screws, S, S, in the proper position, and the necessary motion, in the vertical sense, of the top and bottom rollers, *i. e.* their pressure upon the center roller is effected, regulated, and rendered elastic by means of the springs on either side at T, and hand-wheels at U, U. The hand lever, V, sits upon a cross shaft, carrying a small excenter on either side, acting upon the long ends of the levers, B, B, and thus serves for instantaneously increasing the distance between the rollers by simply putting it down. In this way the difficulty in starting often experienced in all other roller mills, owing to a wedge of material having formed between the rolls, is perfectly and easily overcome. This lever forms a great advantage possessed by Mr. Daverio's mill over all others. By it the distance between the rolls can be altered whilst the mill is working, *without taking the pressure off*, thus the pressure is independent of a regular feed, and an irregular feed does not affect at all the position of the rolls, whereas in other mills if less feed goes in on one side the rolls close in and touch on that side, wear irregularly, and give an irregular product. Any sudden cessation of feed causes a shock to the rolls, which this contrivance entirely prevents.

"The friction rollers are almost as important, on account of the services they render in lubricating the journals, as in reducing the friction. They oil the journals continuously and self-actingly, and running in closed boxes a great saving in oil results. Where the friction roller is above the journal others are provided below it to do the lubrication. Practical men will know that this saves *power i. e. money*, besides ensuring immunity from hot bearings, and less care and attention necessary in working.

"Having now considered the construction of the roller mill as such, let us proceed to examine its application in a complete roller mill system. The gradual development of this implement into a compact, ingenious, and serviceable shape was difficult enough; the questions to be solved, and the opposition and prejudice to be overcome in applying the same in practical milling were still more formidable, especially in this country. The English miller uses wheat from all quarters of the globe, some small and hard grain, some large and soft, some red, some white, and beyond this, has generally a special quality of flour suited to the habits and prejudices of each separate district, to produce. On the old system he meets these requirements by mixing his wheat in varying proportions, but beyond this his mode of manufacture is extremely simple. He grinds his corn at *one* passage through the stones, passes the meal into a scalping reel to take off the bran and coarse pollard, the remainder goes into his silk dressing machine, and is there at once divided into finished flour, sharps and tailings. He may have gone to the extent of adding a purifier for his middlings, a special pair of stones with which to grind the purified middlings, and a centrifugal dressing machine to dress the meal from them; but he is quite an advanced miller if he uses a pair of rollers instead of the last named stones, and endeavors to produce as many sharps or middlings as the old system will allow.

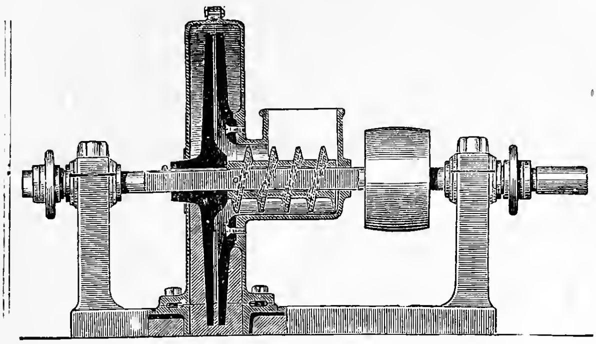
"But to proceed and embrace the roller system entirely, and make the production of middlings the *main* object, requires a much more complicated system, as you will see by the following description of the general features of a Daverio roller mill plant, as devised and simplified to meet the wants of the English trade.

"The process is divided into four main operations. Firstly, the cracking; secondly, the granulation of the wheat-berry; thirdly, the cleaning of the bran; and lastly, the reduction of the semolina or middlings to flour. The wheat first enters a set of cracking rolls, which are set some distance apart, and are either plain or provided with coarse flutes, according to the kind of wheat to be treated. The cracking is an important operation, and has a double object. Primarily it is a continuation of the wheat cleaning, for the grains of corn in their passage to and between the rollers of this mill rub against each other and the rolls are also opened out at the crease, thus letting the dirt which lodges there and on their surface fall away, and what is equally important, the slight squeeze unseats the germ and causes it to fall off, either at once or in the dressing cylinder which follows each mill. Impurities which in stone grinding are injuriously mixed with the flour, are thus removed in the cracking, the product from this operation being about *one* per cent. of the wheat, half of it germ and dirty flour, and the remainder inferior semolina. Besides this, the cracking rolls squeeze and open out the grains without flattening them or breaking the bran to any extent, thus preparing the wheat for *granulation*.

"This operation is performed by four sets of rollers, alternately smooth and fluted, the last being the bran cleaning mill. The broken wheat, after passing each mill, goes through one-half of a special double dressing machine, by which the semolina and flour produced at each passage are removed, and the residue passed on to the next mill. The work of these mills is to reduce the contents of the berry to semolina and middlings, whilst keeping the bran as unbroken as possible, and also making as *little* flour as the nature of the wheat will allow. You will note again that this is the very opposite of the stone grinding, and constitutes the main difference between the old and the new systems. This makes as *little direct flour* and as *much middlings* as possible during the reduction of the wheat; that makes as *much direct flour* and as *little middlings* as possible. The stones produce the best flour at *the beginning* of the process, the rollers keep it till *the end* when it has been removed from all contact with the bran.

"The bran from the third set of rollers being to a great extent denuded of flour is finally passed through the fourth or last set (having very fine flutes) and scraped almost clean. Any flour still adhering to it is recovered by passing it through a detacher consisting of two chilled iron disks with fluted surfaces, one fixed and one revolving at a high speed (see Fig. 4), between which the bran passes and is effectu-

Fig. 4.

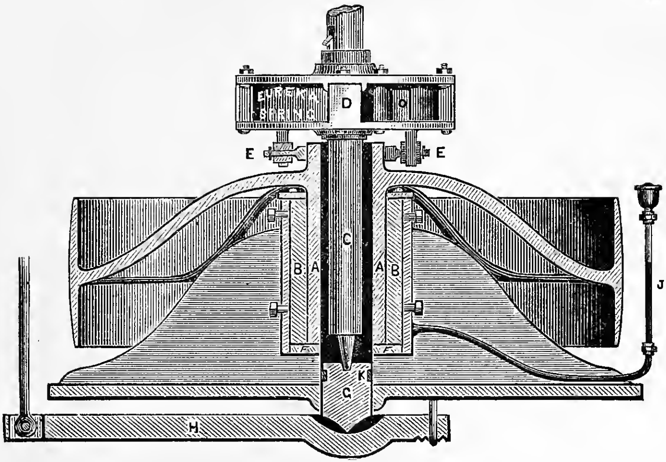


ally cleaned, until it represents but about fifteen per cent. of the wheat. The remaining portion has fallen through the meshes of three dressing cylinders, partly as flour, but principally as semolina mixed with fine bran and pollard. The small quantity of dirty product from the first cylinder is sacked up for separate treatment. The flour and fine middlings from the second and third dressing machines are conveyed into another flour dressing silk, where they are dressed and make *third quality* flour. The coarser particles or middlings which pass over the tail of this silk go to a purifier. The semolina and sharps from the second and third cylinders, or dressing machines, pass to a second purifier, where they are first divided into three sizes, then purified of the bulk of the bran mixed with them and conveyed in rotation unto one of the smooth roller middlings mills, where they are broken down or softened gradually into flour. As they fall from the rolls, partly in flakes, a detacher is used to break these up and facilitate the dressing of the meal in a fourth dressing machine. Here the flour of *second quality* is taken out and the residue of fine middlings passed on by a feeder into the first mentioned purifier, where the fine bran, fluff, and dust are drawn off, leaving the finer middlings pure and ready for further grinding. This is done on another double roller mill provided for the purpose, the meal therefrom is dressed in a fifth dressing cylinder, where the flour obtained is naturally of the *first quality*, being the product of middlings at least several times purified. If the very finest qualities are required, the softening down of the semolina is performed more gradually, it makes the round just described several times, so that the last flour is very fine, being made from the finest middlings purified from every vestige of bran or other impurity. The purifiers above mentioned produce not only pure middlings but also bran containing more or less of light middlings which the blast has carried with it, so that they really divide the material passing through them into two principal sorts, one being semolina, more or less pure, and the other fine bran with a sprinkling of semolina. These sorts are each crushed on separate roller mills. The tailings or residue from purifiers and dressing machines continue to be repurified, reground, and redressed, so long as any flour can be got out of them; they remain at last as pollard, and the flour from these being naturally inferior is mixed with number three flour, or perhaps with that from the cracking process to form a fourth quality.

"The plant thus described will produce, roughly speaking, from good sound wheat, twenty per cent. of number one flour, forty per cent. of number two, and ten to fifteen per cent. of numbers three and four mixed; or it can be arranged to run all these products together, and make one even quality or 'straight grade' of good seventy per cent. *In either case fully fifty per cent. of the flour thus obtained will be much better in color and quality than that ordinarily produced by stone grinding from even better wheats.*

"Notwithstanding that it is much more complicated than the old system, the plant just described is very simple compared with the monster establishments of Hungary, where every granulation is kept separate and passes through its own series of purifying and repurifying, dressing and redressing, until some twenty different qualities are finally produced, of which only about the five first are sent to this country. A large mill is now being erected upon this system in Belfast, in which all the semolina will be purified thrice before *each* rolling, and all the flour dressed thrice before it is finished and packed. In Manchester and London, two large establishments, on the plan I have described, have been working for a considerable time; two others are being erected in England; two more in Ireland; and even in America the change to rollers is in active progress, as several of the most important firms there are going over to the Hungarian system.

"Thus the new method of gradual reduction instead of direct grinding, of the use of rollers and the production of middlings, has been recognized as rational, practical, and suited to the requirements of the age, has been adopted almost universally in Hungary, largely in Germany, is making progress amongst the enlightened millers of America and Ireland, has penetrated in not a few places the prejudice and conservatism with which the English miller is surrounded, and is beginning to shake the gates of the stronghold of stone grinding in France. There can be no doubt that as the taste for pure white bread, with the rich flavor and natural strength of the grain preserved in it, spreads and becomes universal, so the extension of the use of roller mills will naturally follow, and there can be little doubt the use of millstones will correspondingly decrease. It seems very doubtful, however, whether the latter will be ever entirely discarded. One of the best authorities tells us that, 'regarded from mechanical standpoint, the millstone is a very perfect machine, and in the struggle for existence the rollers will never thoroughly banish the stones,' but you will note that it is 'a struggle for existence,' and indeed the defenders of the millstone are often very apologetic, which is a bad sign. But, whatever the result, those I am now addressing can only profit by it. The introduction of roller mills will bring more work for the millwright, the foreman, the draughtsman, and the mechanic; it will at least stimulate the improvement of the millstone and all other milling machinery, and as its tendency is undoubtedly to provide us all with whiter, purer, sweeter, and cheaper bread, I am sure you will agree with me in saying, 'let the best horse win.'"



EQUILIBRIUM DRIVING PULLEY FOR MILL SPINDLES.

Made by JOHN A. HAFNER, Pittsburgh, Pa.

(See Appendix, page xvii.)

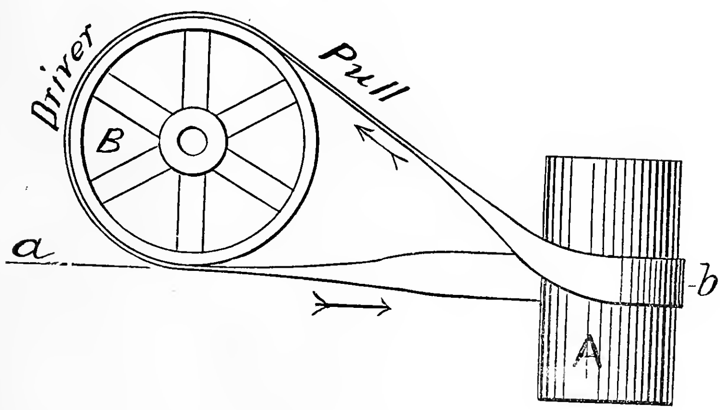
ARTICLE X.

THE ARRANGEMENT OF BELTS.

The following very useful lesson on the arrangement of belts, written by Frank C. Smith, M. E., we take by permission from the columns of the *American Machinist:*

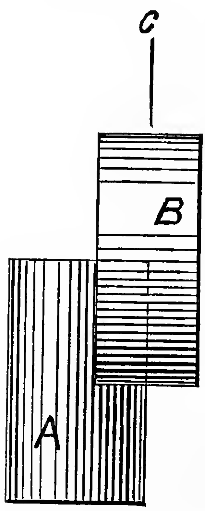
"In putting up a quarter twist belt the following points must be looked after: The pulleys must be far enough apart to allow of an easy twist in the belt. The side of the driving pulley giving off the belt must come on a center line, as a, b, of the one receiving it, as shown in Fig. 1.

Fig. 1.



The center line, C, Fig. 2, of driving pulley, B, must be on a line with the side of the receiving pulley; that is on that side of the receiving pulley from which the belt runs. In transmitting motion from one shaft to another running at right angles to it, the 'idlers' or 'corner pulleys,' C, Fig. 3, must have their peripheries coincide with the center lines of the pulleys, as A, B, in the plan view and in the elevation, Fig. 4; the center lines of the idlers must coincide with the perpendicular centers of the pulleys, A, B, as shown; either of which may be the driver. In case of a difference in size between A and B, the faces of the 'idlers' must be increased to accommodate the angle of the belt. Wooden pulleys when the size of the pulley is large, are preferable to cast iron, especially when the want of a pattern of the required pulley is wanting. The rim of such pulleys is 'built up' of pieces sawed for the purpose, glued and nailed, peaking joints. The arms are 'built in' and at the center are 'halved together;' that is, the arm, A, Fig. 6, is received in one-third of its thickness on each side. The piece B has a recess two-thirds of its thickness deep, as has also the piece C, in the directions shown at A, B, C, Fig, 7. Two cast iron flanges previously bored out are bolted on as shown, and the face of the pulley turned off after it is mounted on the shaft. A set of 'cones' with regular steps—that is with the diameters of the largest and smallest equal to the diameters of any other two pair of steps may be used if a crossed belt is run on them.

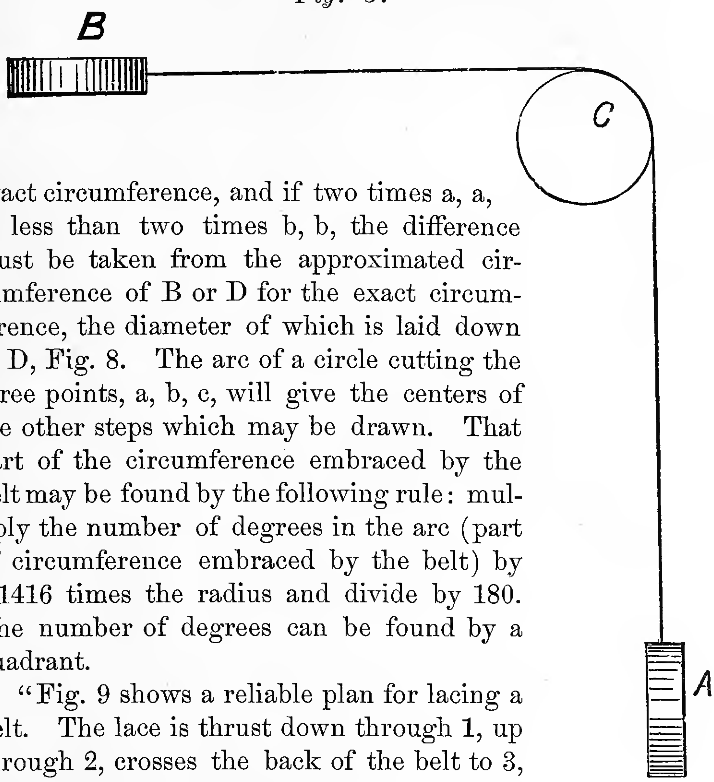
Fig. 2.



"When a straight or open belt is used, the steps can be found by the following method: Knowing the diameters of the largest and smallest steps, we may draw them as shown in Fig. 5, as A, C, with the proper distance between centers; also, an elevation, as A, C, Fig. 8. The length of the belt is that portion of the circumference of each step, A, C, that the belt is in contact with, plus twice a, a.

"The next thing is to find the diameter of the two middle or same sized steps, B, D. By subtracting twice the distance, b, b, from the length of the belt, we get the approximate circumference of either step, B, D. If twice the distance, a, a, is greater than twice b, b, the difference must be added to the approximated circumference of B or D for the

Fig. 3.



exact circumference, and if two times a, a, is less than two times b, b, the difference must be taken from the approximated circumference of B or D for the exact circumference, the diameter of which is laid down as D, Fig. 8. The arc of a circle cutting the three points, a, b, c, will give the centers of the other steps which may be drawn. That part of the circumference embraced by the belt may be found by the following rule: multiply the number of degrees in the arc (part of circumference embraced by the belt) by 3.1416 times the radius and divide by 180. The number of degrees can be found by a quadrant.

"Fig. 9 shows a reliable plan for lacing a belt. The lace is thrust down through 1, up through 2, crosses the back of the belt to 3, down through it, and up through 4, etc. The belt may, when laced across, be laced back again, by going from 10 to 7, up through 8, and down 5, etc., making a firm and lasting joint, which keeps the belt ends flush with each other, the lacing running parallel with the belt on the pulley side.

"Following are some useful rules for ascertaining the diameter of pulleys: Suppose you wish to run a machine

Fig. 4.

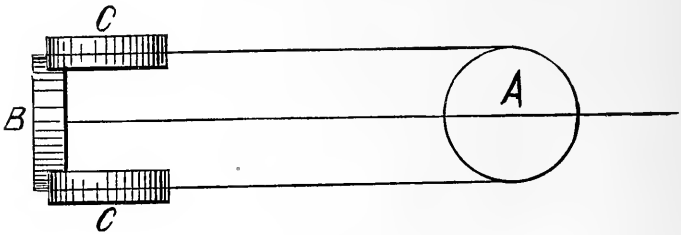
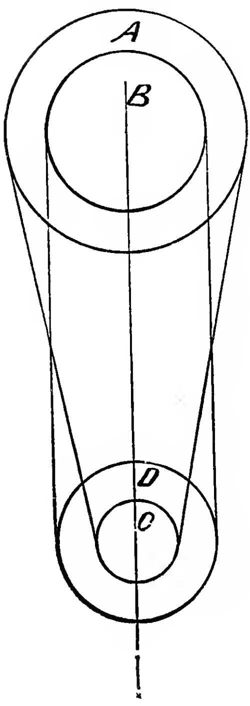


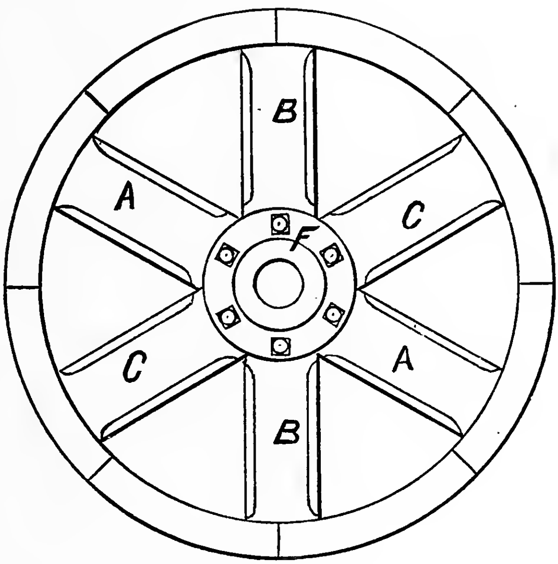
Fig. 5.



at a given speed from a pulley on a line shaft. The revolutions of the line shaft and diameter of the pulley on it being known, multiply them together, and divide this product by the number of revolutions the machine to be driven is desired to make; the quotient equals the size of the pulley to be placed on the machine. If there had been a pulley on it, and you wished to ascertain the number of revolutions it would have made, you would have divided by the diameter of the pulley instead of the revolutions. For exact work, from five to fifteen per cent. more speed than is wanted should be calculated upon, owing to the slip of the belt.

"Belts run over a leather-covered pulley, with the hair side next to the pulley will give the best results. The speed of a belt for exactness should be calculated by adding the thickness of the belt to the diameter of the pulley it runs over; this gives the center of this belt as the diameter of the pulley, "Belts should have an occasional dressing of castor oil. The writer remembers a thirty-inch belt that was immersed in castor oil nearly thirty years ago, and which has never been off of the original pulleys but once since, and only then on account of the removal of the entire shop and engine to new quarters. Pulleys may be 'crowned' three-sixteenths of an inch to the foot in width. The slack side of the belt should be, when possible, on the top side, as it increases the 'hug' of the belt.

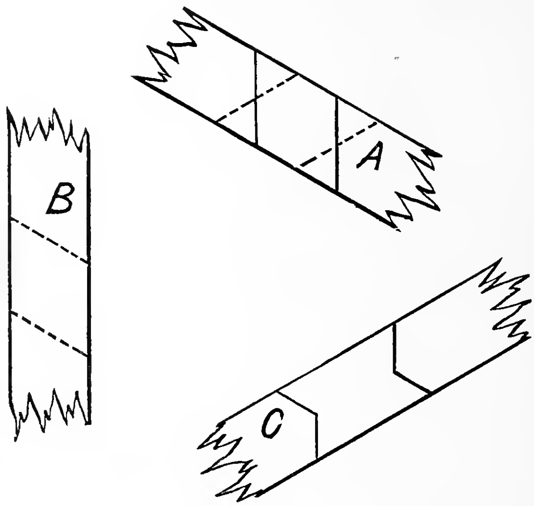
Fig. 6.



"To ascertain the correct length of belt to be taken out or put in when the pulleys are changed, multiply the difference in the diameters of the pulleys by one-half; the product equals the amount necessary. From sixty-five to one hundred pounds per inch in width is the correct amount to be transmitted by a belt three-sixteenths of an inch thick. The following rule has been used for some time by the writer for the width of belts in inches with satisfaction: multiply the horse-power to be transmitted by 5,400, and divide this product by the velocity in feet per minute; multiplied by diameter of smaller pulley in feet. This rule will be found to give a belt wide enough to do the work without slipping or tearing out."

We have already devoted considerable space, in another part of this work to belting, but as the field is exhaustive, the author feels constrained to add some additional remarks

Fig. 9.

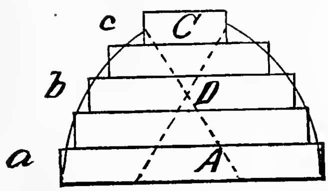


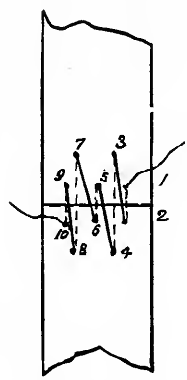
to Mr. Smith's very instructive article. In adjusting a reel, or quarter-twist belt, one important principle or rule should be committed to memory, by retaining which a necessity for examining diagrams will not be required. It is this: the fold or the side of the belt leaving the face of one pulley must approach the center of the face of the other pulley on a line at right angles with the axis of the latter, or it runs on the pulley at right angles with the axis and runs off at an acute angle with the axis. This is true of both pulleys, driver and driven. If this is not fully understood examine Figs. 1 and 2, and then read again, and keep doing so, until the principle is thoroughly understood. This of course applies only to belts untrammeled with guide pulleys or tighteners. By the use of these appliances directions can be changed.

As has been before stated, when a reasonable size has been reached, nothing in theory and but little in practice is gained by increasing the size of the pulley, unless for the purpose of increasing the traveling speed of the belt; this is

Fig. 9.

Fig. 8.





true so far as the co-efficient of friction is concerned; all other things being exactly equal, a belt will slip just as readily on a four-foot pulley as it will on a two-foot pulley; but in cases where belts run at a very high rate of speed the pulleys should be proportionately large to balance or counteract the effects of centrifugal force. The tendency of centrifugal force at high rates of speed is to throw the belt away from the pulley, and that unless guarded against is an important consideration. A belt traveling at the rate of five thousand feet per minute, and running over pulleys thirty-inches in diameter, would have twice the centrifugal force to contend with that the same speed of belt running over sixty-inch pulleys would have; the tendency to throw off would be twice as great, and consequently the tendency to slip, all other things being equal, would be twice as great. For this very important reason belts running very rapidly should run on correspondingly large pulleys.

The following useful matter in relation to belts is taken from "*Use of Belting*," by John H. Cooper:

Cement for Cloth or Leather—Molesworth.—Cut small sixteen parts gutta-percha, four parts India-rubber, two parts pitch, one part shellac, and two parts linseed oil; melt together and mix well.

Water-proof Cement for Cloth or Belting—Chase.—Take ale, one pint; best Russia isinglass, two ounces; put them into a common glue kettle, and boil until the isinglass is dissolved; then add four ounces of the best common glue, and dissolve it with the other; then slowly add one-and-one-half ounce of boiled linseed oil, stirring all the time while adding and until well mixed. When cold it will resemble India-rubber. When you wish to use this, dissolve what you need in a suitable quantity of ale to have the consistence of thick glue. If for leather, shave off as if for sewing, apply the cement with a brush while *hot*, laying a weight on to keep each joint firmly for six to ten hours, or over night.

Elastic Varnish—Smithsonian Report.—Two parts resin, or dammar-resin, and one part caoutchouc are fused together, and stirred until cold. To add to the elasticity, linseed oil is added. Another varnish for leather is made by putting pieces of caoutchouc in naptha until softened into a jelly, adding it to an equal weight of heated linseed oil, and stirred for some time together while over the fire.

To Render Leather Water-proof—MacKenzie.—This is done by rubbing or brushing into the leather a mixture of drying oils, and any of the oxides of lead, copper or iron, or by substituting any of the gummy resins in the room of the metallic oxides.

Water-proof Glue—MacKenzie.—Fine shreds of India-rubber dissolved in warm copal varnish make a water-proof cement for wood and leather. Another: glue, twelve ounces;

water sufficient to dissolve it; add three ounces of resin, melt them together, and add four parts of turpentine or benzine. Mix in a carpenter's glue-pot to prevent burning.

To Preserve Leather from Mould—MacKenzie.—Pyroligneous acid may be used with success in preserving leather from the attacks of mould, and is serviceable in recovering it, after it has received that species of damage, by passing it over the surface of the hide or skin, first taking due care to expunge the mouldy spots by the application of a dry cloth.

Castor-Oil as a Dressing for Leather. MacKenzie.—Castor-oil, besides being an excellent dressing for leather, renders it vermin-proof. It should be mixed, say half and half, with tallow or other oil. Neither rats, roaches, nor other vermin will attack leather so prepared.

Adhesive.—A good adhesive for leather belts is printer's ink. I have the case of a six-inch belt running dry and smooth and slipping, which latter was entirely prevented for a year by one application of the above.

To Fasten Leather to Metal.—A. M. Fuchs, of Bairere, says that in order to make leather adhere closely to metal, he uses the following method: the leather is steeped in an infusion of gall nuts; a layer of hot glue is spread upon the metal, and the leather forcibly applied to it on the fleshy side. It must be suffered to dry under the same pressure. By these means the adhesion of the leather will resist moisture, and may be torn sooner than be separated from the metal.—*Athenæum.*

Dressing for Leather Belts.—One part of beef kidney tallow and two parts of castor-oil, well mixed and applied warm. It will be well to moisten the belt before applying it. No rats or other vermin will touch a belt after one application of the oil. It makes the belt soft, and has sufficient gum in it to give a good adhesive surface to hold well without being sticky. A belt with a given tension will drive thirty-four per cent. more with the hair side to the pulley than the flesh side.—*F. W. Bacon, N. Y.*

Cement—A cement for joining pieces of leather, one which repeated tests have shown to be very efficient, may be made by dissolving in a mixture of ten parts of bisulphide of carbon and one part of oil of turpentine, enough gutta-percha to thicken the composition. The leather must be freed from grease by placing on it a cloth, and pressing the latter with a hot iron. It is important that the pieces cemented be pressed together until the cement is dry.

Water-proof Cement for Belting—*Moore.*—Dissolve gutta-percha in bisulphide of carbon to the consistence of molasses; warm the prepared parts and unite by pressure. To increase the power of rubber belting, use red lead, French yellow, and litharge, equal parts; mix with boiled linseed oil and japan sufficient to make it dry quick. This will produce a highly polished surface.

ARTICLE XI.

MECHANICAL POWERS—SOMETHING ABOUT THE PROPERTIES OF WATER AND STEAM—STRENGTH OF MATERIALS, ETC.

From "*The Mechanic's Text Book and Engineer's Practical Guide*," by Thomas Kelt, we make the following extracts:

"Mechanics, regarded as a science, comprehends the sum of our knowledge relative to the sensible motions of bodies either actually existing or expressed by the opposition of forces tending to produce motion. The science is thus resolvable into a code of discovered laws, applying to the causes which occasion and modify the direction and the velocities of motion, and is therefore distinct from those branches of science in which, although presenting phenomena of motion in sensible portions of matter, we do not consider the circumstances and laws of these motions, but only the effects produced.

"When motion itself is considered, the reasoning belongs to mechanics, and it is probable that as our knowledge of the laws which govern the phenomena that are evolved under the hand of the experimental philosopher becomes more extended, a wider meaning will be given to the science of motion. The definition which is here given of mechanics is not coeval with the name. The science, like most other sciences, has gradually expanded to its present extent. It was originally the science of machines—these being the first subjects of its speculation; and, as every material combination employed for producing or preventing motion may be regarded as a machine, and may be resolved into the same elementary principles as those employed in machines,—the mechanical powers—the name 'mechanics' became to be applied to motion, the tendency to motion of any bodies whatever. Mechanics still continues to be defined by some the science of force, and there does not appear to be any valid objection to the definition. Force is the cause of motion, and its laws are identical with the laws of motion: and consequently, the science of force coincides, in all its parts, with the science of motion, which is mechanics."

THE LEVER.

"To produce mechanical effects, it is rarely convenient to apply directly our available force—meaning by mechanical effect moving a body of a certain weight through a certain space—the assistance of machinery is required. In fact, the essential idea of machinery is, that it renders force available for effecting certain practical ends. Machines prepare, as it were, the raw material of force supplied to us from natural sources. It is transmitted and modified by certain combinations of the elements of machinery, and is given off, at last, in a condition suitable for producing the desired mechanical effect. We do not create force, the end of machinery is just to transmit it, and diffuse or concentrate it in one or more points of action. The various diffused or concentrated forces, then, being added together, will just amount to the original available force.

"All machinery, when analyzed, will be found to consist of a combination of six simple machines, or elements, commonly called mechanical powers. This term is not correctly applied to these elements. They are not powers, or, in other words, sources of power or force, they simply transmit and diffuse or concentrate forces. These six elements are, the lever, the pulley, the wheel and axle, the inclined plane, the wedge, and the screw.

"To understand, therefore, the nature of any machine, a correct idea of these elements is requisite.

"A lever is an inflexible rod, by the application of which one force may balance or overcome another. These forces are termed, respectively, the power and the resistance or weight, not from any difference in the action of the forces, but with reference merely to the intention with which the machine is used; and indeed the same terms are used about all the other mechanical elements. In applying the rod to operate upon any resistance, it must rest upon a center prop, or fulcrum, somewhere along its length, upon which it turns in the performance of its work. Thus, there are three points in every lever, to be regarded in examining its action, namely, the two points of application of the power and the weight, and the point resting on the fulcrum. There is a certain relation to be observed between the magnitudes of the opposing force, and their distances from the fulcrum, namely, that, in every case, the power, multiplied by its distance from the fulcrum, is equal to the weight multiplied by its distance from the same point. From this, simple rules may be deduced for calculation.

"To know the power to be applied, at a certain distance from the fulcrum, to overcome a resistance acting also at a certain distance, multiply the resistance by its distance from the fulcrum, which gives its moment, and divide the product by the distance given. Quotient will be the power, it being observed that the distance and the force be each expressed in the same unit of measure. For example, a weight, 1120 lbs., at 3 inches from the fulcrum, is to be balanced by a force at the distance of 10 feet. Now 10 feet are equal to 120 inches; and the moment of 1120 ℔s. is $1120 \times 3 = 3360$. Divide this by 120, we have 28 ℔s. for the power required.

"Again; to know the distance at which a given force ought to be applied to balance a given weight at a certain distance, we must, in like manner, multiply the weight by its distance, as before, and divide by the given power. 1120 ℔s. for example, at 3 inches distance, are to be balanced by a force of 28 ℔s. To find the distance of this weight, 1120 ℔s. multiplied by 3, give 3360, which, divided by 28, give 120 inches, or 10 feet."

THE WHEEL AND AXLE, OR CRANE.

"The mechanical advantage of the wheel and axle, or crane, is as the velocity of the weight to the velocity of the power; and being only a modification of the first kind of lever, it of course partakes of the same principles.

"To determine the amount of effective power produced from a given power, by means of a crane with known peculiarities:

"RULE.—Multiply together the diameter of the circle described by the handle and the number of revolutions of the pinion to one of the wheel; divide the product by the barrel's diameter in equal terms of dimensions; and the quotient is the effective power to 1 of exertive force.

"*Example.* Let there be a crane, the handle of which describes a circle of 30 inches in diameter; the pinion makes 8 revolutions for 1 of the wheel, and the barrel is 11 inches in diameter; required the effective power in principle, also the weight that 36 lbs. would raise, friction not taken into account:

$$\frac{30 \times 8}{11} = 21.9 \text{ to 1 of exertive force, and } 21.9 \times 36 = 785.5 \text{ lbs.}$$

"Given any two parts of a crane, to find the third that shall produce any required proportion of mechanical effect:

"RULE.—Multiply the two given parts together, and the quotient is the dimensions of the other parts in equal terms of unity.

"*Example.* Suppose that a crane is required, the ratio of power to effect being as 40 to 1, and that a wheel and pinion 11 to 1 is unavoidably compelled to be employed; also the throw of each handle to be 16 inches; what must be the barrel's diameter, on which the rope or chain must coil?

$$16 \times 2 = 32 \text{ inches diameter described by the handle.}$$

$$\text{And } \frac{32}{40} \times 11 = 8.8 \text{ inches, the barrel's diameter,"}$$

THE PULLEY.

"The principle of the pulley, or more practically the block and tackle, is the distribution of weight on various points of support; the mechanical advantage derived depending entirely upon the flexibility and tension of the rope, and the number of pulleys or shieves in the lower or rising block. Hence, by blocks and tackle of the usual kind, the power is to the weight as the number of cords attached to the lower block; whence the following rules:

"1. Divide the weight to be raised by the number of cords leading to, from, or attached to the lower block; and the quotient is the power required to produce an equilibrium, provided friction did not exist.

"2. Divide the weight to be raised by the power to be applied: the quotient is the number of shieves in, or cords attached to, the rising block.

"*Example.* Required the power necessary to raise a weight of 3000 lbs. by a four and five shieved block and tackle, the four being the movable or rising block.

"Necessarily, there are nine cords leading to and from the rising block;

$$\text{Consequently, } \frac{3000}{9} = 333 \text{ lbs., the power required.}$$

"*Example.* I require to raise a weight 4256 lbs., the amount of my power to effect this object being 500 lbs. What kind of block and tackle must I, of necessity, employ?

$$\frac{4256}{500} = 3.51 \text{ cords — of necessity, there must be 4 shieves, or 9 cords, in the rising block.}$$

"As the effective power of the crane may, by additional wheels and pinions, be increased to any required amount, so may the pulley and tackle be similarly augmented by purchase upon purchase. Two of the most useful are known by the term runner and tackle, and the second by that of Spanish burton."

THE INCLINED PLANE.

"The inclined plane is the representative of the second class of mechanical elements. Its fundamental law of action is that of the composition and resolution of forces. The manner in which the advantage is immediately derived from it is, therefore, distinct from that of the first class; there is necessarily a fulcrum, a point round which all the motion takes place, and through which the power acts on the resistance; whereas, in this class, there is no apparent centre of action. The advantage gained by the inclined plane, when the power acts in a parallel direction to the plane, is as the length to the height or angle of inclination. Hence the rule. Divide the weight by the ratio of inclination, and the quotient will equal the power that will just support that weight upon the plane. Or, multiply the weight by the height of the plane, and divide by the length—the quotient is the power.

"*Example.* Required the power or equivalent weight capable of supporting a load of 350 ℔s. upon a plane of 1 in 12, or 3 feet in height and 36 feet in length:

$$\frac{350}{12} = 29.16 \text{ ℔s., or } \frac{350 \times 3}{36} = 29.16 \text{ ℔s. power, as before.}$$

THE WEDGE.

"The wedge is a double inclined plane; consequently, its principles are the same. Hence, when two bodies are forced asunder by means of the wedge, in a direction parallel to its head, multiply the resisting power by half the thickness of the head or back of the wedge, and divide the product by the length of one of its inclined sides; the quotient is the force equal to the resistance.

"*Example.* The breadth of the back or head of a wedge being 3 inches, its inclined sides each 10 inches, required the power necessary to act upon the wedge so as to separate two substances whose resisting force is equal to 150 ℔s.

$$\frac{150 \times 1.5}{10} = 22.5 \text{ lbs.}$$

"NOTE.—When only one of the bodies is movable, the whole breadth of the wedge is taken for the multiplier."

THE SCREW.

"The screw is another modification of the inclined plane, and it may be said to remove the same kind of practical inconveniences incidental to the use of the latter, that the pulley does in reference to the simple lever. The lever is very limited in the extent of its action; so is the inclined plane. But the pulley multiplies the extent of the action of the lever, by presenting, in effect, a series of levers acting in regular succession; and just such a purpose is effected by the screw. It multiplies the extent of the action of the inclined plane, by presenting, in effect, a continued series of planes.

"The screw, in principle, is that of an inclined plane wound round a cylinder, which generates a spiral of uniform inclination, each revolution producing a rise or traverse motion equal to the pitch of the screw, or distance between the two consecutive threads—the pitch being the height or angle of inclination and the circumference the length of the plane. Hence, the mechanical advantage is, as the circumference of the circle described by the lever where the power acts is to the pitch of the screw, so is the force to the resistance in principle.

"*Example.*—Required the effective power obtained by a screw of $\frac{7}{8}$ inch pitch, and moved by a force equal to 50 lbs. at the extremity of a lever 30 inches in length:

$$\frac{0 \times 2 \times 3.1416 \times 50}{875} = 10760 \text{ lbs.}$$

"*Example.* Required the power necessary to overcome a resistance equal to 7000 lbs. by a screw of $1\frac{1}{4}$ inch pitch and moved by a lever 25 inches in length;

$$\frac{7000 \times 1.25}{25 \times 2 \times 3.1416} = 55.73 \text{ lbs. power.}$$

"In the case of a screw acting on the periphery of a toothed wheel, the power is to the resistance as the product of the circle's circumference described by the winch or lever, and radius of the wheel, to the product of the screw's pitch and radius of the axle or point whence the power is transmitted; but observe that, if the screw consist of more than one thread, the apparent pitch must be increased so many times as there are threads in the screw. Hence, to find what weight a given power will equipoise.

"RULE.—Multiply together the radius of the wheel, the length of the lever at which the power acts, the magnitude of the power, and the constant number 6.2832; divide the product by the radius of the axle into the pitch of the screw, and the quotient is the weight that the power is equal to.

"*Example.* What weight will be sustained in equilibrio by a power of 100 lbs. acting at the end of a lever 24 inches in length, the radius of the axle, or point whence the power is transmitted being 8 inches, the radius of the wheel 14 inches, the screw consisting of a double thread, and the apparent pitch equal $\frac{5}{8}$ of an inch?

$$\frac{14 \times 24 \times 100 \times 6.2832}{.625 \times 2 \times 8} = 21111.55 \text{ lbs. the power sustained.}$$

"NOTE.—It is estimated that about one-third more power must be added to overcome the friction of the screw when loaded, than is necessary to constitute a balance between power and weight."

EFFECTS PRODUCED BY WATER IN ITS NATURAL STATE.

"By analysis it is ascertained, that water is composed of the gases oxygen and hydrogen in a state of chemical union; its distinguishing properties, like that of other liquids, being nearly incompressible gravity, capability of flowing, and constant tendency to press outwards in every direction; also that of being easily changed by the absorption of caloric to an aeriform state of any required density of degree or elastic force: hence the principle of the hydraulic press, the water-wheel, the steam engine, etc.

"Because of liquids possessing the properties of gravity and capability of flowing freely in every direction, sides of vessels, flood-gates, sluices, etc., sustain a pressure equal to the product of the area multiplied by half the depth of the fluid, and by its gravity in equal terms of unity.

"But when a sluice or opening through which a liquid may issue is under any given continued head, the pressure is equal the product of the area multiplied into the height from the centre of the opening to the surface of the fluid.

"*Example.* Required the pressure of water on the sides of a cistern 18 feet in length, 13 in width and 9 in depth:

"The terms of measurement or unity are in feet, 1 cubic foot of water $= 62.5$ lbs.; hence $18 \times 9 \times 2 + 13 \times 9 \times 2 — 558 \times 4.5 \times 62.5 = 156937.5$ lbs. weight of water on bottom $= 18 \times 13 \times 9 \times 62.5 = 131625$ lbs.

"*Example.* Required the pressure on a sluice 3 feet square, and its centre 30 feet from the surface of the water:

"$3 \times 3 \times 30 \times 62.5 = 16875$ lbs.

"The weight of water or other fluid is as the quantity, but the pressure exerted is as the vertical height. Hence, as fluids press equally in every direction, any vessel containing a fluid sustains a pressure equal to as many times the weight of the column of greatest height of that fluid, as the area of the vessel is to the sectional area of the column.

"*Example.* Let a cubical vessel, whose sides are each 4 square feet, have a tube inserted 1 inch in diameter, and 6 feet in height, and let both vessel and tube be filled with water; required the whole weight of the water therein contained, and also the whole pressure exerted intending to burst the vessel;

"Cubic contents of the vessel $= 8$ feet, and each foot $= 62.5$ lbs.; then $62.5 \times 8 = 500$ area of pipe's section $= .7854$ inches, and height 72 inches, also a cubic inch of water $= .03617$ lbs.; hence $.7854 \times 72 \times .03617 = 2$ lbs. $+ 500 = 502$ lbs., total weight of water.

"Again; the whole height of the column $= 96$ inches; then $.7854 \times 96 \times .03617 = 2.33$ lbs., pressure of column on an equal area. 144

square inches = 1 square foot, and $\frac{144 \times 4 \times 6 \text{ sides}}{.7854} = 4400.4$ times the area of the pipe's diameter in the whole surface; therefore, $4400.4 \times 2.33 = 10253$ lbs., or total amount of pressure exerted.

"To find the velocity of water issuing a circular orifice at any given depth from the surface.

"RULE.—Multiply the square root of the height or depth to the centre of the orifice by 8.1; and the product is the velocity of the issuing fluid in feet per second.

"*Example.* Required the velocity of water issuing through an orifice under a head of 11 feet from the surface:

"Square root of $11 = 3.3166 \times 8.1 = 26.864$ feet, velocity per second.

"In the discharge of water by a rectangular aperture in the side of a reservoir, and extending to the surface, the velocity varies nearly as the square root of the height, and the quantity discharged per second equal two-thirds of the velocity due to the mean height, allowing for the contraction of the fluid according to the form of the opening, which renders the coefficient in this case equal to 5.1; whence the following general rules:

"1. When the aperture extends to the surface of the fluid: Multiply the area of the opening in feet by the square root of its depth also in feet, and that product by 5.1; then will two-thirds of the last product equal the quantity discharged, in cubic feet, per second.

"2. When the aperture is under a given head: Multiply the area of the aperture, in feet, by the square root of the depth, also in feet, and by 5.1; the product is the quantity discharged, in cubic feet, per second.

"*Example.* Required the quantity of water in cubic feet per second, discharged through an opening in the side of a dam or weir, the width or length of the opening being $6\frac{1}{2}$ feet, and depth 9 inches, or .75 of a foot:

"Square root of $.75 = .866$.

Then $\frac{6.5 \times .75 \times .866 \times 5.1 \times 2}{3} = 14.3839$ cubic feet.

"*Example.* What would be the quantity discharged through the above opening, if under a head of water 4 feet in height?

"Square root of 4 = 2, and 2 × 5.1 = 10.2 feet, velocity of the water per second. And 6.5 × 75 × 2 × 5.1 = 49.725 cubic feet discharged in the same time.

"The combined properties of gravity and fluidity which water possesses, render it so available as a source of motive power; gravity being the property by which the power is produced, and fluidity that by which it is so commodiously qualified to the various modifications in which it is employed.

"Water, it is ascertained, is subject to the same laws of gravity as those of solid bodies, and thereby accumulates velocity or effect in an equal ratio when falling through an equal space, or descending from an equal height. Hence, the velocity attained is as the square root of the height of its fall; and it is now quite satisfactorily decided, that, because of the non-elastic property of water, its greatest is obtained when acting by gravity throughout its whole height, whether it be applied on a water wheel, turbine, or other machine through which circular motion is to be the immediate result.

"In regard to water-wheels, and other machines through which motion is produced by the effort of water, much discrepancy of opinion has, until lately, existed, both as to form and velocity, besides other essential points requisite in gaining a maximum of effect with the least possible strain; but these doubts are now in a great measure removed through experiments by the Franklin Institute in this country, added to those in France by Morin, and the results of a patented machine by Whitelaw and Stirrat, Scotland, combined with pertinent observations and remarks by interested parties in this as well as other countries. Hence have been deduced the following demonstrative conclusions:

"1. That to gain a maximum of effect by a horizontal water-wheel, the water must be laid upon the wheel on the stream side, and the diameter of the wheel so proportioned to the height of the fall, that the water may be laid on about $52\frac{3}{4}$ degrees distant from the summit of the wheel, or the height of the fall, being 1 the height or diameter of the wheel equal 1.108.

"That the periphery of a water-wheel ought to move at a velocity equal to about twice the square root of the fall of the water in feet per second, and the number of buckets equal 2.1 times the wheel's diameter in feet; also, that precautionary means be adopted for the escape of the air out of the buckets, either by making the stream of water a few inches narrower than the wheel, or otherwise.

"3. That, because of water producing a less efficient power by impulse than gravity, turbines, or machines through which the motion is obtained by reaction, are greatly preferable to undershot, or low-breast wheels.

"That a head of water is required sufficient to cause the velocity of its flowing to be as 3 to 2 of the wheel; one-ninth of the wheel's diameter being an approximate height, near enough for practical purposes.

"5. That the effective power of a wheel constructed according to these restrictions, is equal to the product of the number of cubic feet and velocity in feet per minute, multiplied into .001325.

"*Example for general illustration.* Suppose a fall of water 25 feet in height, over which is delivered 112 cubic feet per minute; required the various peculiar requisites for a wheel to be in accordance with the preceding rules:

"1st. $25 \times 1.08 = 27$ feet, the wheel's diameter.
2d. Square root of $25 \times 2 = 10$ feet velocity of the wheel in feet per second.
Also: $27 \times 2.1 = 56.7$, say 57 buckets.
3d. $27 \div 9 = 3$ feet, head of water required.
4th. $112 \times 10 \times 60 \times .001325 = 89$ horses' power.

"The turbine of Fourneyron, in France, and the patented water-mill of Whitelaw and Stirrat, Scotland, have, of late years, attracted a considerable share of public attention; their simplicity of construction and asserted effects in like situations, being equal to those of the best applied water-wheels. In their manner of construction they differ, but in principle they are the same; the action of each being created by a centrifugal and tangential force, caused by the weight or impulsion of a column of water whose height or altitude is equal to twice the height of the fall due to the water's velocity; and in order to produce a maximum of effect in either the one or the other by the pressure and centrifugal force of the effluent water, it is necessary that the emitting tubes or helical channels of the machine be so curved that the apertures shall be in a right line with the radius of the wheel.

"1. That turbines are equally adapted to great as to small waterfalls.

"2. That they are capable of transmitting a useful effect to from 70 to 78 per cent. of the absolute power.

"3. That their velocities may vary considerably from the maximum effect, without differing sensibly from it.

"4. That they will work nearly as effectually when drowned to the depth of 6 feet as when free, and, consequently, they will make use of the whole of the fall when placed below the level of extreme low water.

"5. That they receive variable quantities of water, without altering the ratio of the power to the effect."

STEAM POWER.

"There is no application of science to the arts of more importance, and more extensive in its effects, than that of the employment of steam for driving all kinds of machinery. It is not my intention to enter into the details of the power of steam or the steam-engine, but to give some practical rules, the utility of which has been tested.

"Steam is of great utility as a productive source of motive power; in this respect, its properties are, elastic force, expansive force, and reduction by condensation. Elastic signifies the whole urgency or power the steam is capable of exerting with undiminished effect. By expansive force is generally understood the amount of diminishing effect of the steam on the piston of a steam-engine, reckoning from that point of the stroke where the steam of uniform elastic force is cut off; but it is more properly the force which steam is capable of exerting, when expanded to a known number of times its original bulk. And condensation, here understood, is the abstraction or reduction of heat by another body, and consequently not properly a contained property of the steam, but an effect produced by combined agency in which steam is the principal; because any colder body will extract the heat and produce condensation, bnt steam cannot be so beneficially replaced by any other fluid capable of maintaining equal results.

"The rules formed by experimenters, as corresponding with the results of their experiments on the elastic force of steam at given temperatures, vary, but approximate so closely, that the following rule, because of being simple, may, in practice, be taken in preference to any other:

"RULE.—To the temperature of the steam, in degrees of Fahrenheit, add 100; divide the sum by 177; and the 6th power of the quotient equal the force in inches of mercury.

"*Example.* Required the force of steam correspoding to a temperature of 312 degrees:

$$\frac{312 + 100}{177} = 2.3277^6 = 159 \text{ inches of mercury.}$$

"To estimate the amount ot advantage gained by using steam expansively in a steam-engine:

"When steam of a uniform elastic force is employed throughout the whole ascent or descent of the piston, the amount of effect produced is as the quantity of steam expended. But let the steam be shut off at any portion of the stroke—say, for instance, at one-half—it expands by degrees until the termination of the stroke, and then exerts half its original force; hence an accumulation of effect in proportion to the quantity of steam.

"RULE.—Divide the length of the stroke by the distance, or space into which the dense steam is admitted, and find the hyperbolic logarithm of the quotient, to which add 1; and the sum is the ratio of the gain.

"*Example.* Suppose an engine with a stroke of 6 feet, and the steam cut off when the piston has moved through it; required the ratio of gain by uniform and expansive force:

"$6 \div 2 = 3$; hyperbolic logarithm of $3 = 1.0986 + 1 = 2.0986$, ratio of effect; that is, supposing the whole effect of the steam to be 3, the effect by the steam being cut off at $\frac{1}{3} = 2.0986$.

"Again; let the greatest elastic force of steam in the cylinder of an engine equal 48 lbs. per square inch, and let it be cut off from entering the cylinder when the piston has moved $4\frac{1}{2}$ inches, the whole stroke being 10; required an equivalent force of the steam throughout the whole stroke:

$18 \div 4.5 = 4$, and $48 \div 4 = 12$.
Logarithm of $4 + 1 = 2.38629$.
Then $2.38629 \times 12 = 28635$ lbs. per square inch.

"In regard to the other case of expansion, when the temperature is constant, the bulk is inversely as the pressure; thus, suppose steam at 30 lbs. per square inch; required its bulk to that of original bulk, when expanded so as to retain a pressure equal to that of the atmosphere, or 15 lbs:

$$\frac{15 + 30}{15} = 3 \text{ times its original bulk.}$$

"It is because of the latent heat in steam, or water in an aeriform state, that it becomes of such essential service in heating, boiling, drying, etc. In the heating of buildings, its economy, efficiency, and simplicity of application, are alike acknowledged; the steam, being simply conducted through all the departments by pipes, by extent of circulation condenses—the latent heat being thus given to the pipes, and diffused by radiation. In boiling, its efficiency is considerably increased, if advantage be taken of sufficiently enclosing the fluid, and reducing the pressure on its surface, by means of an air-pump. Thus water in a vacuum boils at about a temperature of 98 degrees; and in sugar-refining, where such means are employed, the syrup is boiled at 150 degrees."

EFFECTS PRODUCED BY WATER IN AN AERIFORM STATE.

"When water in a vessel is subjected to the action of fire, it readily imbibes the heat, or fluid principle of which the fire is the immediate cause, and sooner or later, according to the intensity of the heat, attains a temperature of 212 degrees Fahrenheit. If, at this point of temperature the water be not enclosed, but exposed to atmospheric pressure, ebullition will take place, and steam or vapor will ascend through the water, carrying with it the superabundant heat, or that which the water cannot, under such circumstances of pressure, absorb, to be retained, and to indicate a higher temperature.

"Water, in attaining the aeriform state, is thus uniformly confined to the same laws, under every degree of pressure; but, as the pressure is augmented, so is the indicated temperature proportionately elevated. Hence the various densities of steam, and corresponding degrees of elastic force."

STRENGTH OF MATERIALS.

Chas. H. Haswell's Engineers' and Mechanics' Pocket-Book.

"The component parts of a rigid body adhere to each other with a force which is termed cohesion.

"Elasticity is the resistance which a body opposes to a change of form.

"Strength is the resistance which a body opposes to a permanent separation of its parts.

"Elasticity and strength, according to the manner in which a force is exerted upon a body, are distinguished as tensile strength, or absolute resistance; transverse strength, or resistance to flexure; crushing strength, or resistance to compression; torsional strength, or resistance to torsion; and detrusive strength, or resistance to shearing.

"The limit of stiffness is flexure, and the limit of strength or resistance is fracture.

"Resilience, or toughness of bodies, is strength and flexibility combined; hence any material or body which bears the greatest load, and bends the most at the time of fracture, is the toughest.

"The specific gravity of iron is ascertained to indicate very correctly the relative degree of strength.

"The neutral axis, or line of equilibrium, is the line at which extension terminates and compression begins.

"The resistance of cast iron to crushing and tensile strains is, as a mean, as 4.3 to 1.*

"The mean tensile strength of American cast iron, as determined by Major Wade, for the United States ordnance corps, is 31829 lbs. per square inch of section; the mean of English, as determined by Mr. E. Hodgkinson, for the railway commission, etc., in 1849, is 19484 lbs.; and by Colonel Wilmot, at Woolwich, in 1858, for gun-metal, is 23257 lbs.

"The ultimate extension of cast iron is the 500th part of its length.

"The mean transverse strength of American cast iron, also determined by Major Wade, is 681 lbs. per square inch, suspended from a bar fixed at one end and loaded at the other; and the mean of English, as determined by Fairbairn, Barlow, and others, is 500 lbs.

"The resistance of wrought iron to crushing and tensile strains is, as a mean, as 1.5 to 1 for American; and for English 1.2 to 1.

"The mean tensile strength of American wrought iron, as determined by Professor Johnson, is 55900 lbs.; and the mean of English, as determined by Captain Brown, Barlow, Brunel, and Fairbairn, is 53900 lbs.†

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*The experiments of Mr. Hodgkinson on iron of low tensile strength gives a mean of 6.595 to 1.

†The results, as given by Mr. Telford, included experiments upon Swedish iron; hence they are omitted in this summary.

"The ultimate extension of wrought iron is the 600th part of its length.

"The resistance to flexure, acting evenly over the surface, is nearly one-half the tensile resistance."

TRUSSED BEAMS OR GIRDERS.

"Wrought and cast iron possess different powers of resistance to tension and compression; and when a beam is so constructed that these two materials act in unison with each other at the stress due to the load required to be borne, their combination will effect an essential saving of material. In consequence of the difficulty of adjusting a tension-rod to the strain required to be resisted, it is held to be impracticable to construct a perfect truss beam.

"Fairbairn declares that it is better for the tension of the truss rod to be low than high, which position is fully supported by the following elements of the two metals:

"Wrought iron has great tensile strength, and having great ductility, it undergoes much elongation when acted upon by a tensile force. On the contrary, cast iron has great crushing strength, and, having but little ductility, it undergoes but little elongation when acted upon by a tensile force; and, when these metals are released from the action of a high tensile force, the set of the one differs widely from that of the other, that of wrought iron being the greatest. Under the same increase of temperature, the expansion of wrought is considerably greater than that of cast iron; 1.81* tons per square inch is required to produce in wrought iron the same extension as in cast iron by 1 ton.

"Fairbairn, in his experiments upon English metals, deduced that within the limits of strain of 13440 lbs. per square inch for cast iron, and 30240 lbs. per square inch for wrought iron, the tensile force applied to wrought iron must be 2.25 times the tensile force applied to cast iron, to produce equal elongations.

*The elongation of cast and wrought iron being 5500 and 10000, hence $10000 \div 5500 = 1.81$.

"The relative tensile strengths of cast and wrought iron being as 1 to 1.35, and their resistance to extension as 1 to 2.25, therefore, where no initial tension is applied to a truss rod, the cast iron must be ruptured before the wrought iron is sensibly extended.

"The resistance of cast iron in a trussed beam is not wholly that of tensile strength, but it is a combination of both tensile and crushing strengths, or a transverse strength; hence, in estimating the resistance of a girder, the transverse strength of it is to be used in connection with the tensile strength of the truss.

"The mean transverse strength of a cast iron bar, one inch square and one foot in length, supported at both ends, the stress applied in the middle, is about 900 ℔s.; and as the mean tensile strength of wrought iron is about 20000 ℔s. per square inch, the ratio between the sections of the beams and of the truss should be in the ratio of the transverse strength per square inch of the beam and of the tensile strength of the truss.

"The girders under consideration are those alone in which the truss is attached to the beam at its lower flange, in which case it presents the following conditions:

"1. When the truss runs parallel to the lower flange. 2. When the truss runs at an inclination to the lower flange, being depressed below its centre. 3. When the beam is arched upward, and the truss runs as a chord to the curve.

"Consequently, in all these cases the section of the beam is that of an open one with a cast iron upper flange and web, and a wrought iron lower flange, increased in its resistance over a wholly cast iron beam in proportion to the increased tensile strength of wrought iron over cast iron for equal sections of metals.

"As the deductions of Fairbairn as to the initial strain proper to be given to the truss are based upon a cast iron beam with the truss inserted into the upper flange of the beam, whereby it was submitted almost wholly to a tensile strain, they will not apply to the two constructions of trussed beams under consideration.

"As each construction of trussed beam will produce a strain upon the truss in accordance with the position of the neutral axis of the section of the whole beam, and as the extension of the truss will vary according as it is more or less ductile, it is impracticable, in the absence of the necessary elements, to give an amount of initial strain that would be applicable as a rule.

"From the various experiments made upon trussed beams, it is shown:

"1. That their rigidity far exceeds that of simple beams; in some cases it was from 7 to 8 times greater. 2. That when the truss resists rupture, the upper flange of the beam being broken by compression, there is a great gain in strength. 3. That their strength is greatly increased by the upper flange being made larger than the lower one. 4. That their strength is greater than that of a wrought iron tubular beam containing the same area of metal."

DEFLECTION OF BARS, BEAMS, GIRDERS, ETC.

"The experiments of Barlow upon the deflection of wood battens determined that the deflection of a beam from a transverse strain varied as the breadth directly, and as the cubes of both the depth and length, and that with like beams and within the limits of elasticity it was directly as the weight.

"In bars, beams, etc., of an elastic material, and having great length, compared to their depth, the deductions of Barlow will apply with sufficient accuracy for all practical purposes; but in consequence of the varied proportions of depth to length of the varied character of materials, of the irregular resistance of beams constructed with scarfs, trusses, or riveted plates, and of the unequal deflection at initial and ultimate strains, it is impracticable to give any positive laws regarding the degrees of deflection of different and dissimilar bars, beams, etc.

"In the experiments of Hodgkinson, it was farther shown that the sets from deflections were very nearly as the squares of the deflections.

"In a rectangular bar, beam, etc., the position of the neutral axis is in its centre, and it is not sensibly altered by variations in the amount of strain applied. In bars, beams, etc., of cast and wrought iron, the position of the neutral axis varies in the same beam, and is only fixed while the elasticity of the beam is perfect. When a bar, beam, etc., is bent so as to injure its elasticity, the neutral line changes, and continues to change during the loading of the beam, until it breaks.

"When bars, beams, etc., are of the same length, the deflection of one, the weight being suspended from one end, compared with that of a beam uniformly loaded, is as 8 to 3; and when a beam is supported at both ends, the deflection in like cases is as 5 to 8. Whence, if a bar, etc., is in the first case supported in the middle, and the ends permitted to deflect; and in the second, the ends supported, and the middle permitted to descend, the deflection in the two cases is as 3 to 5.

"Of three equal and similar bars or beams, one inclined upward, one downward at the same angle, and the other horizontal, that which has its angle upward is the weakest, the one which declines is the strongest, and the one horizontal is a mean between the two.

"When a bar, beam, etc., is uniformly loaded, the deflection is as the weight, and approximately as the cube of the length or as the square of the length; and the element of deflection and the strain upon the beam, the weight being the same, will be but half of that when the weight is suspended from one end.

"The deflection of a bar, beam, etc., fixed at one end, and loaded at the other, compared to that of a beam of twice the length, supported at both ends, and loaded in the middle, the strain being the same, is as 2 to 1; and when the length and the loads are the same, the deflection will be as

16 to 1, for the strain will be four times greater on the beam fixed at one end than on the one supported at both ends; therefore, all other things being the same, the element of deflection will be four times greater; also, as the deflection is as the element of deflection into the square of the length, then as the lengths at which the weights are borne in their cases are as 1 to 2, the deflection is as

$$1 : \overline{2^2 \times 4} = 1 \text{ to } 16.$$

"The deflection of a bar, beam, etc., having the section of a triangle, and supported at its ends, is one-third greater when the edge of the angle is up, than when it is down."

(The following remarks and rules in reference to the strength of materials are taken from a work venerable with age, but none the less valuable. The rules are simple, and easily understood:)

"The strength of materials is a subject of great importance in mechanics, and one which, of all the branches of this useful science, is the least understood. Several very eminent mathemeticians have exercised their talents and ingenuity in forming theories for estimating the strength of beams according to the various positions in which they are, but unfortunately, they made no experiments; therefore, they had no better foundation than mere hypothesis; consequently are totally at variance with practice.

"It is not intended, however, in this short abstract, to perplex the reader with theory, but to furnish the artizan with a few properties, which to him will be more useful than many discordant suppositions.

"A body may be exposed to four different kinds of strains. 1. It may be torn asunder by some force applied in the direction of its length, as in the case of ropes, etc. 2. It may also be crushed by a force applied in the direction of its length, as in the case of pillars, posts, etc. 3. It may be broken across by a force acting perpendicularly to its length, as in joints, levers, etc. 4. It may be wrenched or twisted by a force acting in a kind of circular direction at the extremity of a lever, as in the case of wheel-axles, etc.

"The first of these, viz., the direct cohesion of bodies, is one which seldom comes under the consideration of the mechanic or engineer; and if any former experiments can be obtained, they are generally sufficient for his purpose; or no reason can be assigned why the strength should not vary directly as the section of fracture, and is totally independent of the length in position, except so far as the weight of the body may increase the force applied. Neglecting this, and supposing the body uniform in all its parts, the strength of bodies exposed to strains in the direction of their length, is directly proportionate to their transverse area, whatever may be their figure, length or position.

"Experiments on the direct cohesion of all bodies are attended with great difficulty, in consequence of the enormous force required to produce a separation of the parts, in bars of any considerable dimensions.

"Some experiments of this kind, however, have been made, the results of which are as follows, all reduced to the section of a square inch:

		Pounds.
Gold Cast		20,000 / 24,000
Silver Cast		40,000 / 43,000
Copper Cast	Japan	19,500
	Barbary	22,000
	Hungary	31,000
	Anglesea	34,000
	Sweden	37,000
Iron Cast		42,000 / 59,000
Iron Bar	Ordinary	65,000
	Stirian	78,000
	Best Swedish and Russian	84,000
	Horse Nails	71,000
Steel Bar	Soft	120,000
	Razor tempered	150,000
Tin Cast	Malacca	3,100
	Banca	3,600
	Block	3,800
	English Block	5,200
	English Grain	6,500

	Pounds.
Lead Cast	860
Regulus of Antimony	1,000
Zinc	2,600
Bismuth	2,900

"It is very remarkable that almost all mixtures of metals are stronger or more tenacious than the metals themselves, much depending upon the proportion of the ingredients; and these proportions are different in metals.

Oak	9,000
Ash	17,000
Pine from 10,000 to	13,000

ON THE RESISTANCE OF BODIES WHEN PRESSED LONGITUDINALLY.

"It is obvious that a body when pressed endwise, by a sufficient force, may be crushed and destroyed, either by a total separation of the matter by which it is composed, or by bending it, whereby it is broken across; if the length of the body be very inconsiderable the former is the almost certain result; but if its length be much more than its breadth and thickness, it generally bends before breaking.

"Although many experiments, and some very intricate analytical investigations have been made upon this subject, yet little can be advanced that will be of use to the practical engineer. It may be observed, that a pillar of hard stone of Giory, whose section is a square foot, will bear with perfect safety 664,000 lbs.; and its extreme strength is 871,000 lbs.

"Good brick will carry with safety 320,000 lbs. on an square foot; and chalk, 9,000 lbs.

"It requires a power of 400,000 lbs. to crush a cube of one-quarter of an inch of cast iron.

"The most usual strain, and therefore the one with which it is most important for us to be well informed is, that by which a body is broken across, from the force of weight acting perpendicularly or obliquely to its length, while the beam itself is supported by its two extremities, or by one end fixed into a wall, or otherwise.

"From various experiments which have been made, the following results have been deduced:

"1. The lateral strength of beams is inversely as their lengths.

"2. The lateral strengths of the beams are directly as their breadth.

"3. The lateral strength of beams is as the square of their depth.

"4. In square beams the lateral strengths are as the cube of one side.

"5. In round beams as the cube of the diameter.

"6. The lateral strength of a beam with its narrow face upwards, is to its strength with the broad face upwards as the breadth of the broader face to the breadth of the narrower.

"7. The strength of beam supported only at its extremes, is to the strength of the same when fixed at both ends, as 1 to 2.

"8. The strength of a beam with the weight or load suspended from the centre is to the strength when the load is equally divided in the length of the beam, as 1 to 2.

"According to the experiments made by Mr. Banks, the worst or weakest piece of oak he tried bore 600 pounds, though much bended, and 2 pounds more broke it. The strongest piece broke with 974 pounds.

"The worst piece of deal bore 460 pounds, but broke with 4 more. The best piece bore 690 pounds, but broke with a little more.

"The weakest cast iron bar bore 2190 pounds, and strongest 2980 pounds.

"Also, these experiments were made upon pieces 1 inch square, the props exactly 1 foot asunder, and the weight suspended from the centre, the ends lying loose.

"By way of illustration we will add a few examples for the exercise of the reader:

"What weight suspended from the middle of an oak beam, whose length is 10 feet, and each side of its square end 4 inches, will break it when supported at each end?

"By article 1st, the lateral strengths of beams are inversely as the lengths, and (article 4) as the cube of one side.

"Then, as a piece 1 foot long and 1 inch square bore 660 pounds, one 10 feet long would bear 66 pounds, and 66 multiplied by 64, the cube of 4=4224 pounds the weight, the above beam would support. If the ends of the beam were prevented from rising it would bear 8448 pounds; and if the weight was equally diffused in its length, it would support 16896 pounds.

"Required the strength of a hollow shaft of cast iron supported at its two extremes, 5 inches in diameter, the diameter of the hollow being 4 inches, and the length of the shaft 10 feet?

"First find the strength of a solid shaft 5 inches diameter, and then that of one 4 inches, which deduced from the former, gives its strength.

"The strength of round beams are as the cubes of their diameter, and the cube of 5 is 125; this multiplied by 170; the strength of a round bar 1 inch in diameter and 10 feet long, gives 21,375 pounds for the strength of a solid shaft 5 inches diameter and 10 feet long.

"The cube of 4 is 64 multiplied by 171=10,944 pounds, the strength of a solid shaft 3 inches diameter and 10 feet long. Now 21,375—10,944=10,431 pounds, the strength of the hollow shaft required.

"N. B. The diameter of a solid having the same quantity of matter with the tube is 3, but the strength of it would not be half that of the ring. Engineers have of late introduced this improvement into their machines, the axles of cast iron being made hollow, when the size and other circumstances will admit of it.

"Required the strength of a piece of deal 6 inches broad, 2 inches deep, and 5 feet long, placed edgeways, and the weight suspended from the centre? Answer, 6624 pounds.

"What weight will a cast iron beam bear supported in the centre, the length of the beam being 6 feet 8 inches deep, and 1 inch thick? Answer, 10 tons, 8 cwt., 2 quarters, and 8 lbs.

"If a plank be three inches thick, and 12 inches broad, how much more will it bear with its edge than with its flat side uppermost? Answer, 4 times more with its edge uppermost.

"With respect to the fourth strain, viz.: the twist to which bars or shafts in an upright position are liable by the wheel which drives them, and the resistances they have to overcome, little that will be satisfactory can be advanced. Mr. Banks observes, that a cast iron bar an inch square, and fixed at the one end, and 631 pounds suspended by a wheel of 2 feet diameter, fixed on the other end, will break by the twist; though some have required more than 1000 pounds in similar situations to break them by the twist.

"The strength to resist the twisting strain is as the cube of like lateral dimensions.

"In concluding these plain statements it may be necessary to remind our readers, that in applying these rules to practical purposes, care should be taken to make the beams, etc., sufficiently strong; if they are but just able to support the stress they will be in danger of breaking. In most cases the strength should be 2 or 3 times the stress, and where the stress may be inequal, or the pressure exerted in a variable manner, by jerks, etc., the strength should be considerably more than that.

"In all the preceding examples the beams are supposed only just able to support the load.

"The following are the results of experiments made by Mr. Emerson, which state the load that may be safely borne by a square inch rod of each:

	Pounds Avoirdupois.
Iron rod, an inch square, will bear	76,400
Brass	35,600
Hempen rope	19,600
Ivory	15,700
Oak, box, yew, plumtree	7,850

	Pounds Avoirdupois.
Elm, ash, beech	6,070
Walnut, plum	5,360
Red pine, holly, elder, plane, crab	5,000
Cherry, hazel	4,760
Alder, asp, birch, willow	4,290
Lead	430
Free stone	914

Tenacity of copper compared with iron is 5:9 nearly, or 1:1.8; *i. e.*, copper being 1, iron is 1.8.

"Mr. Barlow's opinion of this table is, 'we shall only observe here, that they all fall very short of the ultimate strength of the woods to which they refer.'

"Mr. Emerson also gives the following practical rule, viz.: 'that a cylinder, whose diameter is *d* inches, loaded to one-fourth of its absolute strength, will carry as follows:

	Cwt.
Iron	$135 \times d^2$
Good rope	$22 \times d^2$
Oak	$14 \times d^2$
Pine	$9 \times d^2$

"Captain S. Brown made an experiment on Welsh pig iron, and the result is described as follows:

"'A bar of cast iron, Welsh pig, 1¼ inch square, 3 feet 6 inches long, required a strain of 11 tons, 7 cwt. (25,424 lbs.) to tear it asunder, broke exactly transverse, without being reduced in any part; quite cold when broken, particles fine, dark bluish grey color.' From this experiment, it appears that 16,265 lbs. will tear asunder a square inch of cast iron.

"Mr. G. Rennie also made some experiments on cast iron, and the result was, 'that a bar one inch square, cast horizontal, will support a weight of 18,656 lbs.—and one cast vertical, will support a weight of 19,488 lbs.'

"There have been several experiments made on malleable iron, of various qualities, by different engineers.

"The mean of Mr. Telford's experiments, is 29¼ tons.

"The mean of Capt. S. Brown's experiments, is 20 tons, and the mean between these two means, is 27 tons, nearly;

which may be assumed as the medium strength of a malleable iron bar 1 inch square.

"From a mean, derived by experiments, performed by Mr. Barlow, it appears that the strength of direct cohesion, on a square inch of

		Pounds.
Box	is about	20,000
Ash	" "	17,000
Teak	" "	15,000
Pine	" "	12,000
Beech	" "	11,500
Oak	" "	10,000
Pear	" "	9,800
Mahogany	" "	8,000

"Each of these weights may be taken as a correct data for the cohesive strength of the wood to which they belong, but this is the absolute and ultimate strength of the fibres; and therefore, if the quantity that may be safely borne be required, not more than two-thirds of the above values must be used.

TABLE OF SPECIFIC GRAVITIES.

METALS.

	Specific Gravity.	Weight of a Cubic Inch in Ounces Avoirdupois.
Arsenic	5763	3,335
Cast antimony	6702	3,878
Cast zinc	7190	4,161
Cast iron	7207	4,165
Cast tin	7291	4,219
Bar iron	7788	4,507
Cast nickel	7807	4,513
Cast cobalt	7811	4,520
Hard steel	7816	4,523
Soft steel	7833	4,533
Cast brass	8395	4,858
Cast copper	8788	5,085
Cast bismuth	9822	5,684
Cast silver	10474	6,061
Hammered silver	10510	6,082
Cast lead	11352	6,569
Mercury	13568	7,872
Jeweler's gold	15709	9,091

	Specific Gravity.	Weight of a Cubic Inch in Ounces Avoirdupois.
Gold coin	17647	10,212
Cast gold, pure	19258	11,145
Pure gold, hammered	19361	11,212
Platinum, pure	19500	11,285
Platinum, hammered	20336	11,777
Platinum wire	21041	12,176

"Note.—All metals become specifically heavier by hammering.

STONES, EARTHS, ETC.

	Specific Gravity.	Weight of a Cubic Foot in Pounds Avoirdupois.
Brick	2000	125.00
Sulphur	2033	127.08
Stone, paving	2416	151.00
Stone, common	2520	157.50
Granite, red	2654	165.84
Glass, green	2642	
Glass, white	2892	
Glass, bottle	2733	
Pebble	2664	166.50
Slate	2672	167.00
Marble	2742	171.38
Chalk	2784	174.00
Basalt	2864	179.00
Hone, white razor	2876	179.75
Limestone	3179	198.68

RESINS, ETC.

	Specific Gravity.		Specific Gravity.
Wax	897	Tallow	945
Bone of an ox	1659	Ivory	1822

LIQUIDS.

	Specific Gravity.		Specific Gravity.
Air at earth's surface	$1\frac{2}{7}$	Sea water	1828
Oil of turpentine	870	Nitric acid	1218
Olive oil	915	Vitriol	1841
Distilled water	1000		

WOODS.

	Specific Gravity.	Weight of a Cubic Foot in Pounds Avoirdupois.
Cork	246	15.00
Poplar	383	23.94
Larch	544	34.00
Elm	556	34.75
New English pine	556	34.75
Mahogany, Honduras	560	35.00
Willow	585	36.56
Cedar	596	37.25
Pitch pine	560	41.25
Pear tree	661	41.31
Walnut	671	41.94
Pine, forest	694	43.37
Elder	695	43.44
Beech	696	43.50
Cherry tree	715	44.68
Teak	745	46.56
Maple and Riga pine	750	46.87
Ash and Dantzic oak	760	47.50
Yew, Dutch	788	49.25
Apple tree	793	49.56
Alder	800	50.00
Yew, Spanish	807	50.44
Mahogany, Spanish	852	53.25
Oak, American	872	54.50
Boxwood, French	912	57.00
Logwood	913	57.06
Oak, English	970	51.87
Oak, sixty years cut	1170	73.12
Ebony	1331	83.18
Lignumvitæ	1333	83.31

APPLICATION OF THE FOREGOING TABLE.

"A block of marble, measuring 6 feet long and 4 feet square, lies at a wharf, and the wharfinger wishes to know if his 10-ton crane is sufficiently strong to lift it.:

$6 \times 4 \times 4 = 96$, cubic feet in the block.
171.38 lbs., weight of a cubic foot.

$$\frac{171.38 \times 96}{\text{lbs. in 1 ton} = 2240} = 7 \text{ ton, } 7 \text{ cwt., weight of block.}$$

"The 10-ton crane is therefore sufficiently strong to lift it.

"There are several slabs of limestone which measure altogether 300 cubic feet, and it is proposed to bring them down a river on a raft formed of teak logs, and which can most conveniently form a raft 42 feet long and 18 feet broad, what depth shall it require to be to float the slabs?

198.7 lbs., weight of a cubic foot of limestone.

$\frac{1000}{16} = 62.5$ lbs., weight of a cubic foot of water.

$\frac{198.7 \times 300}{18 \times 42 \times 62.5} = 15$ inches depth the slabs will sink the raft.

"1000 : 12 : : 745 : 9, that is a cubic foot of teak sinks 9 inches in water, of course 3 inches of wood above water; therefore $\frac{15}{3} = 5$ feet depth the raft will sink with the slabs, which, added to 9 inches, gives the depth the raft will sink in the water, and therefore the raft should not be made less than 6 feet deep.

12 : 6 : : 9 : 4.5 = depth the raft will sink.
1.25 = depth the slabs will sink the raft.

6.75 = depth the raft will sink in the water when carrying the slabs."

ARTICLE XII.

THE STEAM ENGINE AND BOILER EXPLOSIONS.

In this work it is unnecessary to say much about steam engines so far as construction and arrangement are concerned. Engines are not, as a rule, made by millwrights, nor are they usually set up or put in place by millwrights. They are made by the manufacturers, and by them or an employe skilled in the business, put in place and started. It sometimes happens though that engines are bought second-hand in very good condition, and they are generally put in place by a home mechanic, who may or may not understand his business fairly well. To such we will say: first plant a firm foundation; don't be afraid of getting it too strong or of wasting material in the construction; better a little waste of material in the construction of the foundation than a constant wear and tear of the machine after it is started, on account of having a shaky foundation. There should never be a perceptible tremor in an engine at work, no matter what the load it may have to carry; but then, as a matter of course, it should not be loaded beyond its capacity. The material used for the foundation of a steam engine should be rock, or rock and brick, or something else not subject to decay. No matter what the material, the foundation should be put down to stay, and to stay just where it is put; but this cannot be done if perishable material of any kind is used. To the foundation the bed of the engine should be firmly bolted by long bolts running up through the foundation, and around which the foundation has been built. Thus the entire mass of the foundation and the engine bed-plate will be clamped together, and if there be weight enough to the foundation no fears of tremor or vibration in the engine while running, need be entertained. In adjusting the parts of the engine, the same rule must be observed as in adjusting other machines. A line drawn through the centre of the cylinder, must pass directly through the center of the crank-shaft, and cross the crank-shaft at right angles. This simple rule must be positively observed in order to insure the engine to work smoothly and satisfactorily. The crank-shaft, like all other shafts, must be level—it is not necessary that the cylinder should be level, but it is necessary that it should be in line, as before stated. The customary method of getting a line through a cylinder is to first construct a cross of two pieces of board, two or three inches wide. Two of these crosses must be made, one for each end of the cylinder. The outer ends of these crosses must be circled to fit the cylinder snugly, and then exactly in the center small gimlet holes must be made, through which a fine line must be stretched reaching beyond the crank shaft. To this line adjustments must be made until all the parts agree.

Where steam power is used for making flour it is usually a matter of some importance to the manufacturer to use the power as economically as possible, on account of its very high cost comparatively. With water power where there is an abundance of water, power is of but little importance, but with light streams it is different; it then becomes necessary to procure the kind of a motor or wheel that will do the greatest possible amount of work with the least possible quantity of water, and on the same principle must a steam engine be selected. If a barrel of flour can be made with from thirty-five to forty pounds of coal, no flour maker wishes to be obliged to consume sixty pounds or more to the barrel. To avoid this, then care must be taken in the selection of the engine. Going over the entire list of engines made for the purpose of making the best selection, is a pretty big field of operation, but it is not really necessary to do that, as there are always a number of prominent engines in the market, all of which are good; and between a large number that could be mentioned, there may not be much choice, so far as economy in the use of fuel is concerned. Engines in every other way well constructed and using an automatic cut-off, are undoubtedly the most economical, but are usually the most complicated, and require more care than ordinary engines; but the difference in the saving of fuel, where fuel is an object, will more than pay for an expert, trusty man to run and take care of the engine. By the use of the automatic cut-off the steam is used just as it is needed, the machine regulating itself in that respect. If by reason of extra work, by putting on more machinery it it necessary to use live steam for a full quarter-stroke, it cuts off at that, but when the extra machinery is thrown off and only an eighth-stroke of live steam is needed, then in a moment it cuts off at that point, and so on through all the variations of heavy and light running.

There is still another method of engine building that is considered economical, and that is the combined high and low pressure engines. For large flour mills that require a great deal of power, it seems likely that engines of this class, well constructed, are the best. They are considered economical for other purposes, and we cannot see why they should not be equally valuable for flour mills on a large scale. Small engines for small mills would be just as well, perhaps, without so many attachments, which add greatly to the first cost, and to the necessary care afterwards. However, we do not know that anything very logical can be offered against the use of this kind of an engine of medium size. Common practice is largely against it, and that is probably about all. The value of a low pressure or a condensing attachment to a steam engine is that by producing a vacuum or partial vacuum in a conveniently arranged apparatus, connected with the engine, the instant the exhaust part of the engine is opened the steam rushes to the vacuum chamber, where it is met by a stream of cold water, which at once condenses it, producing a vacuum in the cylinder the same as in the chamber. The steam is then assisted by the force of the vacuum in pushing the piston back. Whatever is gained by the vacuum pressure, less the power it requires to propel the condensing apparatus, is a clear gain in power, or anywhere from five to ten pounds of pressure to the square inch of piston surface that costs nothing. If it required fifty pounds of steam ordinarily to do the work without the use of the condenser, then if by its use a ten pound vacuum, or atmospheric pressure, could be obtained, forty pounds of steam in the boilers would do the same amount of work as the fifty pounds did without its use. In this, then, is a manifest saving in fuel, as well as relieving the strain on the boilers. But, as has been said, if engines of this kind are to be used, flour mill owners would have to get rid of the idea that many of them seem to have, that any kind of a man is competent to run an engine. Skilled men would have to be used, and skilled, careful men ought to be employed anyhow, no matter much what kind of an engine there may be, because the power generators or steam boilers, require to be carefully handled, not only with skillful hands, but by men of brains and rare good judgment. On the contrary, we are sorry to say that men of the poorest judgment are quite too often employed as firemen and engineers having sole charge of engine and boilers. So far as taking care of the engine is concerned, it is a matter of no moment to any person or party except to the owners, as there is nothing at stake except dollars and cents, but it is somewhat different with the boiler. Human lives are often sacrificed by the explosion of boilers, caused frequently by the ignorance of those in charge. These gentlemen, many of them, after having made a few fires under a boiler, imagine they know all there is to know about the care of boilers, and thus work on in their ignorance and delusion until perhaps they and fragments of their boilers take a sudden flight into the air in search of a place where boilers do not burst; and were this the only damage done the world would suffer no very serious loss; but it quite frequently, in fact most always happens, that others are either maimed or killed by the disaster. To avoid, if possible, any trouble of this kind, is what should be the aim of every user of steam. Steam boilers are but a trifle less dangerous than powder mills, unless handled with great care, and even then no man can approximate a guess as to when an explosion will occur. It is frequently remarked, and by men, too, who ought to know better, that there is no danger of a boiler exploding so long as there is a full guage of water. This is a most fatal error, and has no doubt deluded many a man into ending his mortal career long before he was prepared for doing it. The facts of the case are these: a steam boiler will burst just as readily, other things being equal, with a full guage of water as it will with a partial guage, but the force of the explosion will always be in proportion to the volume of steam in the boiler, and the pressure. A very small quantity of powder, say, an ounce, if well rammed, will burst a good sized rock, but has not sufficient force to remove it from its place, while a pound of powder in the same rock would be liable to scatter it around indiscriminately; and so it is with a boiler. When there is a full guage or over of water, there is not room for a very large volume of steam, and if under such circumstances one explodes, not a great deal of destruction is done; there is force enough to kill a man, or several of them, if they are conveniently situated, but things are not torn up generally so bad. But if on the contrary, there is only a partial guage of water, and the boiler full of steam, and an explosion occurs, the destruction is pretty general. If a boiler were allowed to run empty, or nearly so, until the iron become weakened by heat, it would, of course, under those circumstances, be more liable to burst with a given amount of pressure to the square inch than with the same amount of pressure and a full guage of water, and this fact has, perhaps, led to the erroneous theory that a boiler with a full guage of water would not burst.

In order to make steam boilers sure, or as nearly sure as it is possible to make them, is, in the first place, to have them made of the best material and sufficiently strong to bear the strain. The difference in the first cost is but little, comparatively. One steam boiler explosion frequently causes more destruction of property than would be required to pay for a number of sets of boilers made in the best and strongest manner, as they should be, and when so made should be placed in the care of a competent man, one who knew enough to know that his own life and the lives of others depended on the kind of care he exercised over his charge. If these very necessary precautions were always taken there would be fewer disastrous explosions.

Before closing this article the writer would like to say something about the usual mode of testing a boiler, as he believes this to be as erroneous as the theory so common among many that a boiler will not explode when there is plenty of water in it. It has doubtless come under the notice of many of the readers of this book, that steam boilers have exploded with very great force in a very short time after they had been pronounced perfectly safe by the government, or other inspector. We think the mode of testing now in vogue is not only wrong, but it is ruinous to a very large degree; it serves only to weaken boilers by the great strain they are subjected to, without determining in very many cases their fitness for generating steam at a high pressure. Water is non-elastic, while steam, on the contrary, is highly elastic. A greater water pressure may be brought to bear on the boiler, but the instant there is the slightest yielding at any point, the pressure is to that extent relieved; the fluid being non-elastic cannot follow it up except by forcing more water in, and this is no doubt frequently done, until the joints are started and weakened, without discovering any defect in the boiler. But this is not the case with steam when raised to a high pressure; it immediately attacks the weakened point and follows up the attack. A yielding of the iron does not relieve the strain, as in the case of the water pressure. On the contrary, each thousandth part of an inch of yield is followed up by a still more vigorous outward pressure, relatively, by the ever expanding steam, until at last the hard pressed and tortured iron gives way, retreats as it were, in disorder, and then follows all the effects of a disastrous steam boiler explosion. In this fact may be found the solution to some of the boiler explosions that have followed so soon after an inspector's certificate has been given. The water strain has weakened the boiler, but on account of its non-elasticity, has been unable to follow up and develop the weakness, while the steam, on the contrary, on account of its great elasticity, has discovered the weakness and followed it up until great mischief was done. For these seemingly very logical reasons, if steam boilers are to be put to a severe test, the propriety of which is, to say the least, doubtful, it should be with an elastic fluid that will develop the weakness that it causes, and have it remedied before putting it on duty as a steam generator. The best security is to make the boilers strong enough, and keep them so by careful occasional examinations.

ARTICLE XIII.

RETROSPECTIVE—SOME PARTING WORDS.

We commenced this work with the view of carrying by an easy transition the mind of the reader, or the student in mill building and milling, from the primary to the present highest stage of the art. How well we have succeeded others will have to determine. The writer is a practical millwright, who obtained whatever of knowledge of the business he possesses by close application to the business, without the aid of works of this kind, as, in fact, none are in existence. It is true there are a number of general mechanical works that are very valuable, but they are chiefly designed to aid those who are already well advanced in mechanical skill and knowledge; and the same is largely true of works relating to flour milling especially. It was the lack of a work of this kind, felt by the author in years gone by, that induced him to undertake, in a plain, simple way, the present work. It was that that induced him to begin with the apprentice at the very moment of his first introduction to the jack-plane and hand-saw, to teach him something about how both should be handled, and the importance of handling both always to the best of his ability, on the principle that whatever is worth doing at all is worth doing well. The apprentice should always aim to do his best and strive to make every present effort excel the previous one. By this means only can he hope to become master of his business. If this lesson was not impressed in the beginning of the book, it was intended; and if it was, a repetition of it here can do no harm.

From the first lessons on shoving the plane and the saw, the learner has been carried to the more difficult task of framing—difficult to the beginner only; the advanced mechanic sees no mystery in framing; cutting a mortise requires little or no effort, but with the learner it is quite difficult; do what he will, somehow the chisel seems determined to run under, and the mortise when finished is larger every way at the bottom than at the top. But a little careful practice and the judicious use of a small square soon enables even the apprentice to make a very creditable mortise. After learning to mortise, stave-dressing has been introduced to our apprentice. This is done as a kind of relief from the more difficult task of learning to mortise, and while stave-dressing requires no great amount of skill, it still requires considerable practice to do it well. However, the flour mill builder has but little of that kind of work to do. From stave-dressing we set him to dressing conveyor and other octagonal shafts; this being a job that requires more attention and more skill, longer time is expended in its study. To a man with a matured intellect, whether a mechanic or not, laying off and dressing a conveyor-shaft might not seem a very difficult thing to do, with chances for a little observation; but with the boy at first sight it looks like a herculean task. However, a little practice and some good thinking soon removes all the obstacles. The apprentice boy must learn to think, if he does not he will never learn much of anything else. Habits of correct thinking are of the highest importance to the millwright; let the boy think for himself and think independently, but do not allow egotism and conceit to get the mastery. Following the dressing of conveyor and other similar shafts is the task of putting in the gudgeons; the one follows the other naturally, the latter being by far the most difficult job, sometimes requiring all the skill of the advanced workman; but the beginner has to learn and we have kept him right along, or tried to, in regular order, and we think if the lesson has been well studied the boy will have no serious trouble, ordinarily, in making a fair job of getting the gudgeons in. After the gudgeons have been put in, the boy has been set to making the conveyor, with instructions how to lay out the shaft, bore the holes, and drive the flights.

After the apprentice has mastered the situation so far as presented, which, as a matter of course, takes somewhat longer than it has taken to write it, he is supposed to be able to take a step higher, in fact, become almost a full grown journeyman, in the use of tools at least, and therefore he is next called upon to build a husk-frame. A husk-frame should be put together in the best possible manner, and hence we have not thought it advisable to put the apprentice on it until the rudiments have been well learned, and he has learned to handle tools well and to think well; for by thinking the judgment is improved, and a good judgment where there are no other available guides, is of a vast deal of importance in getting up a good husk-frame; and it is presumed that after working and studying and getting so far along the skill and judgment can be risked on the husk-frame. Following the construction of the husk-frame, necessarily comes the setting and adjusting of the bedstone. This lesson has been taught as well as the circumstances would allow, and is certainly quite full enough to be of material assistance to all who are not already familiar with the operation. Then the mode of making a curb is described, and given all the attention it probably deserves, as it may be regarded as a kind of an intervening lesson, or a sort of a recreation and rest of the brain; it serves to keep the hands skillful without taxing the head to any great extent. After this follows quite a lengthy lesson on furrowing, facing, putting in the irons and balancing the runner. Considerable space is devoted to balancing, not so much in describing a practical mode of doing it as in demonstrating the theory. The author holds that the best way of enabling the learner to balance a stone is to make him fully acquainted with the principles involved, and then let him devise his own method, if the mode of doing it has not already been provided for. This is a lesson for developing the intellect, while it to some extent rests the muscles. Then again follows a general lesson in reference to drivers, springs, portable mills, speed of burrs, etc. These are all matters of a greater or less importance, and should be well studied. If the information here given does not make everything entirely plain, it at least starts a train of thought and reflection, which if followed up as it should be in a practical way soon develops a full knowledge in the seeker after more light.

From this on, the arrangement is more general; the cleaning of wheat is discussed as an important element in good flour making; the arrangement of cleaning machinery is made a matter of some note, in the belief that the more conveniently it can be arranged the better it is, not that the work of machines is in anyway improved, but the trouble and expense of handling the wheat is greatly lessened. The constructing of bolting chests and the arrangement of bolting cloth, and the whole system of bolting generally, is considered at some length, but occupies no more space than its merits deserve, not so much, perhaps, because on successful bolting much depends in flour making, and while the subject has been by no means exhausted, still there can be a great deal of information gathered from the articles on bolting in both parts of the book. Next comes a lengthy dissertation on elevators, the mode of construction, manner of discharging, their speed, and also, something about spouting. The part of this article relating to the speed of elevators will doubtless be severely criticised by many practical men, because of its utter disregard of generally accepted principles involved in the matter; but it can do no harm, as the more the matter is talked about the more we are all apt to learn about it—more especially if the parties who do the talking will talk from a well-poised, practical stand point. The adjusting of shafting, the filling of cog-wheels, and the construction of wooden water-wheels, each come in for a share of consideration, and they are each subjects of importance. Making water-wheels is not now so much done by the millwright as it used to be, still there is a great deal of it done yet, and it is well to know something about how it ought to be done. Cog-wheels, on the contrary, are in every day use and will be; also shafting, which must have a place while machinery moves, and a familiar lesson on both of these is in the estimation of the author of the highest importance, because a millwright who cannot put up a line of shafting well, level and straight, and cog or fill a wheel so that it will run easy and smooth, is not considered much of a mechanic; hence the young millwright should exert himself to understand these matters well. An article on rules for calculating the speeds of gearing and pulleys, makes, as the author thinks, a very valuable feature of the work, as the effect has been made to make the matter plain and simple easily understood, and at the same time reliable. These rules should all be well studied, and committed to memory as far as practicable. The first part of the book closes substantially with a series of tables and explanations on the number of horse-power that can be safely transmitted by gearing, belting, and shafting. These tables have been compiled with a great deal of care, and while, no doubt, imperfections will be developed, they are the best set of tables of the kind in existence known to the author, and are therefore all the more valuable for reference. Tables of this kind certainly assist very materially in systematizing the arrangement of gearing, belting, and shafting—but little is generally known about the relative transmitting power of either—and hence great disproportion is often discovered in the arrangement of each. By a careful study of the subject this could be avoided and greater uniformity, and consequently, better results would follow.

The second part of the work is devoted more exclusively to the later or improved methods of milling. In accordance with the custom, the face of the stone has been changed, wide furrows have taken the place of narrow ones, the face surface has been reduced and made comparatively smooth; this means making ready for high grinding. Then the purifiers are introduced and their arrangement and management discussed; following are further and more elaborate instructions for bolting, introducing a method not so generally practiced or known, ending with a brief description of a "new process" mill, in which all the essential parts are arranged so as to give the reader a very good idea of how such a mill should be built. After all this, the later methods of gradual reduction is very fully described, beginning with a system purely American, and the latest system introduced, and ending with a description of the Hungarian method. This ends the duty of the book so far as it relates to mill building and milling especially.

The remainder of the work relates to matters of a general character, useful to all classes of mechanics, and should be well studied by millwrights particularly who are not already well informed in such matters. But after all, after the book has been well read and well studied, no boy or man must imagine himself qualified to build or operate a mill. Even were the work much larger, more exhaustive, much clearer and more direct than it is, still it would be insufficient to make a thorough millwright or miller of any man. A thorough and complete practical knowledge of this or any other calling can only be obtained by close application and persistent hard work. The boy who expects to succeed in any useful calling, and more especially a mechanical calling, must begin early and work industriously; and were it not so, but little value could be attached to a good trade or useful calling of any kind. If it were possible for a man by a merely theoretical knowledge of a trade or calling to become at once master of it practically, then all would soon be thoroughly practical men, one perhaps no better than the other, thus destroying the incentive to hard work in trying to excel. The proper ambition, and the one that should move the hand and fire the brain of every youth commencing in the world, is to excel in whatever he undertakes, and to do that he must toil, expending brain and muscle, and getting in return therefor knowledge and power. Therefore we say to every apprentice boy that this book, nor no other book ever written, or that ever will be written, can make of him a good practical mechanic, but it can greatly aid him, and for that it is designed. The wearied muscle, made so by the toil of the day, can in the early evening be rested by the gentle exercise of the brain on the book; and the additional knowledge thus obtained imparts new energy for the next day's toil.

And to the miller or mill owner we wish to say that they cannot learn how to build a mill out of a book, not even this one, and must not, therefore, think that anything in the shape of a wood-butcher is competent to build a mill, or any important part of one, by the aid of a book alone. No man who contemplates building a mill, unless he be a millwright himself, should make a single move before consulting a millwright, and when it has been decided upon to build a mill, then should a skillful millwright be employed to draw a plan. The cost of this is something to start with, but it will be more than replaced, or it ought to be if the plan is perfect, before the building is completed, in the loss of time and material in doing guess-work. It is true that incompetent men calling themselves millwrights, and who are fair draughtsmen, may sometimes delude men into employing them to build mills or doing important repair jobs. This can generally be avoided by employing none but those who are known to be good mechanics and men of good judgment. But to the mill owner this book and other good works are useful in affording general information, or for holding in check men who are not thoroughly competent. The mill owner by having a good theoretical knowledge of what he wants, although without the necessary practical knowledge to do it himself, can at least determine whether or not it is being done as it should be, and have the corrections made if any are needed. A work of this kind can never make a millwright, but it is of great value to the boy learning the trade and for reference; of great value after the trade is learned, and equally valuable for millers and mill owners for the same purpose. All may learn something never before known, or at least never considered; but none can take the book and build a mill successfully without having some previous practical knowledge of the business.

And now a word to millwrights in general, the old millwrights, those who are competent and doing business: they should employ apprentices; if they do not the stock of millwrights will soon run out. The business seems to be rapidly degenerating, and yet it should not be so. It is a time-honored trade and should be venerated not only for its past but for the great use it should be to the future. It is presumable the many changes that have been made in the past quarter of a century has a great deal to do with this tendency to degenerate. If it were necessary, as formerly, for the millwright to build or make everything about a mill; if he had to make the water-wheels, the shafts, the cog-wheels, the pulleys, and everything else, in fact, then, perhaps, more attention would be paid to educating new millwrights. But as it is, not nearly so much work is required of the millwright in building a mill, the most of the strictly mechanical work is done at neighboring machine shops; and as that part of the work that is required to be done by the millwright can be, with a good foreman to look after and superintend it, done by good ordinary carpenters, if they can be hired cheap enough to make it profitable, it is by this means millwrights are being daily manufactured in some localities by wholesale. These carpenters, many of them, after working awhile on a mill job esteem themselves competent millwrights, and bid for jobs on their own account, thus injuring the trade in general, and those they do work for in particular. There are very many of just such millwrights in this country to-day who ought to be weeded out, and there can be no better way of doing it than for millwrights to take apprentices and educate them into the business, and thereby create a stock of competent men to fill the places of those who are now in the business, and thus maintain the standing of the trade. In this way can good mechanics be made available and plentiful, and when such are required by mill men in any section of country, they can be readily obtained, without the extra expense and trouble that now frequently attends the procuring of a competent millwright to do a job of work; and, too, it would do away with the excuse often offered in apologizing for a bad job, that no good millwrights were to be had. Educate millwrights from boys, and enough of them, and all will be well done.

APPENDIX.

REMARKS.

The Appendix of this work is devoted exclusively to the business cards of leading mill-furnishing establishments and manufacturers of various kinds of mill machinery and supplies. Those here represented are among the best, and are all strictly reliable houses, with whom any millwright or mill owner can deal, with the assurance of being well and fairly treated.

INDEX TO ADVERTISEMENTS.

A Scientific Conversation in a European Hotel — A Humorous Account of the Primitive Method of Transporting a Mill Stone in Germany.

TRANSLATED FROM THE GERMAN.

Mr. Sigismund Low, a prominent civil engineer of the United States, while traveling in Germany for the purpose of scientific research, met a former college friend, Baron Wuertenau, at Heidelberg, with whom, after discussing various applications of technical science, he had the following conversation:

SIGISMUND LOW. "My nephew wrote me, before I left America, that any information I might be able to give him relating to the latest and best improvements in American mill machinery would be of special service to him."

BARON WUERTENAU. "Pardon the interruption, Mr. Low, but many millers who have visited America tell me that of the large number of improved American machines very many have to be thrown aside as useless.

S. L. "That is quite true; there are many worthless machines put into the market, but in a majority of cases the fault is with the miller, and not in the machine." B. W. "How so?"

S. L. "Well, I have seen stately palace-like buildings fitted up in the most elegant style from grinding floor to roof, built apparently to be ornamental rather than useful, while *the most important part*, the pit gear, runs as if intended to grind bones or cement. Any variation of motion, however slight, will make a burr quiver or wabble, causing rapid changes of the relative positions of the grinding surface, and thus grind too fine at some points and too coarse at others. If the action of the stone is thus defective, all the improved machinery in the mill will not remedy the effect produced by this evil. Let me tell you of a model mill I saw which combines improvements on this vital part of mill machinery. I had heard a great deal of the celebrated model mill built by Mr. Jno. A. Hafner, of Pittsburgh, Pennsylvania, and therefore stopped at that city to see it. I was really astonished at the number of ingenious improvements and sound practical ideas combined in so small a compass, among the most important of which are the Eureka Coil Spring and Eureka Friction Clutch, which are also important improvements for threshing machines driven either by horse or steam, as they save fully twenty-five per cent. of power. Mr. Hafner has certainly reduced the study of springs to a science, as, in addition to his celebrated spring he has invented a clock which has run continuously one year without re-winding. I made a number of tests with the model mill and it exceeded my most sanguine expectation. I purchased this duplicate model for my nephew."

B. W. "What are those two hand wheels near the stone used for?"

S. L. "The one to the left connects with Friction Clutch on driving wheel; the other raises or lowers pinion. Thus the miller can stop or start the stone at will, and lift pinion out of or place it in gear without leaving his post."

B. W. "Why is it that belt motion should vary 20 per cent?"

S. L. "That is easily explained. A belt is merely a transmitter, and not a reservoir or equalizer of power, and if there is any variation in the motion of the driving pulley it is transmitted to the spindle pulley and consequently to the stone."

B. W. "If so many American millers build steam mills upon a plan which *actually loses* 38 *per cent. of power* why do they make so much ado about the gain of two or three per cent. by water wheel?"

S. L. "Thousands of millers throughout the United States have seriously considered this question, and as a result, they are rapidly adopting the Eureka Spring and Hafner's system, which absolutely *saves* this thirty-eight per cent. of power by reducing friction and equalizing the motion. In fact, these improvements have been adopted everywhere in the States, except in a small community of Pennsylvania Dutch, who are, in their characteristic slowness, identical with the native Germans of Hutzelwald, on the Rhine. By the way, have you ever heard the Hutzelwald anecdote?"

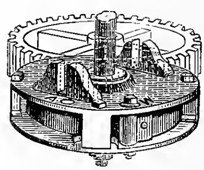
B. W. "I know the Hutzelwalders are a good, honest, industrious, but slow, people, who are adverse to any innovations or improvements, but I have never heard the anecdote."

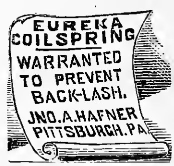
S. L. "Well, these people decided to build a mill. They quarried and cut a mill-stone from the hill, three hundred feet above the mill site, and were at a loss to know how to get it down. They decided to let it roll down, but, unfortunately, it turned to the left, and ran down a ravine. After several days dilligent search they found it in a thicket, one and a half miles from the mill. Simply recognizing the fact that the blunder was made in not giving it a proper start, they, with great difficulty, carried it to the top of the hill from which it was started. Lest it be lost again, one of the party put his head through the eye of the stone, intending to accompany it down the hill in this manner, and in case it departed from the intended course, he promised to whistle, that the others might find it. Hannes (who in his young days had been hostler in an artillery corps), with the air of a military expert, proceeded to make a reconnoissance of the field, and aimed the stone direct for the mill door, gave the command, 'fire!' and off they let it go. The weight of a man on one side, of course, caused the stone to rapidly change its course, and man and stone went crashing through bushes and trees, finally landing at the bottom of a small lake. The parties on the hill vainly waited for a signal—vainly searched for the stone. After carefully considering the matter, they concluded that the man, considering the stone was of considerable value, had ran away with it. Therefore the Burgermeister was authorized to publish the following: 'Reward!!! Five thalers vil becomen to de man as vil arrest eine deutschman mit eine mill shtone arount mit his head.'"

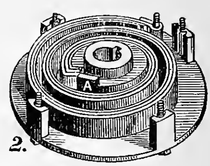
Hafner's Patent Eureka Coil Spring.

For Steam Engines, Mill Spindles, etc.

Can be Applied Above or Below Pinion.



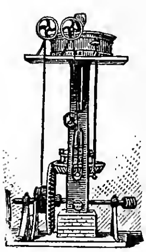




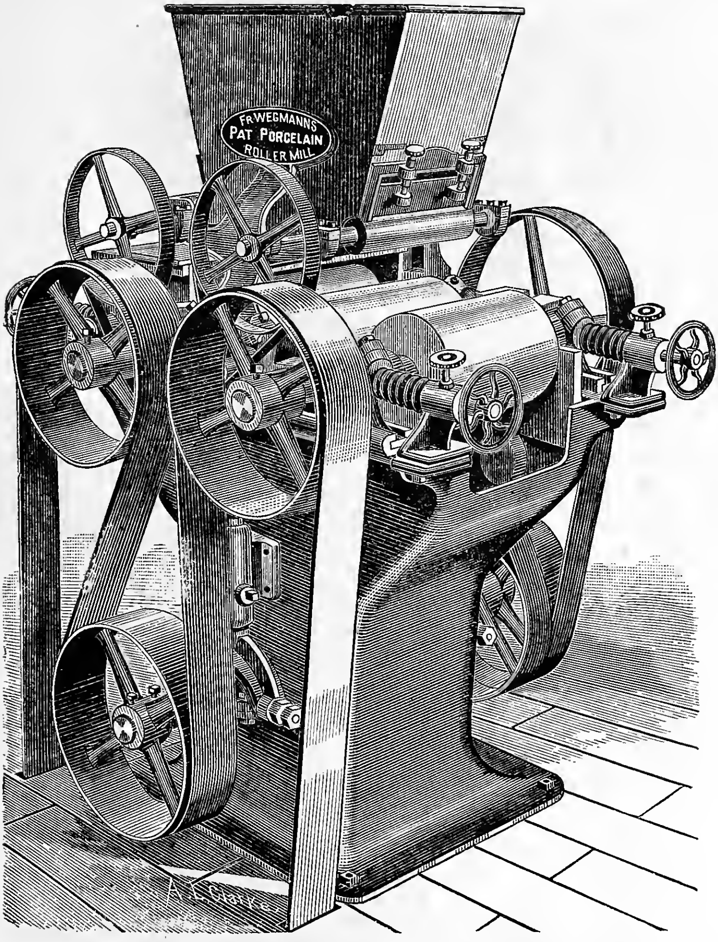
Patented February 2, 1869; December 30, 1873; October 5, 1875. Reissue, June 22, 1875; October 24, 1876.
Patented in Canada, October 25, 1876.

The Hafner Eureka Friction Clutch for Mill Gearing.

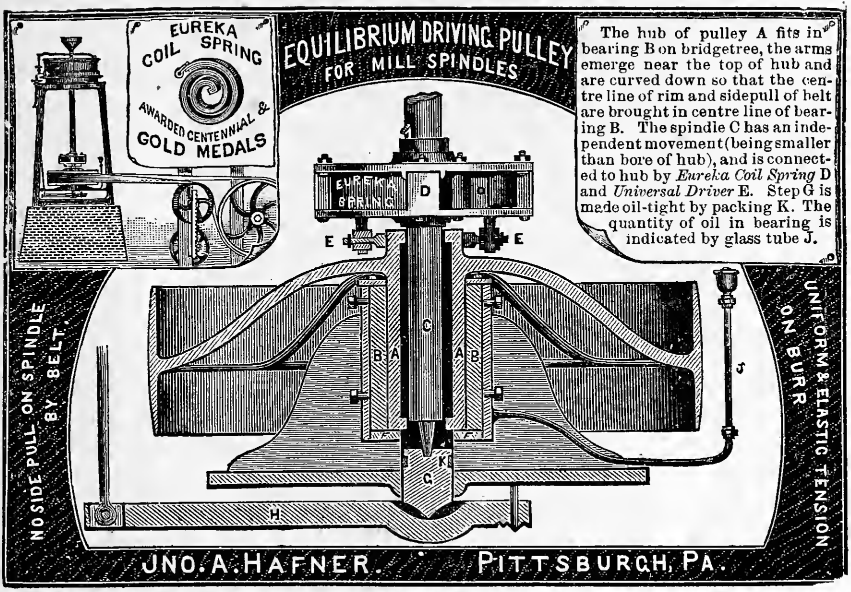
CAVEAT FILED.



Is an invention of great importance, constructed on an entirely new plan; it holds automatically, and is connected with the driving bevel wheel. It is so arranged that the miller turns a hand-wheel on the grinding floor, which will draw a brake upon the clutch and open it, thus stopping the wheel. By turning another hand-wheel (also on the grinding floor), it will either raise the pinion out of gear or put it in gear, as the case may be. When the miller loosens the first hand-wheel, the clutch closes, thus it starts the driving wheel and runs with shaft, whether it is driving the stone or not. Thus there is no wear on the shaft or eye of the wheel; and the miller can lighten the stone, start or stop it, and raise pinion out or put in gear alone while on the floor, without stopping the engine.


FR WEGMANNS
PAT PORCELAIN
ROLLER MILL


WIRE ROPE



The Hafner Equlibrium Driving Pulley

FOR MILL SPINDLES.

The two greatest objections to the use of belts to drive millstones are—

FIRST—SIDE PULL ON SPINDLE.

To prevent this several devices have been resorted to, such as bearings near the toe, etc.; but it is extremely difficult to have the spindle as tight to bearing when tramming as it is when driving a burr.

SECOND—VARIABLE TENSION.

With the very best engines the crank acts with the greatest leverage when it is at right angles to the centre line of stroke; thus the speed and consequently tension of belt on spindle-pulley is greatest at that time—say to the amount of twelve-horse power. But as the leverage gradually diminishes to zero, as the crank is passing the dead points, it is evident that the tension of belt will diminish in same ratio. But as there is a slight degree of stretch in a belt, it may still retain a tension of, say two-horse power, which would make impossible the back-lash in driver, which would otherwise result from the momentum of the millstone. Thus the miller is left under the impression that the stone is driven with smooth and uniform motion, when in reality it is driven by impulses varying from two to twelve-horse power twice in every revolution of the engine.

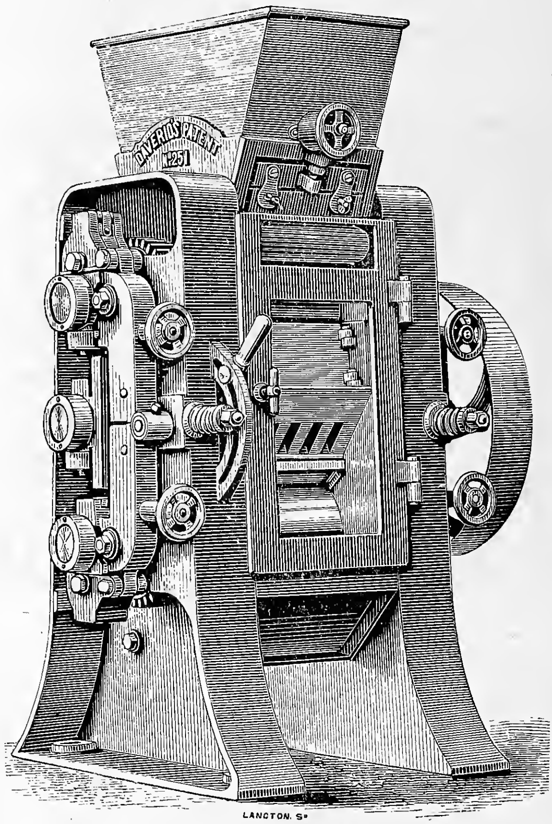
That a stone cannot revolve on a perfectly horizontal plane when affected by such disadvantages, it is unnecessary to repeat. What is desired is to overcome these objections; and for a complete and satisfactory method of doing so, we refer you to the accompanying cut and explanations.

Simon's Complete Roller Milling System

(DAVERIO'S AND SECK'S PATENTS.)

These Rollers are NOT of Porcelain, but of a special Chilled Iron, never cracking, never breaking, never getting loose. Much less heat evolved in grinding.

Old Mills Guaranteed to Double their Production with about same power and space.



These Mills attain a maximum of production with a minimum of power and space. Percentages of Flour equal to that obtained with stones, whilst the quality is vastly superior.

Results Guaranteed Equal to Austrian

Both in Percentages and Quality.

☞ A Complete Milling Plant, on this system, will be exhibited in operation at the coming Cincinnati Exhibition.

☞ Six complete Flour Mills, on this system, in course of erection in England alone.

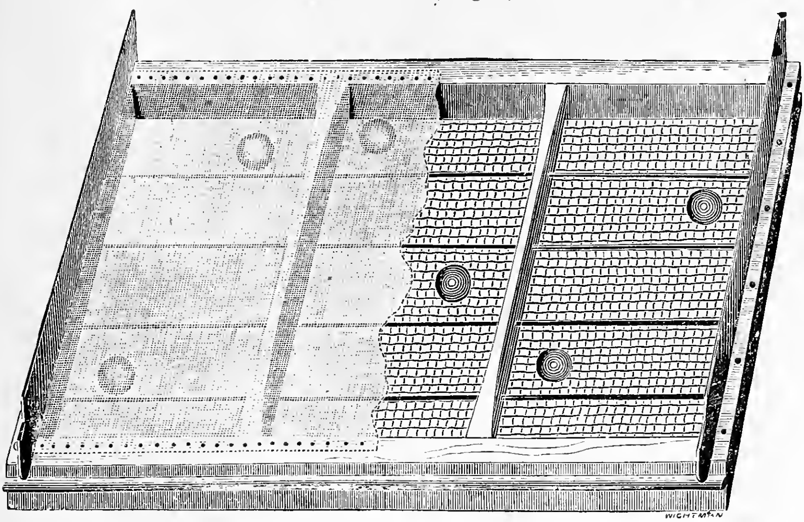
Address,

H. SIMON, Engineer,
Manchester, England.

EXCELSIOR

RUBBER BALL SIEVE CLEANING ATTACHMENT

Patented Jan. 21, 1879, Aug. 12, 1879.



The foregoing cut will fully explain the operation of this simple device. As is well known, we use in our **EXCELSIOR MIDDLINGS PURIFIER** our Patented Interchangeable Sieve, one of which, with Sieve Cleaning Attachment, is shown in above sectional and perspective cut.

Across the bottoms of our sieves, which are covered with bolting cloth in the usual manner, we stretch from side to side a No. 14 wire at intervals of one and one-half inches, and then a wire cloth of one-quarter inch mesh, and in the compartments formed by the wire cloth on the bottom, bolting cloth on top and bars on the sides, we place rubber balls of such size as will freely play in the space. The motion of the shaker, the rough surface of the wire cloth and the cross wires cause the balls to jump and dance in all directions, and these in turn jar the bolting cloth, keeping the meshes free and open so that the operation of the machine is the same at all times.

By this arrangement we avoid the annoyances peculiar to brushes, traveling air blasts and knockers, while our machine is always in order, and each section of sieve carries its own cleaning facilities, ready to work the moment the machine starts up.

This device is so simple and appeals so strongly to the understanding, that we abstain from giving any of the many testimonials at our disposal.

Those having our Excelsior Middlings Purifier without this attachment, can be furnished with rubber balls and wire cloth required, at the following prices per single sieve:

No. 1, 40 cents. No. 2, 45 cents. No. 3. 75 cents.
Nos. 4 and 5, 90 cents.

HUNTLEY, HOLCOMB & HEINE,
Silver Creek, New York.