SCIENCE OF
THRESHING

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SCIENCE OF THRESHING

Treating the Operation,
Management and Care
of Threshing Machinery

BY G. F. CONNER

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PREFACE.

In no other line of industry has the present generation witnessed so marked a degree of development as in the design and manufacture of grain handling machinery. When we consider the difficulties to be encountered and the obstacles to be overcome in taking heads of grain, husking the minute kernels from the covering, afterwards known as chaff, in which Nature has enveloped them, depositing the golden grain in the sack, and delivering the refuse according to the will of the operator in so perfect and expeditious a manner, we may look upon the modern thresher as a marvel of success.

To the thresherman in the field belongs more credit for this achievement than is generally accorded him. He is the final dictator. On his judgment a device must stand or fall. His is the part to suggest, the manufacturer's to execute. And even now, face to face with the proficiency already attained, we find that there is room for more and deeper study. Further progress can be made by all working in unison.

By some the position is taken that there can be formulated no definite rule by which to operate a machine, and this is true to a certain extent. The same may be said with equal truthfulness of any work requiring skill, as skill can be had only by experience. Each and every part of a threshing outfit, from the foot board of an engine to the tail end of the straw

carrier, works under and obeys some law peculiar to itself. Unless both manufacturer and operator understand the various laws and principles which govern a device, it is liable to fail to perform the functions intended, though both parties may have had unlimited experience. This necessary understanding or knowledge can be gained much more easily and successfully than by depending upon the slow process of the school of experience to educate and teach what should have been understood at the beginning. As the mind will grasp information from any source within reach, the written rule is much the better method by which to gain a knowledge of the laws and principles. The mind must first be informed and then the hands made skillful. Recognizing this, the author has endeavored to place before the reader such an exposition of the subject under consideration as will best enable him to reap the best results from his labor.

If this book is the means of aiding anyone in his part of the work, the author will feel conscious of being well repaid for the labor and time consumed in preparing it.

Due acknowledgement is hereby extended to all who have aided in any way to make it a success.

GEORGE F. CONNER.

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Science of Threshing.

CHAPTER I.

THRESHING

Threshing is the process of removing the kernel or grain or seed from the stalk to which it is attached. The ordinary threshing machine of to-day is able to operate successfully on wheat, rye, oats, barley, rice, flax, timothy, millet, buckwheat and peas.

These plants carry the grain or seed in a head, each kernel being surrounded and held in place by a covering or hull. Threshing is the removing of the kernels uncrushed or unbroken from this covering, free from dust, dirt and other parts of the plant. These parts, when removed, form the so-called chaff.

Naturally, the first step in the process of threshing is to loosen the hard kernel from the head. This is most easily done by striking the head. In Biblical times, even now in the far East, this pounding or striking was done by spreading the unthreshed grain

upon a prepared threshing floor and driving horses or cattle over it, the hoof as it came down upon the head splitting open the hull, or seed pod, and forcing out the kernel.

Later this result was accomplished by the flail, which is nothing more or less than a mallet having a long handle which enables the user to stand fairly erect, the loosely hung long head of the mallet striking a quick, sharp, rebounding blow, which produces a jarring shock and causes the kernels to fly out.

With the present plan of threshing, the grain is

struck in a manner similar to the flail, by the rapidly moving teeth of the cylinder as it revolves. The action of the flail is increased many times by the increased number of teeth and the greater speed at which they travel. Stationary teeth in the concave retard and hold the grain in place while being acted on by the cylinder teeth. The "concave" teeth are

arranged so the cylinder teeth can pass between them. The unthreshed grain heads are laid on the teeth of the concave, and the cylinder teeth strike them quick, sharp blows. The tendency of the heads to bound back from the teeth forces the kernels out from the hulls, already split by the contact with the teeth.

Thus it is seen that the cylinder, with its teeth,

and the concave with its teeth, are the parts of the modern threshing machine which perform the work of the horses' hoof of ancient days and the flails of more recent years.

After the grain had been stamped or beaten out on the threshing floor, the heavy berries were separated

from the straw by careful raking, and from the chaff by tossing in the air, the wind blowing the lighter refuse away. Or else air was forced through the grain—as it fell in a thin stream—by a fanning blanket. Later, the fanning mill was invented to both sift and blow out the chaff.

To-day the separator performs the task of raking the straw and sifting and fanning the grain. In addition, it delivers the grain in one place and removes the straw and chaff to another. It performs these widely different steps by,

First.—Loosening the kernels from the heads.

Second.—Separating the kernels from the straw.

Third.—Removing the chaff.

Fourth.—Delivering the grain and straw in separate places.

CHAPTER II.

THE SEPARATOR

While varying in minor details the modern thresher consists of—

First.—The threshing members—the cylinder and concave, with their teeth, the grate and the feed board.

Second.—The separating members, which separate the loosened grain from the straw—the beater, check-board, racks or raddles.

Third.—The cleaning members which remove the chaff and dirt—the cleaning mill or shoe, and screens.

Fourth.—The delivery members which carry the grain in one way and the straw in another—the grain spout, tailings elevator and straw carrier.

THE THRESHING MEMBERS

CYLINDER.

A cylinder consists of a number of parallel bars fastened to the peripheries or margins of circular discs, spiders, or heads by means of bands shrunk around them, the whole being mounted on a suitable shaft. The

CYLINDER

cylinder teeth are inserted in sockets in the bars, and are secured by nuts on the inside, or by wedges. The cylinder should be capable of endwise adjustment so that its teeth may be made to run centrally between the teeth of the concave. The cylinder acts as a balance wheel in which is stored power to maintain its speed when an undue amount of straw is permitted to enter. There are usually nine or twelve bars in the cylinder.

As hitherto indicated, the office of the cylinder is to loosen the kernels from the head. This is accomplished by the cylinder tooth striking the unthreshed head with sufficient force to jar the kernels loose from their retaining hulls. Therefore the cylinder should run with sufficient speed to entirely free all the kernels and not leave any on the straw. If for any reason the cylinder does not do its work thoroughly, the result is wasted grain. In some instances some of the kernels will be partially loosened, but adhere to the head until nearly through the machine, when they will fall out and be carried along with the straw to the straw stack, thus making the machine appear to be at fault in separation by wasting the grain, when in reality the threshing members are not doing their work properly. The usual speed of ordinary cylinder teeth is about 6,000 ft. per minute. Under ordinary circumstances, this will thoroughly dislodge the kernels, if the teeth be brought in contact properly with the heads. In dry, brittle grain, a slower speed may often be used by running the machine

slower which will thoroughly dislodge the kernels and not break the straw so badly. In damp and tough grain a faster speed may be used if necessary to thresh the straw clear of kernels.

On account of the cylinder being so heavy and running at so fast a speed, it should be kept in perfect balance, as it greatly adds to the smooth running of the machine. When the cylinder is out of balance, it is easily detected by the jarring or vibrations in its vicinity. By placing the hand upon the frame work of the machine near the cylinder boxes or bearings, a peculiar jarring may be plainly felt when the cylinder is not true. The side on which this is most evident will indicate the end of the cylinder which is at fault.

If permitted to run out of balance, the cylinder will have a tendency to cause its journals to heat and wear out rapidly, and also to flatten the cylinder shaft on the side that receives the wearing strain. A smoothly running cylinder requires a minimum of power to drive it, as whatever force is used to cause the vibration is so much power lost, or work done for nothing. The working and lasting qualities are also lessened, if allowed to vibrate, as every vibration has a tendency to loosen the framework of the entire separator.

A cylinder may be put in balance by removing it and placing it with its journals resting on two parallel straight edges, such as carpenters' squares set up edgewise. The squares or straight edges should first be trued up with a spirit level, and may be held in

place on edge by driving spikes on either side of them. The cylinder will adjust itself by turning on the straight edges, the heavier side going down. Wedges or pieces of iron of the right weight should be driven in between the band and head on the light side of the cylinder to cause it to balance or remain without turning in any position in which it may be placed.

If cylinders are properly balanced when they come from the shop, this method will usually put them in good running order. However, a cylinder may seem to be in good balance when on the straight edges, and not so when in motion in the machine, the cause being that one end is heavy on one side while the other end is heavy on the opposite side. In such event, the cylinder should be run rapidly in loose boxes, and while in motion a piece of chalk should be held steadily near enough the shaft at the journal to mark it slightly. The chalk will strike and mark the heavy side, and the balancing piece should be inserted as before, both ends being correspondingly trued.

A cylinder is sometimes thrown out of balance by putting in some new teeth irregularly around the cylinder, leaving part of the old ones in. In this case, the remedy is to replace all the old teeth, when much worn, by new ones, thereby redistributing the weight in an even manner.

It will aid the cylinder greatly to work freely and easily if the separator stands still on its trucks while in operation.

CYLINDER TEETH.

The cylinder teeth are made so as to be easily replaced when worn out. The forward side of each tooth is curved slightly.

If perfectly straight, it has a tendency to carry the straw into the machine too rapidly. On the other hand, if worn too much it retards the passage of the straw into the machine, thereby interfering with the feeding. The cylinder should be adjusted so the teeth will pass midway between the teeth of the concave. If permitted to have too much side play, or to run too close to the concave teeth, the teeth will crack the grain and chop the straw up, and at the same time, will permit heads of grain to pass unthreshed through the wide openings which occur opposite the narrow intervals. The teeth sometimes become loose and cause delay. This is especially true of new teeth when first inserted, as they do not always fit perfectly, and the strain to which they are subjected when the straw becomes compressed in moving through, makes them move a little in the bars. Accordingly, new teeth should be watched carefully when first inserted and tightened up until they are well seated, when they will stay in place. Much time will be saved by going over the cylinder each day and tightening up the new teeth. Many devices have been used to keep the nuts from working loose, some of which have considerable merit. Wooden bars have been used inside of the cylinder, the natural spring of the wood permitting the teeth

to yield a little without becoming loose. A twisted or spiral spring bar has been used for the same office. Teeth do not loosen so badly in double as in single bar cylinders, as the extra length of shank holds them from sidewise movement when an excessive amount of straw is encountered. A spring steel split washer is sometimes used under the nut to keep it fast.

It is needless to add that worn teeth retard the proper work of a separator and should be replaced by new ones.

THE CONCAVE.

The concave, so called because of its dished or hollow shape, consists of a rack or grate constructed to conform to the cylinder under which it is adjustably hung. It is provided with teeth which interact with the cylinder teeth. It is adjustable to and from the cylinder. The concave holds the concave teeth in position between the cylinder teeth and forms a floor or grate over which the straw passes while being acted upon by the cylinder. The open space between the teeth permits the shelled grain to fall through as soon as dislodged from the heads, thus

relieving the separating devices from some of the work of removing the grain from the straw. Concave teeth serve the further purpose of retarding the grain while it is being acted upon by the cylinder teeth. The greater the number of teeth the more the straw will be retarded and acted upon by the cylinder. Separators are usually constructed to use concaves of several sections, each section being provided with two or three rows of teeth. In adjusting the position of the concave relative to the cylinder, it must be borne in mind that some grain requires very positive action on the part of the cylinder teeth to dislodge the grain from the head; accordingly, when threshing grain of that sort it is well to set the concave close and employ all the sections. In grain that is less stubborn, a section of the concave may be removed and replaced by one without teeth with good results.

There should be stops provided to prevent the concave from being raised too high so as to give a proper clearance. It is better practice to set the concave up close and use few teeth rather than to lower the concave and employ a greater number. The latter plan leaves a space below the points of the cylinder teeth which permits the straw and whole heads to pass without being acted upon. If the straw be very dry and brittle and inclined to break up badly, it lies more loosely and can therefore be given a considerable more space by letting the concave down.

Some types of concaves are adjustable, both at

their front and their rear edges. The proper positioning of these has given rise to much discussion, as some experts claim that a cylinder is less liable to slug when the front edge of the concave is the higher, than when the concave is fixed in the opposite position, as the wedge shaped opening through which the straw passes broadens as the straw progresses and does not tend to clog or bunch it.

THE GRATE.

A grate formed of slightly separated parallel bars through which the kernels may easily fall is placed just back of the cylinder. It should be so adjusted that the straw in passing from the concave will strike it at an angle; this will aid the separation by affording a comparatively straight or unobstructed path for the flying kernels which are thereby less impeded and fall through more readily. This position also allows the passing straw to sweep the grate cleanly, and to prevent it loading up with chaff and sticks.

THE FEED BOARD.

The feed board is a platform placed in front of the concave and connects with it, as in hand feeding machines on which the sheaves may be cut and spread for presenting to the cylinder. The surface of the feed board and its extensions, or tables, should be smooth, and free from nails or other obstructions, to facilitate the moving of the straw.

If the cylinder does not have sufficient draft or pull to take the straw readily enough, the edge of the feed board which comes in contact with the concave may be rounded or curved; this is usually a good remedy. A desirable point in the working of a separator is also gained in that the straw, which passes more freely over this rounded edge than it would over an abrupt or angular margin, is not broken or cut up to any great extent.

It is good practice to keep the lower edge of the feed board on top of the concave close to the cylinder teeth, even when the concave is lowered, thus every head is acted upon by the cylinder teeth as it passes over the concave.

CHAPTER III.

THE SEPARATING MEMBERS

After the unthreshed grain is passed from the feed board between the threshing members, the cylinder and concave, and has been beaten and jarred by their interacting teeth, the mingled straw and loose kernels of grain are delivered to the separating members.

BEATER.

In its most common form, the beater consists of a shaft carrying two circular spiders or heads between which are secured beater boards or wings which extend edgewise from the center shaft. The office of the beater is to move the straw away from the cylinder back to the separating parts. Its chief usefulness is in preventing the straw from piling up back of the cylinder where it is liable to be caught and wound in between the cylinder and concave. This action of the machine is called "back lashing." It should be so placed as to allow the grain and straw to strike it as they come from the cylinder and pass either over

or under it. It serves as a check to the flying kernels from the cylinder. However, it is not of much benefit as a separating device as its rapid motion tends to carry the grain along and throw a portion of it on top of the moving straw. Consequently, it should be run just fast enough to prevent its catching or winding damp or soft straw, its position being chosen at the proper distance from the cylinder.

Other devices are used instead of the beater to pass the straw back from the cylinder. One form resembling somewhat the cylinder, comprises a drum set with teeth. Some machines work very well without a beater, the cylinder delivering the straw directly to the separating device.

THE CHECK BOARD.

The check board is hung directly behind the beater to arrest flying kernels. It is a sheet iron apron hinged by its upper edge to the separator frame, while its lower edge trails on the top of the stream of moving straw. It should be so adjusted as to prevent any grain passing it and lodging in that part of the straw as it is going through the separator. It also acts as a compressor on the straw, tending to reduce it from the loose, fluffy condition in which it leaves the beater to a more compact layer.

The check board has an important part in the proper action of the separating devices, and its proper adjustment should be carefully studied.

THE SEPARATING DEVICES

The part of the machine which is of equal import-

ance with the threshing members is the mechanism which separates (hence the name "Separator") the shelled grain from the straw in which it is entangled. While the operation seems simple enough on first thought, there are some things involved which render the devising of a successful separator very difficult, and as yet no one has constructed a machine which will remove every kernel from the loose straw under all conditions of threshing.

Gravitation is the form of attraction which causes unsupported bodies to fall. Owing to inertia, a falling body starts to fall quite slowly, its motion downward increasing in a fixed ratio as it continues to fall. A body placed in a vacuum will fall 16 ft. the first second, the first half of the second it falls only four ft. while the last half of the second, owing to its increased speed, it falls 12 ft. It requires one-fourth of a second to fall the first foot. The separating of the grain from the straw is done by gravity; time must be given the kernels to fall out of the straw. In falling they must pass down through the small interstices between the stalks.

If we pick up a quantity of straw between whose stalks and leaves loose kernels of grain are entangled, we may toss the bunch or bundle around up and down a good deal without dislodging the grain. The kernels will remain in the straw. We must move the stalks of the bundles about among themselves in order to shake the kernels out from their resting places, and the more mildly and gently we do this,

within certain limits, the better will be the results.

All the separating devices in use are for this purpose of thoroughly agitating the straw and thereby allowing the kernels to fall. This causes a limit to the quantity of straw which any machine can handle, as time must be given for the dislodging and falling of the grain. If the layer of straw travels too fast, the grain is carried along with it. If it moves too slowly, the size of the column will be correspondingly increased. If the straw be damp and pliable, it will form a more compact mass than if dry and elastic. Some kinds of grain have more leaves than other kinds and these mat down closely. Separation is retarded by these conditions, and the feed should be varied in speed to suit them, so that the straw will have a chance to open up and allow the grain to work down through the interstices and fall out of the layer onto the grain rack before the straw reaches the rear of the machine. The intelligent thresher will bear these matters in mind and not crowd his machine beyond its proper capacity, as the result will be unsatisfactory.

However, any of the separating devices in use will handle very large quantities of grain and straw when operated intelligently, and the aim should be to gain the best results in both quantity and quality of work done.

Having thus noted the requirements to be met in adjusting and managing the separating mechanism, the different types can be intelligently explained.

The separating devices in use may be divided into three general classes: first, the kinds wherein the straw is given an intermittent or step by step movement through the machine by means of a vibrating or oscillating rack or table; second, kinds where the straw is given a continuous onward movement by traveling raddles; third, where the straw encounters a combination of these two mechanisms.

There are also accessories such as revolving pickers, racks, beaters and fingers which will be duly considered.

THE RACK.

The rack or table usually consists of a series of grates or parallel slats arranged to carry the straw, while allowing the grain to fall through.

In some forms of racks a series of risers are placed on the surface, which have lifting fingers which are operated by a lever and shaft; they tilt backwards along the rack and are given an up and down motion as the rack vibrates, lifting and tossing the straw as it passes over them.

Motion is imparted to the racks by means of a crank. In some instances the rack is hung to links so that the crank gives it a swinging motion like a pendulum, as is shown in the adjacent cut, its path being concave, or the rack may be supported on the upper ends of rockers in which case it oscillates back and forth in an upwardly curved or convex path.

The rack has a tendency to jar and compress the straw on each upward stroke, tossing it into the air very slightly and moving back from under it. The elasticity of the straw causes the mass to expand while clear of the rack. As it falls, it meets the now ascending rack and is thus given another sharp compressing blow which tends to move the different straws in the mass upon each other. The most effective blow is given by the rack at the middle of the stroke, as the peculiarities of the crank motion cause it to travel fastest at about this point.

It is plain that if a quantity of straw and grain should lie on the rack and vibrate up and down with the rack, and not move away from it, the stalks would maintain their relative positions and not give the kernels a chance to fall out. To be effectively cleaned, each stalk must be moved as related to its neighbor. This inter-motion of the stalks constitutes the chief feature of effective separation.

The motion of the rack should be such that its upward stroke will move the straw onward slightly, while the rack is permitted to descend from under it. Gravity will then start the straw downward with increasing speed as it approaches the rack. The

motion thus attained will cause it to strike the rack with a sharp jarring motion at the midway point before mentioned; if the rack swing has been properly timed the weight of the falling straw will add to the shock, while the stiffness of each straw will cause it to move relatively to its neighbor; as soon as released at the up end of the stroke, the mass will expand to its normal condition. This jarring, compressing and expanding motion accomplishes the desired result in a remarkably perfect manner when the layer of straw is not too thick or bulky. If it is so deep that the jarring motion is not felt in its upper part the result is not so good. The upper part will float along undisturbed because of the elasticity of the intervening straw; if the rack is vibrated so as to throw the straw quite high, it is liable to toss the grain too far and the latter, being heavier, will go higher than the straw because of its greater momentum, and retard the separation.

Thus the straw should be made to pass over the rack in a layer of even thickness of just the depth to be thoroughly and quietly agitated from top to bottom, and the motion of the rack should be such as to strike it upward blows at the most effective point; that is, midway of the upward stroke.

The stroke of the rack is usually from five to nine inches in length and the number per minute varies inversely as the length, the long, slow stroke passing as much straw along as the short stroke of higher rate.

The manner of separation is seen to be the moving of the stalks among themselves to free the confined kernels and allowing gravity to act on them, causing them to fall out. The speed and motion that moves the stalks among themselves with the least upward motion is the best for effective separation.

RADDLES.

The ordinary raddle is constructed of parallel belts running over pulleys, connected by slats which are situated far enough apart to permit the grain to fall through while carrying the straw along. If their motion is quite rapid they work very well, as the movement keeps the sheet of traveling straw comparatively thin, thus giving the kernels opportunity to fall through. The raddles should be of sufficient length to allow all of the grain to work out before the straw is passed over.

Some raddles are agitated by being driven over irregularly shaped pulleys which produces a rapid jarring motion. This has the effect of moving the straws slightly among themselves.

The point where the straw falls on the raddle needs special attention. The straw should be delivered to the raddle in a thin, loose mass, for when large or close bunches are allowed to drop on it, it carries them along without giving them a chance to separate or spread out, and thus prevents the kernels from falling through.

As the straw falls on the slats of the raddle, the rapidly moving bars give the straw sudden jar or

jerk and have a tendency to tear the mass or layer of straw apart. The greater part of the separation is done at this point where the straw falls on the raddle. The operation seems to be more effective if the straw is permitted to fall a little distance before it strikes the raddle. The impetus of the falling straw added to the force of the blow given while the direction which the straw takes is changed, also aids in the separation; if the straw is moving in the same direction as the raddle when it comes in contact with it, the jarring and pulling apart motion is eliminated, and the straw passes along quietly without change of direction or change of position of the stalks in reference to each other, so that the kernels are not disentangled.

THE COMBINATION OF RACK AND RADDLE.

In the combination of the vibrating rack with the traveling raddle, the straw usually passes over the rack first and is then delivered to the raddle; the straw is pulled apart and thinned by the rapid motion of the raddle, which disposes of the straw very quickly and usually faster than it is delivered. This pulling apart process greatly aids separation at this point.

CHAPTER IV.

GRAIN CLEANING MEMBERS

In separating the grain from the straw, a large quantity of chaff and refuse passes out with the kernels. This is disposed of by passing the uncleaned grain over a series of sieves, through which a current or blast of air is forced. The combination of sieves and blast fan is called the cleaning mill or shoe, and takes the place of the fanning blanket of the old threshing floor or the fanning mill of recent years.

There are three things to be considered in reference to the cleaning mill or shoe, on which its successful working depends, namely, the sieves, the blast, and the sieve motion. The sieves should be adapted to the kind of grain to be threshed and as few as will do the work should be used, a greater number retarding the blast and catching straw and sticks. The blast should be strong enough to flow constantly through the sieves, even when the latter are heavily loaded. The motion of the sieves should be sufficient to insure movement of the chaff and kernels on the sieve surface.

THE SIEVES.

The sieve comprises a frame, mainly of wood, and a woven wire or sheet metal body. The best practice of to-day favors perforated or corrugated sheet metal sieves, although the wire mesh is still used.

A properly constructed sieve permits the grain to fall through it, passing the chaff and refuse over it, without allowing the straw and sticks to be retained in the meshes, and directs the blast in the proper direction. In practice, a sieve adapted to each kind of work is used, though some combinations of sieves work very well on several different grains. The usual plan is to permanently secure the upper sieve, called the chaffer, it being of sufficiently large mesh to adapt it to the coarsest grains. The lower sieve or sieves are interchangeably secured so that they can be varied according to the work to be done.

Adjustable sieves are constructed to change the size of the opening of the meshes to suit different kinds of grain, the usual construction being a frame in which are hinged cross slats. The adjusting of the slats changes the opening, also changes the angle of the blast through the sieve. When the slats are tipped back the openings are reduced in size, and the blast directed in a more backward direction.

The openings in the sieve must be large enough to permit the free passage of the clean kernels, and should be sufficient in number not to retard the blast. If the openings are too small or too few in number, the grain accumulates on the sieve and passes over into the tailings elevator, by which it is carried back to the cylinder. This greatly reduces the capacity of the machine as it needlessly increases the amount of grain it is required to separate. If the openings, on the other hand are too large, they permit the sticks

and straw to pass out with the grain, causing it to be dirty and poorly cleaned.

The openings should be so shaped as to direct the flow of the blast in the proper direction, which is approximately at right angles to the sieve surface. This prevents the blast from blowing the grain along the sieve surface. If there are too many openings, —and this is the case in a wire sieve—too much of a blast passes through; this causes so strong a current above the sieve that it prevents kernels which are lifted from the surface, from falling again until the rear of the sieve is reached.

The sieves should be stiff and rigid so as not to spring at the center; otherwise the motion will be too violent there and throw the grain so high as to keep it from falling through the sieve. A sieve frame which travels two inches at each stroke and makes two hundred and fifty strokes a minute, goes five hundred inches every minute; if its center springs an inch, it goes three inches at every stroke, or seven hundred and fifty feet a minute, a motion which may be altogether too violent for that part of the grain which falls on the center of the sieve.

THE FAN.

A fan is a device for producing a blast or current of air. The usual form used in separators consists of a central shaft from which radiate arms which carry blades or wings. These revolve in a casing, and the rapid motion of the outer ends of the blades forces the air to rush out of an opening in the side of the

casing.

This air is replaced by a current which enters a central opening at the ends of the casing.

Fans are *overblast* when the upper blades travel towards the outlet; they are called *underblast* when the lower blades move toward the mouth.

THE BLAST.

The blast is an important feature of the cleaning mill. It should lift the chaff and light matter and prevent it from falling through the sieve openings, and at the same time maintain a continuous flow through the sieve. It should be strongest in the sieve openings, and light above the sieve surface. When these conditions are secured, if the blast lift a kernel, it will ascend but a short distance before it again returns to the sieve; if the blast were as strong above the sieve as at the meshes, the kernel would be blown out with the blast and wasted.

To obtain these conditions, the solid or blind portions of the sieve should be in proper proportion to the openings; practice establishes this at about five to seven. That is to say, the solid portion of the sieve should be about five-twelfths of the surface, and the openings should be, in the aggregate, about seven-twelfths of the surface. It will be observed in using a sieve of these proportions, that the blast will be only seven-twelfths as strong just above the surface as in the meshes. It is to be noted that this statement is more strictly correct when the direction of the blast is at about right angles to the sieve.

The blast should be sufficiently *strong* to insure its continual flow under all circumstances and conditions, but *not fast* enough to blow any of the grain over with the chaff.

There is a difference between a blast of strong pressure and a blast of high speed. A current of air may be traveling slowly, and still go with force and be difficult to stop, as is that produced from a slow moving air-pump; or it may be moving quite rapidly but with no particular force more than the momentum produced by its own weight, like the zephyr of a summer day or the breeze from a lady's fan. The least obstruction would stop or turn such a blast. THE KERNELS OF GRAIN WILL FALL THROUGH A BLAST OF ANY PRESSURE OR STRENGTH, BUT WILL NOT FALL THROUGH A VERY RAPIDLY TRAVELING BLAST.

The chaff is easily lifted on account of its light weight. To do good work then, it requires a mild or slow blast delivered with strength or force. This blast should be spread under the entire surface of the sieve and be made to flow through every mesh. It should be strongest and of greatest quantity at the front end of the sieve, which receives the grain and chaff, for it is here that the greatest work is to be done in lifting the sheet of chaff intermingled with grain. It should decrease in quantity and pressure toward the rear end where the least work is required. Thus if a light kernel has been lifted with the chaff at the front end, it will have a chance to fall before reaching the rear end of the sieve. If the blast is

made to pass through the chaff, as soon as it enters the upper sieve it will lift and scatter it, the lightest flying out first, thus giving the kernel an opportunity to fall through the sieve much more quickly and freely than if the blast were not strong enough to keep the meshes open and clear of chaff. Besides, if the blast ceases to flow through any of the meshes, the fine dust and chaff will fall through and cause the second sieve to be overloaded, and thus the grain may retain a part of the chaff and dirt.

SIEVE MOTION.

The motion of the shoe should be sufficiently strong and rapid to move the grain and chaff on the surface of the sieves. Too strong a motion will interfere with the kernels falling through the meshes properly, and cause the grain to be carried over, either with the chaff or into the tailings spout. It is found in practice that the upper sieve or chaffer requires a more violent and positive motion than the lower sieves, on account of the great quantities of chaff and cut straw to be carried. For this reason the chaffer is usually placed in a different frame and given a longer stroke while the remaining sieves have a short and rapid motion.

The coarser and looser the material to be handled, the longer and more vigorous the motion should be. The straw rack which is loaded with loose, fluffy straw, requires quite a long stroke to be effective, while the conveyor and chaffer sieves need less motion and the shoe sieves still less.

It will be seen that if the straw rack had a slight motion, it would not handle or scarcely move the straw at all, while if the conveyor and chaffer sieves had as much motion as the straw rack, they would throw the grain so fiercely as to prevent a good portion of it from passing through. This is because of the difference in the elasticity or springiness of the materials to be moved. It is thus quite essential that the motion should be adapted to the class of work to be done. In *end shake* sieves, that is, where the stroke is endwise of the machine, this motion should be upwards and backwards with quite an uplift, and should be just strong or rapid enough to cause the grain to be carried along as quietly as possible.

In *side shake* sieves, that is, where the motion is sidewise to the machine, the motion should be sufficiently strong and long to cause the sieve to move continually under the grain and chaff, thereby aiding the blast in carrying the chaff along toward the rear.

The blast may be at a greater angle from the perpendicular in side shake sieves than in end shake sieves as it is the only means of carrying the chaff and refuse along to the rear.

In the end shake sieve, the upward and backward motion assists in moving the mass.

Side shake sieves may be given an upward rocking at each side, as the stroke is finished. This is accomplished by using comparatively short hangers and adjusting them at an angle (sidewise to the machine). As the sieve is moved sideways, one side will continue to rise, and the other to lower

somewhat, causing it to give the grain a slight upward motion at each stroke. This motion varies in different places on the surface of the sieve, being nearly parallel thereto at the center.

The blast and sieve motion should be properly gauged one by the other, and by the working conditions. It is necessary for a shoe using a weak blast to be given a greater motion to assist in carrying off the refuse and chaff, when the blast is overtaxed, as when an undue amount of chaff and cut straw loaded with dust is delivered to it, or in damp threshing.

CHAPTER V.

THE DELIVERY MEMBERS

WIND STACKERS

The use of an air blast for stacking the straw has become common. The air, straw and chaff are blown from the interior of the machine by a suitable fan through a pipe, the object being to direct the blast so that a stack may be easily formed.

When the pneumatic stacker was first introduced the item of power was an important one. The first fans used had large wings running at a high rate of speed, and it is safe to say that it required as much power to operate the stacker as it did to run the rest of the separator. At first the fans were belted to run from 1,000 to 1,700 revolutions per minute; the enormous power required to do this either stalled the engine or slipped the belt so that in fact the fans were driven at much slower speed.

In present practice the fan is driven at from 300 to 500 revolutions per minute and the blades of the fans have been reduced, so that the power required is greatly lessened. The work performed by the fan of the wind stacker is setting the air and straw in motion and forcing it through the straw pipe. The more air set in motion and the greater speed given it, the more power required. The weight of air passing

through the straw pipe exceeds that of the straw, that is, there are more pounds of air than pounds of straw set in motion by the fan. So, in determining the work performed by the fan, the item of air can be figured, as the more straw there is, the less air there is, and consequently the less weight. The actual foot pounds or horse power expended is determined as follows: Multiply the area of the straw pipe by the number of feet the air travels per minute; multiply this by the pressure required to produce this speed; the result, which gives the number of foot pounds, divided by 33,000 is the horse power. Thus, the area of the usual 15 in. stacker pipe is 176 sq. in. A pressure of one ounce per sq. in. gives a velocity of 5.161 feet per second to the air. $176 \times 5.161 = 908,336$ ounces, which, divided by 16, the number of ounces in a pound, equals 56,271 foot pounds. Dividing this by 33,000, the number of foot pounds in a horse power, equals $1\frac{3}{4}$ horse power approximately. At this velocity and pressure about 14 tons of air and straw per hour pass through a 15 inch pipe (of which about ten tons of air and four tons of straw represent a fair average.) There is of course more dry straw blown through in a given time than wet straw.

Some power is lost by leakage around the fan and at its center; also cutting and chopping the straw. A slow moving fan moving a large amount of air steadily is better than a fast turning one, as the increased friction of the more rapid current absorbs a great deal of energy. Some experiments along this

line strikingly show this increase. A good type of fan was run at its normal slow speed of approximately 400 revolutions per minute and furnished the normal pressure. The speed was then gradually increased one-quarter, or to practically 500 revolutions per minute. It was found that the pressure had increased about $16 \frac{2}{3} \%$, and the power $35 \frac{1}{3} \%$, or in round numbers, an increase of one-quarter in speed gave an increase of one-sixth in pressure and used one-third more power.

HANDLING THE THRESHED GRAIN.

There are a variety of weighers, measurers, sackers and wagon loaders on the market and in use to handle the cleaned grain as it comes from the machine.

Included among these is a class that measures the grain as it is threshed and registers the number of bushels as delivered; also a class that measures the grain instead of weighing it, and keeps a tally or record of the amount. There is also a short sacker, requiring a man to operate it, which aids in sacking the grain, and a wagon loader which delivers the grain to either side of the machine without making record of the amount handled.

CHAPTER VI.

FEEDING

Supplying the grain or feeding should be done as steadily and uniformly as possible in order to keep a continuous stream of grain passing through the cylinder. This keeps the engine working with uniform steam and tension on the belt.

When grain is fed into the cylinder, the speed of the latter is checked. As soon as this checking is felt on the main drive belt, the engine speed is decreased until the governor has time to act and, by admitting more steam, restore the normal motion to the engine. This change causes the engine to pull harder on the belt. If, while this tension is on, the cylinder suddenly runs out of straw, the speed at once increases in obedience to the extra strain on the belt, as it takes a little time to communicate this change of speed to the governor and have it cut off the steam. The result is a see-sawing motion every time that a bundle goes into the machine, unless it is properly divided and lapped on the preceding bundle. An entire bundle, especially if it is large or compact enough to slug, should never be allowed to enter the cylinder.

The average cylinder teeth are about three inches long. The concave teeth occupy about one-third of

the space between the concave and cylinder bars, thus leaving about two inches through which the bundle must be passed. This *compressing process* of the teeth consumes a large amount of power. A five hundred pound cylinder has a momentum or striking force of thirteen hundred and twenty tons. This indicates the terrible strain on the machine when a bundle is fed in of sufficient size to stop the cylinder, although this does not often happen. But the power consumed when the bundles are not properly divided up is enormous, and is still further increased when the straw is damp and tough, as tough and pliable straw clings more firmly to the cylinder teeth than does dry and brittle straw.

SELF-FEEDERS.

Self-feeders are of comparatively recent development, though they have been experimented with for several years. After patient study and many unsuccessful trials, the feeder and band cutter has reached

a degree of perfection that makes it a desirable part of the complete threshing rig.

The office of the self-feeder is to cut the bands, loosen the bundle, dividing it in a sufficiently thin body, and present it to the cylinder in a manner that will not permit slugging or choking of the cylinder. To do this successfully it is necessary that the bundles should be drawn out or *elongated endwise*, or divided in some way that the cylinder may not receive the whole bundle at one time. The usual method of accomplishing this is to pass the lower part of the bundle towards the cylinder *slowly* while the top part has its speed increased by some faster traveling mechanism above it, forcing the top straws ahead while the lower ones are being retarded and this must be accomplished before the bundle reaches the cylinder. The more thoroughly this is done the better the feeder and the machine seem to work.

There has been some experimenting with *governors* to regulate the amount being fed to the machine and they are being used with more or less success. Some depend on the *speed of the cylinder* to disengage a mechanism whereby the feeder is thrown out of gear when the speed is reduced below a predetermined number of revolutions per minute. Others regulate by the amount or bulk of the traveling column of straw.

The bundles in most feeders are first deposited on the carrier, on which they are carried along to the band cutting device by means of a raddle constructed of belting with laterally secured slats, or a canvas cov-

ered table. As the bundles move towards the cylinder, they are acted upon by the band cutters, which should be sufficiently near together and travel close enough to the table, to insure all the bands being cut. It is also necessary that the bundles should be thoroughly picked apart and loosened up before reaching the cylinder. The band cutters in most of the feeders perform this office also, by passing the knives rapidly into the bundle among the straws in such a manner as to throw the top straws ahead toward the cylinder.

A separator with a properly constructed self-feeder will require but very little more power to thresh a given amount of grain in a given time, as it divides up the bundles and feeds clear across the cylinder much better than is done by hand. But with the use of self-feeders the pitchers usually pass the bundles along a little faster because they do not have to use the same caution about placing them on the table as they do in hand feeding. The only thing they need to observe is the amount or quantity being handled.

CHAPTER VII.

OPERATION

In operation the separator, like any other machine, does its work best when properly adjusted and managed. There is no machine which has a more varied scope of work or which has to encounter so many conditions. It is rare that there are two fields of grain grown, ripened, cut and handled under like conditions; one may be in a condition to shell from the straw readily, while in another the kernels may cling to the head so as to make it almost impossible to dislodge them. One stack may be brittle and break too readily, while the next may pass through without this annoyance. One kind may be stiff and stubborn and another soft and pliable; one lot may have many blades or leaves on the stalks, another only the plain stalks and heads; one kind may have a light, fluffy chaff and heavy kernels, and another the reverse, heavy chaff filled with sap and light kernels. Some fields are filled with weeds and foreign matter which the machine is expected to distinguish and separate from the grain.

Then again, there are conditions of the weather which appreciably influence the working of the machine, and cause a wide variation in the amount of power required. Some days are bright and sunshiny, others damp and foggy. Some are warm or

hot, others cold. There may be a hard wind blowing or there may be none. All these various conditions affect the machine, each in a peculiar way. The operator is expected to save every kernel, perfectly cleaned, and do many other things equally well nigh impossible, notwithstanding these varied conditions. The man who best understands the machine and its workings will come the nearest to perfection in managing it.

As before stated, the cylinder is a vital part and should receive special attention and be kept in good condition. If it is out of balance appreciably, it should be taken from the machine and set on the straight edges, as explained before, and restored to balance by inserting counterbalancing weights in the light side. The boxes should not run too tight, as the extra friction consumes a large amount of power.

The teeth should not be allowed to become so worn and rounded as not to draw the straw into the machine freely. By replacing the worn by new teeth, evenly distributed around the cylinder, the straw will be readily pulled in and the grain threshed clean. Care should be taken to keep the teeth properly spaced; any bent ones may be trued up with the tooth straightener, or by the use of a heavy hammer.

The *cracking* of grain is usually caused by one or more cylinder teeth running so close to the concave bottom, or teeth, as not to permit a whole kernel of grain to pass; the resultant wedging cracks or breaks the grain. Another cause is the repeated passing of

the grain through the cylinder by the tailings elevator. Each time a kernel receives a blow from a cylinder tooth it is partially disintegrated, and many blows crack or break it open.

Only enough concave teeth should be used to retard the passage of the straw through the concave a sufficient length of time to allow all the kernels to be loosened. More teeth than are required to do this consume power unnecessarily as well as cut up the straw to such an extent as to interfere with the proper workings of the separating and cleaning mechanisms. The machine will often do better work with two or four rows of teeth than with more. In handling *oats*, two rows of teeth are commonly enough, except when the kernel is small and light and the oats, which may have been cut when green, seem tough and cling to the heads; in this case high speed in the cylinder and more rows of teeth in the concave are required to loosen all of the kernels from the straw.

For use in sections of the country where *flax* is grown the concave should be specially designed with teeth set near together, as some conditions require very close adjustment to enable them to break open the balls containing the seeds. Under some conditions, the ball is often found to be saturated with an oily, gummy substance which makes it very tough; it is then liable to break off from the stalks and pass whole through the machine. To meet such conditions, use all the concave teeth possible and run the cylinder at a high rate of speed, arranging the parts

at the rear of the machine to return the unbroken balls through the tailings elevator.

In threshing *barley*, plenty of concave teeth and a high cylinder speed break off or "nub" the beard effectually.

The *grate*, as before indicated, which lies back of the cylinder, should have its rear edge raised so that the straw and grain, as it comes from the cylinder, should strike its face at a slight angle. This keeps it clean and prevents it from loading up with thick or brittle straw.

The *beater* should be in a position for the straw and grain, as it comes from the cylinder, to pass it without changing its course too much; that is, it should be so adjusted that the straw will not strike it near its center, as the straw would then have to change its course to pass around it.

If the beater is arranged to allow the straw to pass under it, the wings of the beater or beater boards should have just sufficient contact with the straw to keep it moving.

In the scheme of separation, the first essential feature is to have the threshing members deliver the straw to the separating devices with the kernels all threshed from the heads and the straw unbroken. Whole straw will not pack as closely and hold the kernels in consequence as does broken or cut straw. Stalks that are heavily loaded with leaves form a compact, homogeneous mass which retains the kernels, and are consequently hard to separate.

Oats are frequently hard to separate. In some

sections of the country rust is prevalent; this forms on the stalks and leaves before they are harvested, making them brittle, while it blights the kernels, which are, in consequence, light. The rust on the stalks has a certain clinging roughness that causes them to adhere to each other and therefore retards the disintegrating effect of the rack or raddle which does not move them among themselves but allows them to travel along in a compact mass. In such case, all that can be done is to adjust the machine to the best advantage, run at good speed and regulate carefully the amount fed to the other conditions.

Rye is usually very easily separated, as the stalks are stiff, and comparatively little chaff and dirt is found. In some instances the straw is so loose and fluffy as to prevent it being worked back fast enough by the separating devices, thereby causing the body of the machine to choke up. In case this happens, cut the straw up by inserting more teeth in the concave. By weighting down the check board of a vibrating or rack machine it will compress the straw somewhat and give the table a better chance to handle it. A convenient way of doing this is by fastening a piece of wood or iron lengthwise along its back by suitable screws or bolts.

As stated before, it is quite essential that the machine stand quite still on its truck while in operation. There is a great difference between the operation of the machine when the frame work is standing still and the mechanisms have their full motion, and

its working when the frame does a part of the moving, which the mechanisms complete.

There is another reason why the separator should be made to stand still. When the engine is running, one part of the drive belt is drawn tight while the other is slack. The harder the engine is being driven, the tighter will the belt be drawn; if the separator is rocking on its trucks to and from the engine it will take up some of the slack of the belt as it sways toward the engine and when moving backward away from the engine the belt will either have to stretch or slip upon the pulley, as it cannot change the speed of the cylinder. As the slack has already been taken up it is very likely to slip, an action which is very hard on the pulley lagging, and on the belt, and which wastes a great deal of power. This slipping and straining of the belt is greatly augmented if the engine also moves upon its trucks, as the vibrations of the two machines will not be the same, and when one is rocking in one direction, and the other in the opposite direction, there will be double the pull on the belt. If a horse power is used, there is the same need for the separator to stand still, as the strain from the oscillations and vibrations are very severe on the tumbling rods.

If the separator fails to take the grain out of the straw properly, it is usually because of one or more of the following reasons, viz.:

The separator is not standing still on its trucks; it is not running at the proper speed; the cylinder fails to thresh all the kernels out of the heads; the

separating device or shoe is not level; or the machine is being crowded beyond its capacity.

The shoe or cleaning mill should receive special study by anyone who intends to make threshing a success. Though the device appears very simple, it has many features, as already stated, which are not generally understood.

The motion of the shoe varies in different machines. In some it is as short as five-eighths of an inch, in others it is four inches; though there is not so much speed variance in the motion of the upper sieve or chaffer, which generally is from three to four inches. The following rule is as close to a correct expression of the true principle of its working as can be stated:

“The shorter the stroke, the more vibrations per minute are required; the longer the stroke, the fewer vibrations per minute are required.”

The speed should be just strong and quick enough to throw the straw but slightly at the upper finish of the stroke; if it does more than this, it will carry or throw the grain, as well as the dirt, and a part of it will pass out with the chaff. If the motion is not strong enough to cause the grain to leave the upper surface of the sieve slightly at each stroke, the meshes become filled with grain and chaff, and the sieve or chaffer becomes choked to such an extent as to allow but little to pass through. If the mechanism is such that the upper part of the stroke is strong and quick, while the lower part is slow and gentle, it

is all the better, as the upper part of the movement will do the throwing and agitating, while the slow part of the stroke will allow the sieve time to come to rest for an instant, thereby permitting the kernels to fall through.

The *boxes* and connections that operate the shoe should be kept in good order and not permitted to work *loose*, as the lost motion causes a pounding that jars the sieve, which springs and trembles; this impedes the passage of the grain.

CHAPTER VIII.

THE BLAST

The *blast* requires its share of attention, and when it is once thoroughly understood and mastered, it becomes an obedient servant capable of accomplishing good work. But few changes have been made in the blast fans since they were first used in separators. They have faults as well as virtues; they do not always send the proper amount of blast just where it is intended they should or where it is needed the most.

There is a great difference in the condition of the material which the shoe has to handle at different times, each section of the country furnishing a particular kind or quality of grain to be threshed. In parts of the country where spring wheat is raised, there is more work for the shoe to do, as there is more chaff; the straw, as it is stiff and hard to thresh, breaks up more than does that of the winter wheat raised in other sections of the country. Though the kernels of spring wheat are not much heavier than the berries of the winter variety, the chaff and dust from the former is much more dense and weighty than from the latter, requiring more than double the pressure of blast to penetrate and lift it.

The cylinder and concave should be adjusted to

get the grain out with as little cutting up of the straw as possible, thereby relieving the shoe of an undue amount of work.

As the grain and chaff are delivered to the front end of the chaffer, the kernels are more or less thoroughly intermingled with the refuse, the mixed mass being of a depth and quality dependent on the amount being threshed. It is plain that if the meshes of the chaffer are not large enough to let the whole mass through, the most of the kernels will be carried along with the chaff and dirt by the action of the chaffer to the rear end. But force a little blast through and watch the result; as the blast comes through the meshes, it lifts grain, straw and all. The kernels at the bottom of the mass will fall of their own weight through the sieve. As the blast continues on its way up through and between the different particles of the mass, it loosens and separates it, carrying the lightest bits farthest, and allowing the others to fall of their own weight. By watching the blast still longer it will be noticed that the particles which are traveling through the air are entirely free from contact with each other, every particle seeming to try to avoid its neighbors as much as possible. There are never any bunches clinging together, but the mass is thoroughly divided, thus producing the very best conditions for separating the kernels from the chaff.

The blast should be strong enough at the front of the sieve to always flow through the very first

meshes with sufficient force to keep them cleared and to itself pass up through the layer of chaff and grain as it passes along; but it should not blow fast enough to lift the light kernels very high. There is a difference between strength of blast and speed of blast. The blast should have strength, but not much speed. A horse might be very strong and able to move a heavy load, but not move it very fast. The horse would then be able to go at a constant and uniform speed whether loaded heavily or lightly. So the blast in the shoe should be able to move at its regular, constant speed, regardless of the amount of grain to be handled. It is plain that it should be the strongest at the front end of the chaffer where the load is heaviest, the chaff being mixed with the grain and packed together at that point. After the blast has once penetrated the layer and has lifted the chaff up in the air it does not need as strong a blast to keep it there. In some wrongly constructed chaffers, the reverse conditions are found; the blast being strongest at the rear end of the chaffer and weakest at the front end. In such cases, the heavier the load of chaff which comes in at the front end, the harder the blast will be at the rear, for as soon as a little too much grain and chaff enter the front end and clog the meshes, the blast ceases to escape there and is forced along under the sieve to its rear end; here it is confined and deflected upward by the bottom of the shoe, escaping through the rear meshes with force enough to carry kernels and all along with it.

If a shoe is found in this condition, the remedy is

to arrange the blast or deflecting boards in such a manner as to cause the blast to strike the front end more forcibly.

To aid in this adjustment, it will be well to consider first, some of the peculiarities of the fan and its action on the air. As it revolves the wings make the air revolve along with it. As each wing passes the outlet, a small portion of the air is thrown off by centrifugal force, other air coming in through the inlet to take its place in the center of the fan.

As the fan revolves there is a slight increase of pressure of the air against the front side of the wing, and a corresponding decrease along the rear side, the sum of these plus and minus pressures being nearly equal to the atmospheric pressure.

As each wing passes the outlet opening in the shoe the air starts to rush in behind the wing from the shoe to fill the slight or partial vacuum on the rear of the wing. A small portion thus enters the fan casing; the next wing as it comes round, has a tendency to force this intruding portion back before it has entered very far. This alternate rarefaction and compressing action of the fan causes the low vibrating or humming sound heard in fast running fans. Now this action of the air is not uniform along the entire length of the wing. The most air is forced out at the center of the shoe, which materially affects the action of the blast through the sieves.

When a fan whose casing is open at both ends to admit air, is in motion, the two opposite moving col-

umns of air rushing in from either end meet at about the center. This meeting of the opposing blasts increases the pressure somewhat at this central point, consequently the fan delivers more freely at the center of the outlet; further, the air rushes in more freely behind the ends of the wing as it passes the outlet as the pressure or vacuum is greater there than at the center of the wing; therefore, the air passes from the sieves into the fan near the ends of the wings, instead of from the fan through the sieves. This motion is more marked in long than in short fans, therefore in wide than narrow machines.

A further explanation of this usually unrecognized phenomenon is this: As the air rushes from the ends towards the center of the fan, there is little side pressure towards the sieves at the ends of the fans and the extra pressure in the sieves forces the air back into the fan; that is, the air, for a little distance from the fan ends, travels in the wrong direction; as the air comes from the center of the fan, it thus swings back upon itself, forming an eddy. Should this counter current be strong enough, it results in carrying some of the grain along with it into the fan. This effect is so marked in some machines that the corners of the fan are worn by striking the grain blown in by this motion of the blast. This effects the perfect cleaning, as the direction of the blast is down at the corners of the sieves, thereby carrying the chaff and dirt into the grain.

This whirling motion can be tested in any machine by taking the sieves out and running the machine

empty. When the machine is in motion, take a cane or stick of convenient length and fasten one end of a ribbon four or five inches long to one extremity. If held in the blast near the fan outlet, the ribbon will indicate the way the current of air is moving.

Further study of the blast will show that its direction is not in a direct line from the point of delivery of the fan along the stationary blast boards at the top or bottom, towards the sieves, but tends to follow the curve of the fan casing until it comes against the blast board. Furthermore, in the case of an under-blast fan, the blast does not leave the fan and travel in a straight line along the bottom board towards the sieves, but extends in a thin sharply defined current along near the fan, and increases slightly in thickness until it reaches the top blast board, from which it is deflected down and back.

The slight compression of the air at the center, makes it veer off at an angle towards each corner, so that it blows harder at the rear corners than it does at the central portion.

Two or three narrow wind boards one or two inches wide, placed parallel to each other and the fan in the forward part of the shoe below the sieves, greatly aid in equalizing and adjusting the blast. They should be set at an angle which will deflect the blast toward the forward part of the sieves and should be near enough together to require a little pressure to force the blast between them. This arrangement makes the air pass out along the entire length of the fan opening to relieve the pressure on

the fan side, and will tend to make the blast uniform for the entire width of the sieve.

As before stated there are a great variety of sieves, the woven wire ones having the preference in former years. They admit the blast very freely and the straws run through the meshes and fill them up, so they are in some disfavor now. The present tendency is toward sheet metal sieves having either a plain perforated surface or irregular lips and corrugations and lips. Chaffers are frequently made of wooden slats set at an angle, or with plain wood, perforated at an angle to the surface.

The angle of the blast as it passes through the sieve should be upward rather than backward. The reason is that a kernel will fall through a perpendicular blast better than through an angularly directed one, and a perpendicular blast also lifts the chaff from the sieve better.

The correct direction is given the blast by proper adjustment of the lip or slat forming the sieve meshes, the blast taking its direction from the lip.

The *holes* or meshes should be only large enough to allow the grain to pass through freely. *When the sieve is properly constructed and the blast properly adjusted, there need be no waste and the grain will be well cleaned.* When the shoe is working properly, there will be a very small quantity of tailings to return to the cylinder. (Tailings, so-called, are the grain and chaff which did not go through the sieves, but are passed over the chaffer.) That this is so will be seen if it is remembered that when the blast strikes

every mesh in the chaffer properly, it will prevent any chaff from passing through and will blow it into the straw to be carried away with it. Besides, if the chaffer is properly constructed and has the right motion, as soon as the blast clears the forward meshes of chaff, the grain will fall through at once, and will then have the entire length of the sieve to travel over before reaching the tailings spout, so that there will be little chance of its being carried around with the tailings. This is the crucial test of a properly adjusted shoe, for if the blast does not pass through the layer of grain and chaff until it has passed half way along the sieve, or more, it is plain that a part of the chaff has been sifting through the sieve where there is no blast felt. The chaff will then find its exit along the next lower sieve to the tailings spout. A portion of the grain cannot pass through the chaffer at the front end, but is carried along with the chaff to the point where the blast first affects it. This may be so near the tailings spout as to cause the grain to be carried over into the straw, or to go back to the cylinder with the tailings, thus overloading the elevator and unduly taxing the capacity of the separating and cleaning devices, and this continued return of the kernels to the cylinder is liable to crack or crush them. As few sieves as possible should be used. Oats usually require only one. In weedy wheat, in some instances, a second sieve in the shoe will improve the cleaning. Flax, if at all weedy, may be run through two sieves below the chaffer. The mistake is often made of trying to run flax through a

sieve with too small meshes, thus causing it to pass over the tailings spout and increasing the impedance of the blast. Some kinds of flax have larger seed than do others, and this must be remembered in adjusting the mill.

In fast flax threshing, the most satisfactory work can be done by using a finishing sieve (of perforated sheet metal, not wire) having meshes three-sixteenths of an inch across.

CHAPTER IX.

BELTS

The success of a machine depends largely on the belts. Their proper care, management and adjustment are of importance.

Their material should be of the best quality. If leather, they should run with the grain or smooth side to the pulley, as they will run more easily, transmit more power, and last longer. They will run more freely because the flesh or rough side will expand more easily and adjust itself to the curve of the pulley in running around it, thereby adding to the life of the belt. The smooth side will transmit more power because it brings more surface into actual contact with the pulley.

Belts should be run just tight enough to perform the work without slipping, for power consumed in slipping is lost. A belt that slips, tends to partially run off the pulley and soon wears out the pulley facings.

If belts become dry and hard, they should have a dressing of neatsfoot oil with a little rosin mixed in it. Enough rosin should not be used to leave the surface of the belt in a sticky condition. A pliable belt will transmit more power than a belt that is dry and hard.

Rubber is used quite extensively in some places and

when of the best grade is very economical, as its first cost is less than that of the best grades of leather. Chain or link belting is sometimes used and in some places is preferable to any other. It never slips or runs off, and does not become unlaced. When link belting is used it should not be run when too tight as it causes a trembling or jarring vibration as each link passes the sprocket.

LACING A BELT.

There is a right and a wrong way to lace a belt. The ends to be joined should first be cut squarely

across. A belt punch to make the holes for the lacings should form an aperture big enough for the lacing to pass freely without straining the fibre of the leather; otherwise there is a tendency to tear out, and

the lacing to break off. For ordinary work a punch making a hole about five-sixteenths of an inch across is the most convenient size for ordinary work. A smaller one should be used for the holes for the lacing ends, which should pass through tightly.

In punching the holes, care should be taken to space them evenly at equal distance from the belt edge. An odd number of holes, as three, five or seven, according to the width of the belt, gives the best result.

The start should be made by passing the lacing ends through the two center holes from the flesh side. Then lace from the center once through each hole until the belt edge is reached, using one end of the lacing for the holes on one side of the center, and the other end for the other holes on the other side of the center. Then pass the ends of the lace through each outside hole again, thence through the succeeding holes, until the center is reached. Then pass the lace ends up through the small retaining holes. By starting as described, it leaves the ends of the lace projecting on the pulley side, which prevents them from slapping and wearing off as they pass round the pulley. It also leaves the belt lacings crossed on the pulley face of the belt, thus giving more surface for contact.

When finished the lacing has been passed through each hole twice, and is what is called double lacing. The lace end should project about three inches when finished. Punch the small retaining hole in line with

the others so that it can be enlarged and used when the belt stretches and is cut and relaced.

Good lace leather of uniform width of about five-sixteenths of an inch should be used, with the ends tapered for convenience. The smooth side should be placed out, as the lace will then last longer.

Pulleys are crowned or larger in the center to cause the belt to run in the center of the pulley. If the shafts of two pulleys are parallel, the belt has a tendency to run to the large part of the pulleys. If the shafts of two pulleys are nearer together at one end, the belt when doing work or is tight, has a tendency to run towards the ends nearest together. If one shaft is level and the other high at one end, the belt has a tendency to run towards the low end. If a belt slips, it will run off on the side of the pulleys nearest together.

CHAPTER X.

BABBITING BOXES.

With a little care and practice, anyone of ordinary ability can babbitt boxes.

Babbitt metal is made of block tin and antimony, the best grades containing a little copper. Zinc should not be used in babbitt as it has a tendency to cause the boxes to heat, and besides does not wear long. In preparing the box to babbitt, remove any old babbitt and clean well, as any grease and moisture would, when heated, generate gases and blow the molten metal out. Bolt the box in the position for which it is intended, as otherwise the tightening will throw it out of adjustment and line.

Place shimmiing (pieces of pasteboard) between the margins of the halves of the box, to allow an excess of metal, to allow for wear. In preparing this shimmiing see that its inner edges butt against the shaft, in order to separate the babbitt in the lower half from the babbitt in the upper half. Cut two or three small notches, each about one-quarter of an inch long and one-eighth of an inch deep, in the edges of the shimmiing to allow the metal to flow through into the lower half of the box, the little fins thus formed being readily broken. Hold the shaft in place in the box by inserting a leather strip wrapped around the shaft at the box end.

With clay moistened to the consistency of stiff dough seal up all the openings thoroughly, save the oil hole. Plug this up with a stick, packing the clay around it in funnel shape, to pour the metal in. After all is in readiness, remove the stick with care that no clay falls into the hole.

To be poured successfully, the metal should be of a temperature to burn wood. To test it insert a stick of wood occasionally into the melting pot, and when the babbitt makes the stick smoke or turn black, it is of the right temperature.

When pouring, the metal should be turned in as fast as it will run through the opening, to insure its filling the lower half of the box; do not stop until the box is full, as the metal chills very quickly and will not unite with fresh metal, after it has once set.

After pouring, remove the clay and break the box apart by driving a cold chisel between the halves, dressing off the points of the broken fins formed in the notches of the shimming. If the lower half of the box is not filled, enlarge the openings in the shimming and try again.

Relieve the shaft by scraping some of the babbitt from the inside of the box, removing the most near the inside edges; in bolting the cap on, insert an extra piece of shimming at the box edges, otherwise the box would be too tight if left as babbitted, and would heat.

By inserting a stick in the oil hole before the metal has cooled, it will form an oil hole and save drilling or punching one.

CHAPTER XI.

LUBRICATION.

The life of a machine and ease of operation depend in a large measure on the manner in which its journals are kept lubricated.

In selecting lubricants keep in mind the purpose for which they are to be used. In hot, dry weather a thicker and heavier oil can be used than in cold weather. In places or bearings subjected to external heat, mineral oils are preferable to those containing animal or vegetable matter. There is a tendency among dealers to supply the cheapest quality of oil, which usually proves the dearest to the buyer.

In many of the machine oils vegetable matter mixed with kerosene or other light mineral oil is used as it can be sold very cheaply. The kerosene soon evaporates at the ends of the journal, leaving the vegetable matter in the box where it thickens and gums, causing the box to heat or the shaft to run hard. Oil of this nature is hard on paint, where it spreads out over the woodwork, causing the varnish to corrode and become dull.

A good grade of oil for general purposes is what is known as black or crude oil. It is a mineral product with all the light oils removed, and may be had of different grades of density. The heavier qualities

can be used advantageously in warm weather, while the lighter grades will be found to run more freely in cold weather and do not thicken as easily.

Hard oils work well in journals when properly fed. Cylinder oils should be selected in view of standing a high temperature.

GETTING READY.

If the machine is one that has been in use the previous year, it should be inspected carefully and every piece put in proper condition to maintain a fall's run, before the time announced as the commencement of the threshing season.

See that every box on the machine is properly adjusted, the worn ones being set up, and if much worn, rebabbitted. A shaft should not be so loose in a box as to rattle or move back and forth much, neither should it be too tight to run easily. The bearings of a shaft which produce or withstand a vibrating or oscillating motion, should have special attention and not be allowed to get loose, as the least play will permit the shaft to pound at each stroke and soon wear flat. This will cause the vibrating or oscillating part to run or work anything but smoothly, and may interfere with its performing its proper work.

The oil cups should be gone over and the vertical ones should have a piece of waste inserted to retain the oil and keep out the dirt and dust.

Every belt should be properly laced and stretched

to the right tension. If a belt is too tight, it is much the better plan, instead of overstraining it when putting it on, to let out the lacing and then take it up when the belt has found its place. If dry and hard, a little neatsfoot oil in which a little resin has been dissolved will soften a belt and add to its life. The rivet heads on the pulley lagging must not project for they cut the surface of the belt as it passes over them.

See that every bolt and nut in the machine is in its proper place and tightened. If the frame of the machine is warped, try to get it in line. Replace worn cylinder and concave teeth with new ones. Special attention should be given to the straw rakes and raddles that they be in good condition. If wooden trucks are used, the tires must be examined to see if they are tight; if iron wheels are employed, every spoke must be screwed up to its proper tension.

The tool box is an important adjunct to a well equipped outfit. It should be provided with the necessary tools, such as hammers, wrenches, chisels, files, etc., as well as assorted sizes of bolts, screws, rivets and nails that are liable to be needed at any time. Much valuable time is often saved by being able to replace such small parts as are liable to be lost or broken. Each tool and article should have a place in the box and be kept there, so that it can be found when wanted, and will be missed from its usual position as soon as mislaid or lost. The box must be well covered to exclude all dirt and chaff.

If the machine be a new one, everything should be

put in its proper place and all nuts gone over and tightened. It is very good practice to leave each nut standing square with the piece on which it rests; this not only gives the machine a symmetrical and workmanlike look, but it accustoms the eye to seeing the nuts stand squarely, so that it readily detects any change in position due to loosening, and thereby allows of instant attention, preventing loss. Remove all cinders and dirt from the boxes and running parts and pack them with waste, as before stated, to exclude all foreign substances. Finally, before assembling the crew, run the machine empty for a time to see that all the parts are properly adjusted; this gives a chance also to adjust the belts, which when new, stretch after being run a short time.

CHAPTER XII.

THE CREW.

It is the duty of the manager to see that everything is operating properly; look after the welfare and comfort of the crew and see that each performs the task assigned him; economize time and keep the expense down so as to accomplish the most work with the least outlay; and in general, lay out and plan the work so that there is no waste of time either on the part of the machine or the men attending it. Much of the success of the machine depends upon this.

To make the machine do its best, it is necessary that each man should perform his part; this should be seen to by the manager and the allotment of work should be under his exclusive control. There is no place where there is greater necessity for a head and leader than around a threshing machine. The manager should assert his rights in a firm and mild manner, should never lose his temper or show anger, should not abuse any one or permit any bullying among the crew. It is very demoralizing to have a bully among the crew, especially if he be permitted to exercise his inclinations on his fellow workmen. Harmony in the crew rests largely with the manager, and he should see to proper adjustment there as well as in the machine itself.

The *feeders* should be sufficiently acquainted with the machine to be able to work in harmony with it, in order that the work progress successfully. The motion and working of the machine should be watched by them so that any faults may be corrected.

It is good practice, and usual in hand feeding, for each to take his turn, one feeding a given time or amount of grain, and then being relieved by the other. The feeder is the one who is depended upon to regulate the amount to be threshed and the quantity of grain cleaned per day depends on him in a large measure.

The feeding should be even and continuous and at as constant and steady a rate as possible at all times, in order that the crew may become accustomed to the average amount of straw and grain to be handled, and so be able to judge of the labor required of them. The motion of the one feeding should be adapted to the kind and condition of the grain to be threshed. The more the straw is divided and spread out, the less power will be consumed in passing it through the cylinder. When the power is limited, as in threshing with horses, this fact should be well borne in mind.

In steam threshing, where more grain is being handled and there is plenty of power, the feeder has about enough to do to keep the bundles passing in without spending much time in spreading them out. He should, however, feed as continuously as possible in order that a bundle may be engaged and drawn in by the cylinder before the preceding one has passed

entirely through. This aids in lessening the amount of power required.

The *band cutters* should cut the bands and pass the bundles to the feeder in such a way as will aid him in doing his work. To assist the free moving of the bundles across the table, it should be kept clear of clinging straws. Care should be taken in the use of the knife used to cut the bands, as many a feeder has had his hand cut by inattention or carelessness on the part of the band cutter. Each band cutter should become accustomed to one side of the machine and always work there, as he can perform his work better than if he changes about.

The *pitchers* are depended upon to get the unthreshed grain to the machine as fast as needed in a way that will facilitate the work. There should be enough pitchers provided so that the machine will not have to wait for grain or run partly empty, as this will cause some of the rest of the crew to stand idle and will curtail the earnings of the machine for the day's run.

It is good practice for each man to keep his particular position on one side of the machine for the entire time he is with it. He thus becomes accustomed to handling the bundles in a certain way on that side, while on the other, the position and movements are reversed. The work will be performed with greater expedition and ease as the muscles become accustomed to certain movements.

The *straw crew* takes care of the straw as fast as it is delivered from the carrier.

It is as easy to form and build a good, symmetrical stack, as to push the straw back without reference to the form of the pile. If the stack be commenced well up towards the machine so that the stacker drops the straw near the center of the stack; the straw will not have to be moved as far as if the carrier deposited it at the edge of the stack; in the latter case the straw or part of it, would have to be moved the entire width of the stack. Also, if the center be better tramped than the edges, the latter will settle more so that the straw will incline downward on the outside, making a better watershed; if the bulk of the straw has to be moved from the center of the stack, as happens when the stacker delivers there, the straw men will naturally stand there, thereby packing it closely.

CHAPTER XIII.

WASTING GRAIN

There is no place on earth where a kernel of grain looks as large and is of so much value as at the tail end of a machine. To see some hunt and search for them, one would think each one a diamond or priceless gem. There is no time when a farmer is so careful of his property as right then. Any amount may be wasted by the harvester or in handling the grain, but let him discover a few kernels going into the straw through the separator and he at once loses his reason and imagines ruin stares him in the face. He will show them to the operator with an autocratic air of "do better or quit."

In a bushel of oats, 32 lbs., there are about 600,000 kernels. In a bushel of wheat, 60 lbs., there are about 1,000,000 kernels. If the farmer should hold his hand where the grain is wasting fastest for half a minute, and should catch ten kernels, he would say that half of it was going in the straw. Let us see. Counting 26 days for a month and 10 hours for a day, it would take him over *three months* to catch a *bushel* of wheat. Oh, yes, he says, but he only held his hand under a small part of the falling chaff. Well, suppose the machine was 52 inches wide and his hand only two

inches, and the grain wasting equally across the entire width, it would then take *three days* at the same rate for enough kernels to pass to fill a bushel measure.

In order to waste five bushels in a day of ten hours' run, there would have to be 138 kernels escape every second or 8,240 every minute. It is very deceiving when the quantity of grain comes to be measured by the kernel. While most threshers are willing to do all in their power to save the grain for their customers, the farmer should remember that absolute perfection is impossible, and that the actual waste is but very small as compared to the amount threshed.

It is difficult to state what per cent. a machine may waste and still be doing reasonably good work. There have been several tests made to determine this, but the conditions varied so that there are scarcely two reports alike. In ordinary threshing, when the conditions are not unfavorable and the machine is not being over crowded, it should not waste more than one-third of one per cent; this will be only a little over three bushels per thousand. Calling 10 hours one day, and threshing 1,000 bushels, to waste three bushels would necessitate losing all which would lay on the palm of the hand, every 15 seconds, not a very long space of time, only a quarter of a minute. This would show very plain and the machine would appear to be wasting very fast. If the kernels are still in the head, unthreshed, the waste may be in much larger proportion; a kernel in every head or two soon counts up.

PART II.

TRACTION and
PORTABLE
ENGINES

INTRODUCTION.

The conditions which arise in the operation of the engine of an up-to-date threshing outfit demand a thorough knowledge of the principles which underlie its workings.

The following pages are designed to explain the principles on which practical and economical operations of traction engines are based.

GENERAL THEORY OF THE GENERATION OF STEAM

CHAPTER I.

HEAT

The generation of steam from water depends upon the expenditure of heat. It is well to understand what is meant by the term heat.

Heat is a form of energy. It is in fact a mode of motion among the particles or molecules which compose matter. If the molecules are moving or vibrating back and forth among themselves, the sensation of heat is produced. This term is only relative; what seems cold to one person is hot to another; but if we start from a common basis we may say that a high rate of vibration in the molecules produces heat. A low rate produces a very much less degree of heat, which we are used to calling cold. Inasmuch as any body in motion is capable of overcoming resistance, that is, doing work, we say that it has kinetic energy; therefore, the molecules which are vibrating to produce the effect called heat possess this energy, and hence, we are right in saying that "heat is a form of energy."

In other words, the molecules of a heated body

do work just as truly as does a man who shovels dirt.

The more heated the body is, the faster do the molecules vibrate, and the more work can they do, or the more energy they have.

Temperature is a term used to denote the rate of vibration of the molecules of a heated body. It does not express the quantity of energy which a body has, but it does express the way in which the molecules are vibrating. Thus, a body having a high temperature is said to be hot; a body having a low temperature is said to be cold. The temperature of a small piece of iron may be very high, yet it does not have as much heat as a large piece which may be of the same temperature.

Bearing these facts in mind, and especially that heat is but a form of energy, or work, let us see how it is made to do work, such as running a threshing machine.

A heated body may impart the energy of its moving molecules to an adjacent body, or, commonly speaking, heat it. If the heated fuel in the boiler fire-box communicates its heat, its power to do work, its energy, to the walls of the box and shell of the boiler, the latter may in turn, heat or energize or impart the power to do work, to heat water in the boiler. When you heat water, its temperature rises, that is, its molecules commence to vibrate faster and faster. When the temperature reaches 212 degrees, a change occurs in the vibration of the molecules. Their rate of vibration does not increase, but the length of vibration increases, the molecules tending

to move farther apart. This causes the body of water as a whole to expand. Another effect of heat is still further exemplified in the expansion of railroad rails in summer, the expansion of tires for setting, etc.

In other words, the molecules of a substance which is heated, are just as capable of doing work is an able-bodied man armed with a shovel.

If heat is applied after water in an open vessel has reached a temperature of 212 degrees, the temperature of the water does not change, but instead, the extra energy imparted has resulted in making the molecules increase their length of vibration as well as their rapidity. The molecules have lost their power of inter-attraction or cohesion, and are attempting to fly apart or expand. In other words water at the temperature of 212 degrees at atmospheric pressure changes from a liquid to a gas, and this gas, if allowed to expand fully, occupies 1,700 times the volume or space which the water did. This gas is known as steam. This energizing of water or putting its particles or molecules into motion, this generating of steam, is accomplished by heating it. As before said, if then this heat has imparted a power to do work, it is evident that a certain amount of heat must impart a certain ability to overcome resistance, a certain energy, and vice versa, the energy will produce a certain amount of heat.

If the water is confined so that it cannot expand, as in a boiler, and extra heat be applied, the tempera-

ture will continue to rise. If the molecules cannot increase the length of their vibration, they increase the number of vibrations. When heat is applied, water either expands or rises in temperature. Expanded water or steam is of the same temperature as the water from which it is made. It contains more energy but is of the same temperature.

CHAPTER II.

LATENT HEAT

This excess energy—heat—which is used in turning the water into steam and which the thermometer does not register is termed “Latent Heat.” Latent comes from the Latin word meaning “concealed” or “hidden” and hence is very appropriate.

If we place water in a cylinder, the lower end of which is closed, and bring a sliding piston down on it, we may heat the water to the 212 degree point and not see that any appreciable change has taken place. If, however, we continue to impart heat to the water the thermometer does not show an increase, provided that the piston be not too heavy. Roughly speaking, as long as the piston is free to move the water does not rise in its temperature; that is, the specific heat does not increase, but the latent or non-apparent heat does. As a result the energy of vibration of the molecules increases to such an extent that the water or steam increases in volume 1,700 times; and as a consequence the piston must move or force must be applied to the other side to hold it in place against the steam.

In other words, the heat which has been given to the water, or the energy, or work-doing power, has so set its molecules vibrating that their motion has

become appreciable and that they are capable of doing work of a kind that can be used.

Now if the heat given to water when it is turned into steam is capable of making the steam do work, there must be a certain quantity of heat which will do a certain amount of work. The standard by which we measure heat is known as the British Thermal Unit; or, as commonly abbreviated, the B. T. U. This is the quantity of heat which is required to raise one pound of water one degree in temperature. Careful experiment has demonstrated that you must impart at least one B. T. U. of heat to water after the 212 mark is passed to enable the steam to lift one lb. in weight 778 ft., or 10 lbs. in weight 77.8 ft., or 100 lbs. in weight 7.78 ft. In other words, one B. T. U. is equivalent to 778 foot-pounds, and you thus have the energy which is expended by the vibrating, moving molecules of the water to which heat has been applied, measured by something which all can understand, and which is the common term to denote the pull required on the driving belt of the separator.

It has been found that the burning of one pound of coal gives out sufficient heat to raise the temperature of 14,000 lbs. of water from 62 to 63 degrees, or in the language of heat, the coal gives out 14,000 B. T. U. One B. T. U. can raise 778 lbs. one foot, or is equivalent to 778 foot-pounds. Therefore, one pound of coal can raise $14,000 \times 778$, or 10,892,000 foot-pounds; this amount of power would raise 7,000 lbs. 1,556 feet.

The burning of the fuel in the fire-box of the boiler causes the molecules of the fuel to start vibrating at a high rate of speed, or to rise to a high temperature. This energy of motion in the molecules is communicated to the surrounding air and to the walls of the fire-box. Obviously it is necessary to see that as much of this energy as possible be saved or rather directed to the point where it can be used, and so the fire-box of the boiler should be such as will best retain the heat and best transmit it to the water in the boiler.

We have further seen how the heat affects the water to which it is imparted through the walls of the fire-box, and as a final step in our reasoning, we have seen how the vibration of the molecules of the water finally overcomes that mysterious force which tends to hold them together as water, and causes them to fly apart or expand. This power of expansion we make to do work by putting something in the way of the expanding particles which they must move before they can go as far as they otherwise would, and we thus turn the energy of the vibrating molecules of the burning fuel into an energy which we can harness and direct as we please.

It will be remembered that when water was heated to 212 degrees, the temperature remained the same, while the heat which was afterwards applied disappeared as far as the thermometer was concerned, and this we called hidden or latent heat. It is found by careful experiments that it takes about 144 units of

heat or B. T. U. to change a pound of ice to water at 32 degrees. It is found that it takes a quantity of heat expressed by about 966 B. T. U. to change one pound of water into steam, and this, therefore, is 966 times as much heat as is required to raise a pound of water from 62 to 63 degrees. Thus the latent heat of steam or amount of energy which is transmitted to steam at a temperature of 212 degrees is about 966 B. T. U. At different temperatures, the latent heat of steam differs. The heat which is taken into the water when it changes from water to steam is given off again when it condenses or turns back to water.

CHAPTER III.

COMBUSTION OF COAL.

When coal is exposed to heat in a furnace, a portion of the carbon and hydrogen, associated in various chemical unions as hydrocarbons, are volatilized and passed off. At a low temperature, naphthaline, resins and fluids with high boiling points are disengaged; at a higher temperature, volatile fluids are disengaged; and at still higher, olefiant gas, followed by common gas, light carburetted hydrogen, which continues to be given off after the coal has reached a low red heat. What remains after the distillatory process is over, is coke, which is the fixed or solid carbon of coal, with earthy matter, the ash of the coal.

TABLE NO. I.

Taking the fixed carbon, or coke remaining in the furnace after the volatile elements are distilled off, at 60 per cent., in round numbers, the following is an approximate summary of the condition of the elements of average coal, after having been decomposed, and prior to entering into combustion:

100 POUNDS OF AVERAGE COAL, IN THE FURNACE			
Composition.		Decomposition.	
	Lbs.		Lbs.
Carbon Fixed	60	Fixed Carbon	60
Carbon Volatilized	20	Hydrocarbons	24
Hydrogen	5	Sulphur	1 1/4
Sulphur	1 1/4	Water or Steam	9
Oxygen	8	Nitrogen	1 1/5
Nitrogen	1 1/5	Ash	4
Ash	4		
About		100	
About		100	

This shows a total useful combustible of $86\frac{1}{4}$ per cent., of which $26\frac{1}{4}$ per cent. is volatilized. While the decomposition proceeds, combustion proceeds, and the $26\frac{1}{4}$ per cent. of volatilized portions, and the 60 per cent. of fixed carbon, are successively burned.

TABLE NO. 2.

Total heat evolved by various fuels and their equivalent evaporative power, with the weight of oxygen and volume of air chemically consumed.

Fuel.	Weight of Oxygen Consumed per lbs. of Fuel.	Quantity of Air Consumed per lb. of Fuel.			Total Heat of Combustion of 1 lb. of Fuel.	Equivalent Evaporative Power of 1 lb. of Fuel from and at 212°.
		Lbs.	Lbs.	Cu. ft. at 62°.		
Hydrogen	8.0	34.8	457	62000	62.40	
Carbon, making Carbonic Acid	2.66	11.6	152	14500	15.0	
Sulphur	1.00	4.35	57	4000	4.17	
Coal, av. dessicated....	2.45	10.7	140	14700	15.22	
Coke, av. dessicated....	2.49	10.81	142	13548	14.02	
Lignite, perfect	2.04	8.85	116	13108	13.57	
Asphalt	2.74	11.85	156	17040	17.64	
Wood, dessicated	1.40	6.09	80	10974	11.36	
Wood, 25 % moisture....	1.05	4.57	60	7951	8.20	
Straw, 15¾% moisture....	0.93	4.26	56	8144	8.43	
Petroleum	3.29	14.33	188	20411	21.13	
Petroleum Oils	4.12	17.93	235	27531	28.50	

TABLE NO. 3.

Silver..... 1000	Iron 375	Boiler Scale .. 60
Copper 850	Tin 350	Brick 11
Gold 800	Lead 200	Soot 10

The above table shows the relative heat conducting power of different substances.

The fact that soot and boiler scale are such poor heat conductors shows how essential it is that the fire-box and flues should be kept free from soot and the boiler from scale, to give the action of the fire free access to heat the water. An ordinary threshing engine will give from two to four horse power more, when clean of soot and scale than where dirty.

TABLE NO. 4.

The following table shows the chemical composition of ordinary firewood.

Carbon	37.5	per cent.
Hydrogen	4.5	per cent.
Oxygen	30.75	per cent.
Nitrogen	0.75	per cent.
Ashes	1.5	per cent.
	75.0	per cent.
Hygrometric water	25.0	per cent.
	100.0	

TABLE NO. 5.

conditions, is about as follows:

The composition of straw in its ordinary air-dried

	Wheat Straw, Per cent.	Barley Straw, Per cent.	Mean, Per cent.
Carbon	35.86	36.27	36.075
Hydrogen	5.01	5.07	5.
Oxygen	37.68	38.26	38.
Nitrogen	.45	.40	.425
Ashes	5.00	4.50	4.75
Water	16.00	15.50	15.75
	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00

TABLE NO. 6.

1 Cord hickory or hard maple weighs 4,500 lb. equals 2,000 lbs. coal.
1 Cord white oak.....weighs 3,850 lbs. equals 1,711 lbs. coal.
1 Cord beech, red or black oak weighs 3,20 lbs. equals 1,445 lbs. coal.
1 cord poplar, chestnut or elm weighs 2,350 lbs. equals 1,044 lbs. coal.
1 Cord average pine.....weighs 2,000 lbs. equals 890 lbs. coal.
1 Ton dry straw.....weighs 2,000 lbs. equals 1,110 lbs. coal.

CHAPTER IV.

PROPERTIES OF STEAM

If we heat water in an open vessel, it soon reaches the temperature of 212 degrees. If we continue to heat it, it boils, or the energy imparted to its molecules is such that their vibrations become violent enough to cause them to fly off and thus the vapor or steam arises. If we now close the top of the vessel, the molecules in their attempt to escape encounter resistance and hence have to expend some of their energy in overcoming this, that is, an extra quantity of heat must now be given to the water to make it turn to steam. If it rests under the weight of the atmosphere alone, or about 14 lbs. to the square inch, the water will boil at 212 degrees. If the pressure be increased to 32 lbs., the water will not boil until it reaches a temperature of 254 degrees. If the pressure be diminished to about six lbs. to the square inch, the boiling point is about 170 degrees, hence the law or general statement: *An increase of pressure on the surface of a liquid raises the temperature at which it boils; a decrease of pressure lowers the temperature.* The temperature of boiling water always corresponds to its pressure. We call steam which is in contact with the surface of water, saturated steam. Under the law just given, its temperature depends on the pressure in the boiler.

CHAPTER V.

SATURATED STEAM AND ITS PROPERTIES.

Temperature is not the only property of saturated steam which changes with the pressure. Other characteristics also change. These may be stated briefly as follows:

1.—The amount of heat which is required to raise a pound of water from 32 degrees, or freezing, to the point at which it boils or steams at a given pressure. That is expressed, of course, in the only term we have to measure latent heat, in B. T. U., and is called the **HEAT OF THE LIQUID**.

2.—The amount of heat which is required to change water at the temperature at which it boils into steam of the same temperature. **THIS IS CALLED LATENT HEAT OF EVAPORIZATION, OR LATENT HEAT.** This, too, is expressed in B. T. U.

3.—The total amount of heat required to change a pound of water at 32 degrees to steam of the required temperature and pressure. This is called the **TOTAL HEAT OF EVAPORIZATION, or simply, TOTAL HEAT.**

It is plain that the **TOTAL HEAT** is the sum of the **LATENT HEAT** plus the **HEAT OF THE LIQUID**.

4.—The number of cubic feet occupied by a pound

of steam at the given pressure; or the SPECIFIC VOLUME.

5.—The density of the steam; that is, its weight per cubic foot at the required pressure.

All these properties may be collected in a table so as to be readily seen and this is known to engineers as the steam table.

STEAM TABLE.

THE PROPERTIES OF SATURATED
STEAM.

Pressure above Vacuum in Pounds per Square Inch.	Temperature, Fahrenheit Degrees.	Quantities of Heat in British Thermal Units.			Weight of a Cubic Foot of Steam in Pounds.	Volume.	
		Required to Raise Temperature of the Water from 32° to <i>t</i> °.	Total Latent Heat at Pressure <i>P</i> .	Total Heat above 32°.		Of a Pound of Steam in Cubic Feet.	Ratio of Vol. of Steam to Vol. of Eq. Weight of Dist. Water at Temp. of Maximum Density.
1.	2.	3.	4.	5.	6.	7.	8.
<i>p</i>	<i>t</i>	<i>q</i>	<i>L</i>	<i>H</i>	<i>W</i>	<i>V</i>	<i>R</i>
1	102.018	70.040	1043.015	1113.055	.003027	330.4	20623
2	126.302	94.368	1026.094	1120.462	.005818	171.9	10730
3	141.654	109.764	1015.380	1125.144	.008522	117.3	7325
4	153.122	121.271	1007.370	1128.641	.011172	89.51	5588
5	162.370	130.563	1000.899	1131.462	.013781	72.56	4530
6	170.173	138.401	995.441	1133.842	.016357	61.14	3816
7	176.945	145.213	990.695	1135.908	.018908	52.89	3302
8	182.952	151.255	986.485	1137.740	.021436	46.65	2912
9	188.357	156.699	982.690	1139.389	.023944	41.77	2607
10	193.284	161.660	979.232	1140.892	.026437	37.83	2361
11	197.814	166.225	976.050	1142.275	.028911	34.59	2159
12	202.012	170.457	973.098	1143.555	.031376	31.87	1990
13	205.929	174.402	970.346	1144.748	.033828	29.56	1845
14	209.604	178.112	967.757	1145.869	.036265	27.58	1721
14.69	212.000	180.531	966.069	1146.600	.037928	26.37	1646
15	213.067	181.608	965.318	1146.926	.038688	25.85	1614
16	216.347	184.919	963.007	1147.926	.041109	24.33	1519
17	219.452	188.056	960.818	1148.874	.043519	22.98	1434
18	222.424	191.058	958.721	1149.779	.045920	21.78	1359
19	225.255	193.918	956.725	1150.643	.048312	20.70	1292

1	2	3	4	5	6	7	8
<i>p</i>	<i>t</i>	<i>q</i>	<i>L</i>	<i>H</i>	<i>W</i>	<i>V</i>	<i>R</i>
20	227.964	196.655	954.814	1151.469	.050696	19.73	1231.0
22	233.069	201.817	951.209	1153.026	.055446	18.04	1126.0
24	237.803	206.610	947.861	1154.471	.060171	16.62	1038.0
26	242.225	211.089	944.730	1155.819	.064870	15.42	962.3
28	246.376	215.293	941.791	1157.084	.069545	14.38	897.6
30	250.293	219.261	939.019	1158.280	.074201	13.48	841.3
32	254.002	223.021	936.389	1159.410	.078839	12.68	791.8
34	257.523	226.594	933.891	1160.485	.083461	11.98	748.0
36	260.883	230.001	931.508	1161.509	.088067	11.36	708.8
38	264.093	233.261	929.227	1162.488	.092657	10.79	673.7
40	267.168	236.386	927.040	1163.426	.097231	10.28	642.0
42	270.122	239.389	924.940	1164.329	.101794	9.826	613.3
44	272.965	242.275	922.919	1165.194	.106345	9.403	587.0
46	275.704	245.061	920.968	1166.029	.110884	9.018	563.0
48	278.348	247.752	919.084	1166.836	.115411	8.665	540.9
50	280.904	250.355	917.260	1167.615	.119927	8.338	520.5
52	283.381	252.875	915.494	1168.369	.124433	8.037	501.7
54	285.781	255.321	913.781	1169.102	.128928	7.756	484.2
56	288.111	257.695	912.118	1169.813	.133414	7.496	467.9
58	290.374	260.002	910.501	1170.503	.137892	7.252	452.7
60	292.575	262.248	908.928	1171.176	.142362	7.024	438.5
62	294.717	264.433	907.396	1171.829	.146824	6.811	425.2
64	296.805	266.566	905.900	1172.466	.151277	6.610	412.6
66	298.842	268.644	904.443	1173.087	.155721	6.422	400.8
68	300.831	270.674	903.020	1173.694	.160157	6.244	389.8
70	302.774	272.657	901.629	1174.286	.164584	6.076	379.3
72	304.669	274.597	900.269	1174.866	.169003	5.917	369.4
74	306.526	276.493	898.938	1175.431	.173417	5.767	360.0
76	308.344	278.350	897.635	1175.985	.177825	5.624	351.1
78	310.123	280.170	896.359	1176.529	.182229	5.488	342.6
80	311.866	281.952	895.108	1177.060	.186627	5.358	334.5
82	313.576	283.701	893.879	1177.580	.191017	5.235	326.8
84	315.250	285.414	892.677	1178.091	.195401	5.118	319.5
86	316.893	287.096	891.496	1178.592	.199781	5.006	312.5
88	318.510	288.750	890.335	1179.085	.204155	4.898	305.8

1	2	3	4	5	6	7	8
<i>p</i>	<i>t</i>	<i>q</i>	<i>L</i>	<i>H</i>	<i>W</i>	<i>V</i>	<i>R</i>
90	320.094	290.373	889.196	1179.569	.208525	4.796	299.4
92	321.653	291.970	888.075	1180.045	.212892	4.697	293.2
94	323.183	293.539	886.972	1180.511	.217253	4.603	287.3
96	324.688	295.083	885.887	1180.970	.221604	4.513	281.7
98	326.169	296.601	884.821	1181.422	.225950	4.426	276.3
100	327.625	298.093	883.773	1181.866	.230293	4.342	271.1
105	331.169	301.731	881.214	1182.945	.241139	4.147	258.9
110	334.582	305.242	878.744	1183.986	.251947	3.969	247.8
115	337.874	308.621	876.371	1184.992	.262732	3.806	237.6
120	341.058	311.885	874.076	1185.961	.273500	3.656	228.3
125	344.136	315.051	871.848	1186.899	.284243	3.518	219.6
130	347.121	318.121	869.688	1187.809	.294961	3.390	211.6
135	350.015	321.105	867.590	1188.695	.305659	3.272	204.2
140	352.827	324.003	865.552	1189.555	.316338	3.161	197.3
145	355.562	326.823	863.567	1190.390	.326998	3.058	190.9
150	358.223	329.566	861.634	1191.200	.337643	2.962	184.9
160	363.346	334.850	857.912	1192.762	.358886	2.786	173.9
170	368.226	339.892	854.359	1194.251	.380071	2.631	164.3
180	372.886	344.708	850.963	1195.671	.401201	2.493	155.6
190	377.352	349.329	847.703	1197.032	.422280	2.368	147.8
200	381.636	353.766	844.573	1198.339	.443310	2.256	140.8
210	385.759	358.041	841.556	1199.597	.464295	2.154	134.5
220	389.736	362.168	838.642	1200.810	.485237	2.061	128.7
230	393.575	366.152	835.828	1201.980	.506139	1.976	123.3
240	397.285	370.008	833.103	1203.111	.527003	1.898	118.5
250	400.883	373.750	830.459	1204.209	.547831	1.825	114.0
260	404.370	377.377	827.896	1205.273	.568626	1.759	109.8
270	407.755	380.905	825.401	1206.306	.589390	1.697	105.9
280	411.048	384.337	822.973	1207.310	.610124	1.639	102.3
290	414.250	387.677	820.609	1208.286	.630829	1.585	99.0
300	417.371	390.933	818.305	1209.238	.651506	1.535	95.8

EXPLANATION OF THE TABLE.

Column 1 gives pressures of from one to three hundred pounds. These are not gauge pressures obtained by reading the gauge, as these do not include the pressure of the atmosphere, which is about 14.7 lbs. per square inch. The gauge is set to register zero when there is nothing but the air pressing on the water in the boiler, and hence 14.7 lbs. must be added to all gauge readings to obtain these ABSOLUTE PRESSURES.

Column 2 gives the temperatures to which the steam rises when at the pressures of column 1.

Column 3 gives the HEAT OF THE LIQUID, or the number of B. T. U. required to raise a pound of water from 32 degrees to the boiling point corresponding to the given pressure, or the amount of energy which goes to do this work.

The values in column 3 may be closely approximated by subtracting 32 degrees from the temperature in column 2. This is not strictly correct for all values, as the specific heat of the water, instead of remaining at a constant, increases slightly.

Column 4 gives the LATENT HEAT OF EVAPORIZATION. This is the amount of energy which is absorbed in changing water from the boiling point to steam of the same temperature as the boiling point of the water, and is measured again in the very useful B. T. U.

Column 5 gives the TOTAL HEAT OF EVAPORIZATION, and may be obtained by adding the corresponding values of columns 3 and 4.

Column 6 gives the SPECIFIC VOLUME of a pound of steam at the given temperature or pressure, which is expressed in pounds, being the weight of a cubic foot of steam at the pressure given.

Column 7 gives the number of cubic feet occupied by one pound of steam at the given temperature, or its SPECIFIC VOLUME.

Column 8 gives the ratio of the volume of a pound of steam at a given pressure to the volume of a pound of water at the temperature of 39.1 degrees. This is equal to the weight of a cubic foot of water at 39.1 degrees, or 62.425 lbs., divided by the weight of a cubic foot of steam of the required or given pressure, as found in column 6.

We have thus followed the results of the application of heat to water and found that it is but the taking of the energy of an already heated body, as the fuel in the fire-box of the boiler, and transmitting it to the molecules of the water, or, as better expressed, it is transmitting the rapid vibrations of the molecules of the fuel to the molecules of the water until the latter are moving at such a rapid rate and with such a swing that they overcome cohesion, that mysterious attraction which particles of one kind of matter have for each other, and tend to fly apart, or as we say, expand, and this at a tremendous rate.

By taking advantage of this appreciable movement of the molecules, we are able to do work or overcome resistance with them.

CHAPTER VI.

THE BOILER

A steam boiler is an apparatus in which heat is transferred from burning fuel to water; where the energy of the vibrating molecules of the burning fuel is transferred to the molecules of the water, until the motion of the latter becomes so violent as to cause the mass or volume of steam to expand with a force which can be readily harnessed for use.

A boiler consists of the fire-box, in which the combustion takes place, the water space, in which the water is heated through contact with a heating surface which surrounds the fire-box, passages to conduct away the smoke and other products of combustion, and various accessories to furnish water and regulate the heat, etc. We have seen what a little loss of heat means in the way of loss of energy, or power to do work, and therefore the fire-box should be constructed to direct as much of the heat of the flames and burning gases to the surface against which the water lies as possible; there should be no "dead" corners where there is a loss of heat, and the smoke passages should be so disposed as to utilize the heat from the escaping gases.

Boilers for traction engines may be roughly divided into three classes: The locomotive boiler, the return flue boiler, and the vertical or upright

boiler. The locomotive boiler is so called from its resemblance to the type used in locomotive practice.

Its parts are, first, a rectangular fire-box, *a*, held in position in the shell of the boiler by stay bolts, *c*.

Second, the waist, a cylindrical portion, *d*, through which pass the tubes or flues, *e*, connecting the fire-box with the smoke box, *f*.

Third, the steam dome, *g*, from which the steam may be taken.

ILLUSTRATION IN SECTION OF BOILER.

The flat portions of the boiler above the fire door and over the front ends of the flues, are stayed by long rods called stay rods. The crown sheet over the fire-box is supported by stay bolts.

In a return flue boiler, the fire box extends the whole length of the boiler, which is usually tubular, and the flues come back through the shell returning the smoke to the fire door end.

The vertical type comprises merely a vertical, cylindrical shell with vertical flues and fire-box under them.

The main object in the distribution and arrangement of the parts are twofold. First, direction of the heat of the fuel against spaces or walls the other side of which are in contact with the water, so that the energy of the burning fuel may not be dissipated or wasted on the outer air, or outer parts of the boiler. Second, presenting as large a surface of water as possible to the heated surfaces. The fire-box should be arranged with proper grates and draft openings to suit the fuel to be used and should be easily cleaned. The water spaces should surround the fire-box as completely as possible so as to present a large heating surface and prevent its plates from overheating. The boiler should be cleaned regularly of all mud and settlings left by boiling away the water. When using ordinary well water, once a week is often enough to clean out. In muddy or alkali water, the boiler may require to be emptied oftener than once a week.

CHAPTER VII.

BOILER FEEDERS.

ATMOSPHERIC PRESSURE.

The atmosphere or air surrounding the earth has a weight or pressure on the surface of the earth of about 15 lbs. per square inch. This pressure varies at different heights. Three and one-half miles up the pressure is only one-half that at the surface. Down in the mines the pressure is greater than at the surface. The pressure is everywhere pressing on all objects on their lower sides as well as on their upper sides and has a tendency to fill all space. Air is elastic and when relieved of its pressure it will expand; when under pressure it will contract and occupy less space; at one-half the pressure it will occupy twice the space; at twice the pressure it occupies one-half the space.

As the water in the boiler evaporates or passes off in steam, it must be replaced, and this is done by devices adapted to force water into the boiler. There are two general kinds of boiler feeders in common use, *pumps* and *injectors*.

PUMPS.

Pumps are either self acting, (*independent*), or else they are operated by the piston or crosshead of the engine, hence called *crosshead pumps*. Their

main features do not otherwise differ. The essential parts consist of a barrel in which a plunger works, an inlet valve to the barrel, and an outlet valve.

The plunger must have an air tight packing around it at the end of the barrel which it enters, to exclude the air, so that when it is drawn out, the attempt of the outer air to get in will force the water in through the inlet valve. When the plunger is forced back in, the water is pushed out through the outlet valve which permits its escape but closes against its return. The figure shows a pump having a piston, *A*, barrel, *B*, inlet valve, *C*, and outlet valve, *D*. There is an air chamber, *E*, opening into the pipe beyond the outlet valve, so as to relieve any undue sudden pres-

sure in the pipe, while a check valve, *F*, beyond the chamber prevents any back pressure from the boiler. A very essential feature of the pump is an air relief cock, *G*, by which the air ahead of the piston and in the passages of the pump can be allowed to escape when the pump is first started, the cock being kept open until water passes out of it.

When the piston, *A*, is forced ahead into the barrel, *B*, it pushes the water in the barrel out through the outlet valve, *D*. At each stroke of the pump, the barrel is alternately filled and emptied, thus imparting an intermittent motion to the column of water going into the boiler. To partially overcome this starting and stopping of the water so suddenly and frequently, an air chamber, *E*, communicating with the feed pipe is placed between the pump and the boiler. When the water is suddenly forced out of the pump by the plunger, a part of it enters the air chamber, compressing the air; when the plunger reaches the end of its stroke and ceases to force the water, the air in the air chamber expands and causes the water to continue to flow into the boiler after the valve, *D*, has closed, thus lengthening the pulsations of the water and acting as a spring or cushion for the water column. Care should be taken that the air chamber is tight so that the air cannot leak out and spoil the cushioning of the water, as it is hard on valves, packing and joints of the pump if the plunger is obliged to set the whole column of water from the pump to the boiler into motion as suddenly as it would do if the air cushion were not there.

Sometimes high speed pumps with long inlet pipes work better with an air chamber just outside the inlet valve, communicating with the inlet pipe to give the column of water flowing into the pump a more uniform motion.

If there is any air admitted to the pump it expands, and reduces the vacuum caused by the withdrawal of the piston, thereby diminishing the pressure of the outer air on the water at the feed pipe mouth, and to that extent impeding the inflow of water. If the water is too hot, so as to steam, the vapor fills the cylinder instead of the fluid, and so interferes with its working.

INJECTORS.

Injectors make use of a jet of steam to force the feed water into the boiler. Although there are many makes and kinds, they all work on the same general plan.

The injector consists in general of a suction chamber, a condensing tube, and an overflow valve. Live steam is taken from the boiler directly through a pipe to the injector. As it is forced through the condensing tube, it forms a vacuum therein so that the water is lifted and enters the condensing tube, intermingling with the steam. The water being cold, this condenses the steam and greatly reduces its bulk, so that the combined columns of water and steam, as thus condensed, are smaller than the column of steam alone as it comes from the boiler; so there is a less volume or bulk of water entering

the boiler than there is leaving it in the form of steam. The resulting unbalanced pressure thus keeps up the circulation and the injector works continuously.

All joints should be kept tight to prevent air from entering the injector; as air does not condense like steam it would prevent the injector from working properly.

CHAPTER VIII.

BOILER PARTS.

FUSIBLE PLUGS.

A very necessary adjunct to the boiler, especially in the case of traction engines, is the fusible plug, which is placed in the crown sheet to give notice of low water. The plug consists of a brass bushing filled with an alloy of tin, lead, and bismuth which melts at a low temperature. So long as the furnace crown is kept well covered with water, its comparatively low temperature prevents the plug from melting and it remains intact. But the moment that the water gets low enough to uncover the top of the plug, it melts quickly and the combined water and steam from the boiler rushes down on the fire and so reduces the heat before the crown sheet is damaged. This fusible plug of alloy is inserted in a bushing which is screwed home in a hole in the crown sheet.

GRATES.

The ordinary type of furnace grate is made of cast iron bars which are placed side by side in the furnace. The thickness of the lugs cast on the sides of the bars determines the width of the air spaces between the bars. These spaces admit air to the bed of fuel; consequently the width of the spaces depends upon the fuel to be burned and the amount of air it needs.

For anthracite coal the spaces should be from three-eighths of an inch to half an inch wide; while for coals that cake much, the width of the spaces may be from five-eighths to three-fourths inches. For wood or straw the spaces must be still wider. The bars are about three-fourths inches wide at the top and taper toward the bottom.

SAFETY VALVE.

A safety valve is attached to a boiler to prevent the steam from rising above working pressure. When steam is generated more rapidly than it is used, its pressure must of necessity rise, and if no means of escape are afforded it, the result must be an explosion.

The ordinary form of valve used on traction engines merely comprises a circular plug or closure held to its seat against the outward thrust of the steam pressure by a suitably disposed spring. There are many different forms, but they all amount to the same thing, differing only in their minor details.

The *area* of the valve is the area of the opening in the valve seat on which the spring pressed valve plug rests, or is the projected area of the valve plug surface which is in direct contact with the steam when the valve is closed. The area should be large enough to discharge the steam as fast as the boiler will generate it, as otherwise the pressure will rise even when the valve is open. The following rule is a safe one to follow in computing the area necessary for the boiler:

Divide one-half of the number of pounds of steam generated per hour by the blow-off pressure increased

by 10; the result will be the valve area in square inches.

The safety valve should be placed in direct connection with the boiler so that there is no possible chance of cutting off the communication between them.

THE STEAM GAUGE.

The steam gauge indicates the pounds pressure of the steam in the boiler. The article is too well known to need special mention.

So far there have been described the device in which the steam is generated and a few of the accessories by which note is kept of the condition of the steam and water in its interior. It must not be lost sight of that the boiler and its fire-box are but a means to transfer the latent heat, that is, the rapid vibrations of the molecules of the burning fuel, to the molecules of the water in the boiler, which tend to cause the latter to fly apart and thereby impart motion to an engine piston. Remembering this fact, and that it means dollars in the pocket of the engine owner to have as many of these foot-pounds of energy transferred without loss as is possible, it is well to heed the following hints.

CHAPTER IX.

CARE OF THE BOILER.

The boiler should be examined carefully to see that all the plates exposed to the fire are free from heavy scale and not banked with dirt and mud. If the boiler be an old one, stay bolts and flat surfaces should be examined for breaks and ruptures, and the shell should be tested for thin places caused by the rusting of the metal, by pounding with a hammer. Thin places easily dent under the hammer blows, and if they extend over a large section of the boiler it is unsafe to run even at a very low pressure.

The position of the gauge glass should be determined so that the engineer may know how much water there is on the crown sheet when the gauge shows an inch or more. This is easily done by removing the hand hole plate at the rear of the boiler after the engine is in a level position. Then open the valves leading to the gauge glass and fill the boiler with water until the crown sheet, which may be readily seen, is covered with the depth of water required; this may be from two to five inches, according to the arrangement of the steam and water space. By noting the depth registered in the gauge glass when the desired depth is obtained, the engineer will have means of knowing just how much water

there is in his boiler. The position of the engine must be taken into consideration also, as he will carry a greater depth when the engine is tilted back, so causing the water to run up in the gauge, to insure that the forward or upper end of the crown sheet be covered. Conversely, if the engine be tilted forward, he will carry less, as the gauge glass will be at the higher end of the crown sheet. If the engine be tipped sideways, this must also be taken into account to prevent a burned fire-sheet. If the engine be traveling along the road, good watch will have to be kept, as it is difficult to tell, from the agitation of the water, just how much there is. In running down a steep hill, the water is liable to run forward in the boiler and leave the crown sheet bare. Therefore, before reaching the crest of the hill, the boiler should be filled enough to insure the covering of the crown sheet; the fire may also be deadened for a time by putting on a layer of fresh coal.

When steaming up, the boiler should be properly filled and a fire started in the fire-box with all the drafts open and the spark arrester removed from the stack, when possible, as it impedes the draft. When using natural draft only, the fuel on the grate should be as thin as possible.

When steam commences to rise, the steam gauge should be watched closely to see if the hand commences to move and indicate the pressure. If it stays stationary until a pressure of five to ten pounds is obtained, it should be removed and tested, as it is inaccurate and not to be relied on.

When the steam gauge registers fifteen or twenty pounds, the blower may be opened, but this should be done with caution, as the fierce heat resulting from its use is very trying on the parts directly exposed to the fire. The heat too will be unequally distributed in different parts of the boiler and the result will be unequal expansion and consequent leakage and weakening of joints. The initial or first firing of the boiler should be done with care, in order to bring all the parts to as even a heat as possible. The average sized traction boiler should be allowed from forty-five minutes to an hour in which to come to a full head of steam.

Soot and scale are very poor conductors of heat, and the fire walls and flues should be kept as free from them as possible in order that they may have a fair chance to transmit the heat as directly as possible to the water. The losses consequent on leaving the firewalls lined with dirt amount to a considerable, from the extra amount of fuel required to generate the heat.

The boiler should not be blown off when hot, as the sudden cooling is as bad as the sudden heating, while any scale on the shell and flues hardens and bakes on the walls, thereby being removed with difficulty.

The boiler should be properly jacketed with a covering of non-conducting material to prevent loss of heat by radiation.

Inasmuch as the traction engine uses all kinds of water, some highly alkaline or soapy, thereby foaming, and others highly acid, corroding the plates,

the boiler should be cleaned frequently and all deposits removed.

When boilers are worked to their fullest capacity, and the engine makes a sudden demand for more steam, the reducing of the pressure will suddenly liberate a large quantity of steam, and the violent effort this makes to escape from the surface of the water, will cause increased foaming and priming. In case the increased roaring in the exhaust gives warning of this, the throttle may be closed momentarily, and then opened again gradually, without allowing the engine to lose much headway.

CHAPTER X.

FIRING.

The fire should be kept as regular as possible, and this may readily be done by placing the fuel on the grate in such a manner as to insure an even fire. This may be conveniently done in the following manner:

Shovel regularly as possible to the fire-box.

First, shovelful at left hand, back corner; close door and wait.

Second, shovelful at right hand, back corner; close door and wait.

Third, shovelful at right hand, front corner; close door and wait.

Fourth, shovelful at left hand, front corner; close door and wait.

Fifth, shovelful at right hand, center of box; close door and wait.

Sixth, shovelful at left hand, center of box; close door and wait.

And repeat in same order. Wait the same time between each shovelful, so that there is uniform, regular adding of fresh fuel.

A thin fire on the grate is more economical than a thick one, as it permits the air to come in contact with each part of the burning coal better than if the fuel is laid deep on the grate. With a little care in

watching the fire bed and allowing no places on the grate to be bare of burning coal and no part so loaded as to prevent air from passing up through the grate freely, a fierce and hot fire can be maintained with a minimum expenditure of coal.

The ashes below the grates should be kept cleared away and the spaces between the grates open to allow free passage of the air.

Oftentimes the water used deposits lime or like substances on the inside of the shell. These cake over the heating surface, and as they are not ready conductors of heat, the boiler will require more fuel than it should in order to generate steam enough. Consequently, if the engineer finds that an engine is not supplying power enough, he should first find if the boiler and its smoke passages are in proper order. In the narrow spaces between the side plates of the fire-box and outer shell, scale sometimes accumulates to such an extent as to completely fill the interval between the plates. The energy of the molecules of the burning fuel is largely expended in heating this scale and as a consequence the water is not turned to steam rapidly enough.

In order to keep the parts in direct contact with the fire from burning out or leaking, the water must be kept in the boiler at a level which will cover them. The engineer is aided in this by the familiar water glass, also by a row of gauge cocks placed one above the other. By opening these the depth of the water can be readily determined.

In a traction engine, such as used with a threshing

outfit the boiler not only has to maintain its form against internal stress, but it performs the office of a frame on which the engine is mounted, therefore it must be strong to withstand this strain as well as the steam pressure.

CHAPTER XI.

THE MECHANISM OF THE STEAM ENGINE.

In the theory of the generation of steam it will be remembered that the heat of the burning fuel was but the motion (vibrations) of its molecules; that if this motion was transferred to the water in the boiler (through contact with the sheet and flues) it absorbs a portion of the heat, that is, its molecules commence to vibrate rapidly until the boiling point is reached, at which point it fails to increase in temperature though the fire continues to burn. This was because a portion of it, the heat, the energy, the work-doing power of the molecules, was transferred into giving a longer swing to the molecules of the water until they lost their power of staying together (their cohesion), and separated, forming an elastic, expanding gas called steam. The engine is but an instrument for transmitting the motion of expanding particles of steam into a regular, constant movement which may be made to do work, and the better the parts are arranged and adjusted with this in view, the more and better work it will do.

THE CYLINDER.

The usual method of obtaining work from heat is to admit the steam from a boiler, where it has been

generated at high pressure, into one end of a cylinder fitted with a piston. The end into which the steam is admitted is open to the entrance of the steam from the boiler and the other end is open to the atmosphere (in the simple engine), so that the piston may move freely in that direction. The pressure of the steam from the boiler drives the piston to the opened end of the cylinder. When the piston has reached that end of the cylinder, that end is put in communication with the boiler and the other end is opened to the air, and the piston returns, driving the used steam out before it. When the piston is at that end of the stroke, the operation is repeated and the piston is thus made to move back and forth indefinitely.

The piston moves to the right or the left because the work doing properties of the steam behind the piston are greater than are those of the expanded or partially expanded steam, or exhaust steam. This means that the vibrations of the molecules of steam on the boiler or pressure side of the piston are greater than those on the other, or exhaust side. The molecules of the former are moving faster than the molecules of the latter and thus the difference between the energy of the former and that of the latter is just equal to doing the work of moving the piston.

It is necessary to change the to-and-fro motion of the piston to a continuous rotary motion in one direction. The usual form of mechanism for accomplishing this is known to engine men as the crank motion.

A represents the cylinder provided with a piston, *B*, while *C* is the piston rod. A link or connecting rod, *D*, is jointed or pivoted to the end of another link or crank arm, *E*, the other end of the latter being rigidly secured to a shaft, *F*, which revolves in fixed bearings. When the piston, *B*, is at the end of the cylinder farthest from the crank or connecting rod, which is commonly called the head end of the cylinder, the piston rod, *C*, connecting rod *D* and crank *E* are all in the same straight line. As the piston returns to the other end of the cylinder, the crank arm is caused to revolve about the end fixed to the shaft and so imparts a continuous motion to the latter. The parts which move back and forth are called the reciprocating parts. The outer end of the cylinder or head is called the outboard or cylinder end; the other end is called the inboard or crank end. If the crank moves in the direction indicated by the arrow it is said to run over. If it moves in the other way it is said to run under. *H* is the head end and *G* the crank end of the cylinder; *N* and *N'* are the cyl-

inder heads, through the latter of which runs or slides the piston stem or rod. Steam is prevented from escaping around the rod by means of a stuffing box, *K*, in which expansive packing is placed and secured by the stuffing box head. The piston rod is connected at its inner end to the piston head which slides loosely in the cylinder, and is provided with expansion packing rings, *M*, which spring out and bear evenly around against the cylinder wall and so make a steam tight joint.

Steam is admitted to the cylinder through a supply pipe, *S*, which enters a steam chest, *O*; from thence it passes through steam ports, *P*, which conduct it to each end of the cylinder. The ports are formed in a valve seat, *Q*, on which a slide valve, *T*, moves backward and forward through the agency of the valve stem, *R*, which passes out of the steam chest through a stuffing box similar to the piston stem box and is operated by an eccentric on the main shaft.

The valve is so arranged as to simultaneously cover in one position one of the steam ports and an exhaust port, *U*. There is a steam passage through the under side of the valve, so that when the ports are so connected, the exhaust steam can escape under the valve through the exhaust pipe. Only one steam port is open at a time, and this enables the steam to get in behind the piston and drive it forward; meantime the valve is shifting, so that the steam is soon cut off and as the piston reaches the end of its stroke, the opposite port is uncovered and the steam again enters behind the piston at the other end. In the

figure the port to the left is being closed while that to the right is in communication with the exhaust port. After the left port is entirely closed the piston will be driven to the end of its stroke by the expansion of the steam already admitted.

It will be seen that it is necessary to keep the valve seat and face of the valve true, so that the steam may not leak through and thus cause a waste. In any form of valve used (the one shown is the common slide), it is necessary that the valve either move on or seat itself on the seat accurately so as to prevent loss of power.

In case a slide valve is used, fashioned as that illustrated, there is a heavy pressure of steam on its upper surface. This pressure is often lessened by the shaping of the valve so that the steam bears on parts of the valve which are on the opposite side to the parts above the ports. This, of course, balances in part the pressure, as only that part of the valve above the port which it is covering and the surrounding valve seat is not sustained by an equal and opposite pressure. These forms of valve are called "balanced valves." In any type of valve it is necessary to lubricate well, and this is conveniently done by feeding in a continuous supply of oil to the steam as it enters the steam chest from the boiler.

The cylinder is somewhat longer than the stroke of the piston. The space between the piston head and cylinder head when the latter is at the end of its stroke is called the *clearance*; the clearance is bored larger than the diameter of the cylinder and is called

counterbore. The counterbore of the cylinder ends is to prevent the formation of shoulders from the wear of the piston, and its subsequent pounding, which would take place if the cylinder were originally of one diameter throughout its length.

In packing the stuffing boxes, it is desirable that the packing be placed as evenly as possible around the rods, and the glands be drawn home as evenly as possible, so as to prevent undue pressure on either side of the rods. Inasmuch as the rod may not run exactly true, and is rarely of exactly the same diameter throughout its length, the packing must be elastic. Long usage sometimes glazes and hardens the packing; when in this condition, the gland should not be forced up as the rod will become cut and there will be excessive friction and consequent loss of power.

One side of the crank disc is made heavier than the other to counterbalance the weight of the connecting rod and reciprocating parts. This is done to prevent the vibration which would otherwise take place, racking the engine and alternately tightening and slacking the drive belt.

The journals on this part of the engine should receive great care and not be allowed to become loose from wear and thereby occasion knocking and pounding. The pillow block or bearing in which the main shaft of the engine runs should be kept sufficiently tight so that the shaft will run true and also to withstand the pressure of the piston and connecting rod. The bearing may be tightened by removing a

liner and screwing the cap down just hard enough to make the shaft run true without causing a great deal of friction.

There are means of taking up the wear in the bearing brasses of the crank and wrist pin or crank pin, as it is more correctly called. These comprise wedges held against the outer side of the brasses by encircling straps, and drawn in or out by properly arranged screws. The brasses should not be drawn so tightly as to heat and cling to the shaft, the particles of brass thereby becoming abrading particles.

It must be remembered that taking up the brasses in this manner changes the length of the connecting rod and makes the clearances at the two ends of the cylinder unequal. This must be remedied by the insertion of shim or liner plates, or by changing the length of the piston rod.

THE ECCENTRIC.

Motion is imparted to the slide valve by an eccentric on the main shaft. This consists of a disc, 9, secured to the shaft so that its center does not coincide

with the shaft center. It therefore follows that this center, *O*, describes a circle around the shaft, and the diameter, *W*, of this circle is the *throw* of the eccentric. The eccentric strap, 10, which surrounds it, and the eccentric rod, 11, will consequently travel back and forth a distance equal to this diameter. The radius of this circle is the *radius* of the eccentric. The eccentric is in effect a crank and reciprocates the valve stem and valve. The connection between the eccentric and valve stem may be made in a number of ways.

THE SLIDE VALVE.

The D-slide valve is the most common of the valves used to distribute steam in the engine cylinder. A section of such valve is shown in the figure in its central position. *pp* are the *steam ports*, *oo* the *bridges*, *E* the *exhaust port*, *ST* the *valve seat*. The flanges of the valve, *ab* and *cd*, are seen to be wider than the ports which they cover. Of this extra width the parts *ee* are called the *outside lap*, and the parts *ff* the *inside lap*. *F* is the valve stem connecting with the eccentric.

As the motion of the valve is given by the eccen-

tric, the valve is in mid-position when the radius of the eccentric is vertical. When the radius is hori-

zontal, and extending to the left, the valve is in its position nearest the head end of the steam chest.

There are many varieties of valves; the description of the working of one will explain the operation of all.

These figures show in skeleton the disposition of the parts when the piston is at the different points of the stroke. Of course, in order to give a clear view, the comparative dimensions of the parts have been distorted.

The parts a, b, c, d, are joints or journals to allow the parts to take proper positions in the different views. O is the main engine shaft on which the crank is secured.

A shows the position of the crank, piston and valve at the beginning of the forward stroke. The valve has just started to open the steam port at the head end to admit live steam to the cylinder, and has uncovered the exhaust port to allow the steam from the inboard end of the cylinder to escape through the exhaust.

B illustrates the position of the various parts at the end of the first quarter of the revolution. The crank is upright, both steam ports are fully uncovered. The piston is more than half way along its stroke, on account of the angularity of the connecting rod.

C shows the end of the first half of the revolution with the crank at the dead center, the piston at the end of its stroke, and the valve covering the head end port against live steam, and commencing to open the exhaust port at that end, while the port at the inboard end is just started to open to the live steam.

D is the third quarter of the revolution, the crank being at the lowest point, and both inlet and outlet ports being wide open.

E shows the parts at the end of the revolution in the same position as at the starting point.

To compensate for the shortening of the valve stem and the eccentric straps from the take up for wear, as well as for taking up the crank and shaft bearings, it is necessary to set the valve so that it will have even throw or travel in relation to the center of the engine stroke.

THE GOVERNOR.

When an engine is running at a constant speed the work done by the steam in the cylinder must just

equal the resistance overcome at the flywheel rim. Should the resistance become less than the work, the excess power causes the moving parts to move faster and faster, and the engine "races" or "runs away." If, on the contrary, the resistance at the flywheel rim is greater than the work done in the cylinder, the engine slows down and finally stops. The work required of an engine does not, of course,

remain constant, and it is necessary to have some means for varying the amount of steam to the cylinder automatically to suit the work to be done. A device for doing this is called the "governor." One type of governor is shown in the figure. Two or more controlling weights are so hung as to revolve around a stem and to move outwardly therefrom under centrifugal force against the tension of the springs. The spindle is rotated by a pulley and a belt connection or the like from the main shaft of the engine. The side motion of the balls moves the valve through which the steam must pass on its way to the steam chest. This is a "balanced valve" so that its closure moves easily. It is so connected to the balls by appropriate mechanism that the valve admits more steam when the balls are turning slowly, as when the engine is running slowly, than when the balls are rotating rapidly and so moving away from the spindle. Thus steam is admitted in proportion to the work to be done, as the increase in load and slowing down of the engine is met by an increase in the steam admitted to the cylinder, while a decrease in the load and consequent increase of the engine speed is counteracted by the shutting off of the steam.

SPEED CHANGER.

Speed changers are now provided for traction engines which permit of the speed being changed from the foot board while the engine is in motion.

TRACTION ENGINES.

The accompanying figure shows the most common type of combined engine and boiler. The parts are indicated by the reference letters. *A*, boiler; *B*, drive wheels or traction wheels; *C*, front truck wheels; *D*, bull gear; *E*, bull pinion; *F*, main pinion; *G*, steering chain drum; *H*, steering drum bracket; *J*, steering chain; *L*, front axle or king bolt bracket; *M*, smoke stack; *N*, extension front or smoke box;

O, damper; *P*, damper regulator; *Q*, smoke box door; *R*, high pressure cylinder; *S*, low pressure cylinder; *T*, steam supply pipe; *u*, governor; *a*, cylinder lubricator; *b*, governor belt; *c*, crank disc; *d*, connecting rod; *e*, girder frame; *f*, crosshead; *g*, piston rod; *h*, stuffing box; *i*, crank pin; *W*, fly-wheel; *j*, friction shoe; *l*, whistle; *m*, safety valve; *n*, reverse lever; *p*, throttle valve lever; *q*, quadrant; *r*, steering wheel; *ss*, injectors; *tt*, check valves; *w*, water tank; *x*, draw bar; *y*, draw bar spring.

CHAPTER XII.

SETTING THE VALVE.

When the engine is turned so that the crank arm, piston stem and cylinder are lying in line, as when the piston is at the end of its stroke, the engine will not turn when the steam is admitted behind the piston, as it is pushing directly against the shaft. The engine is then said to be on a *dead center*. Obviously there are two dead centers corresponding to the two extreme positions of the crank.

In order to set the valve it is often necessary to place the engine on its dead center. A method of doing this is explained as follows:

When the crosshead is very near the end of its throw, make a mark *b*, on one of the guides opposite the outer edge of the crosshead. Now turn the engine

in the direction of the arrow until the outer edge of the crosshead again comes in register with the mark,

b. While the engine is in this position, take a tram, *d*, or a common pair of dividers, and adjust its scratch point at about the height of the center of the crank shaft above the floor. Place one end on the floor or engine bed and with the scratch point make a mark, *e*, upon the edge of the flywheel. The engine will not be on the center exactly; the crank pin will be slightly above the center. Turn the engine in the direction of the arrow, *x*, until the edge of the cross-head comes even with the mark, *b*, on the guides. The flywheel will have made nearly a revolution and the crank pin be the same distance below the center that it was above it. The tram point will now make a new mark, *e'*, on the rim. Make a mark on the rim midway between the mark *e* and the mark *e'*, and then turn the engine until the center mark, *f*, is opposite the tram point. The engine is then exactly on its dead center. Find the dead center at the opposite end in the same way.

To set the valve, put the engine on its dead center, place the valve on its seat and connect it with the valve rod; shift the eccentric on the shaft until the valve has the required lead. Turn the engine the way it is to run, until it is on the other dead center. If the lead is the same as at the other end of the throw or stroke, the valve is correctly set; if it is not, the valve rod must be lengthened or shortened until the lead at either end is the same. If now the lead be too much, the eccentric may be shifted back on the shaft; if too little, it may be shifted ahead.

If the engine has a reversing gear, the reverse

lever should be set so as to bring one of the eccentric rods in line with the valve stem, and then proceed as above directed; then shift the lever and bring the other eccentric stem in line, and again set the valve; in each instance turn the engine for each setting in the way it would normally run when the parts are in the position given; this turning the engine in the way in which it should go as you set it, accounts for and allows for any lost motion in the parts.

TRACTION GEARING.

Power is usually transmitted to the drive wheels from the main engine shaft through a train of gearing. This gearing is arranged to suit the form and equipment of the engine. It usually consists of a friction clutch and a main pinion which are secured together and run on the main shaft. This main pinion engages an intermediate gear which in turn engages a compensating gear. The latter imparts motion to a pair of bull gears which are secured to the traction wheels, the two gears being connected to the compensating gear through an intermediate gear. By the application of the friction brake the engine is coupled to the drive wheels, its motion being greatly reduced in passing through the gearing, and thus the engine is propelled. The compensating gear allows the two traction wheels independent movement so as to follow the curves and irregularities of the road, whereby there is no slipping of the wheels in turning corners, and a consequent loss of power.

THE TRACTION OR DRIVE WHEELS.

The traction or drive wheels should be of sufficient width of tire or tread to give good tractive power. They are provided with spuds or lugs to prevent slipping and are of a variety of forms. The larger the traction wheel in diameter the more easily the engine will traverse soft ground.

A large wheel is less liable to slip and revolve on the ground as it has a greater bearing, owing to the small angle of contact presented to the front side of the wheel.

CHAPTER XIII.

WHISTLE SIGNALS.

The whistle can be made to do service if its use is rightly understood, but it is very poor practice to toot and blow it promiscuously without any plan or method. If all threshermen would adopt and use a prescribed code of signals, those connected with the machine would soon become accustomed to them and understand what they mean.

The less the whistle is used the better, as it scares high spirited horses, excites persons not accustomed to it, and attracts the attention of all within hearing from their work. This time lost would not be very much for one man, but twenty-five or one hundred men losing from one-half to noe minute apiece, is an item which if multiplied often during the fall's run will be of enough magnitude to deserve attention.

CODE.

One long continuous sound is given to attract attention at such times as in the morning or at noon to indicate the working place.

Two long continuous sounds with a short interval between them is to denote the work completed for that day or at that place, as the case may be.

One short sound is to stop.

Two short sounds with a short pause between them, to go ahead or commence work.

Three medium short sounds means to hurry, given to indicate to those hauling grain that the machine is about to wait for them.

One long, continuous sound followed by three shorter ones is a signal to the waterman that the supply of water is about exhausted.

A continuous succession of short and rapid sounds denotes fire or other distress and should be responded to by all within hearing of the call.

No one should ever sound the whistle but the engineer, as one unaccustomed to it cannot give the proper expression to the sound.

The stroke of the whistle lever should be full and steady, and well timed. The valve should not be opened too suddenly, but with a clean and steady pull, and should be closed gradually. The spaces between the sounds should be well timed and of equal length. This will give expression to the sound, pleasing to hear. An old thresherman once said he could tell the character of the engineer by the way he sounded the whistle.

The tone or pitch of a whistle may be changed by screwing the bell up or down. The lower down the sharper the tone will be, and more piercing to the ears of those near by. When the bell is farther up the tone will be of lower pitch and can be heard at a greater distance and is not so distressing to those near by. When set in a position, it should be left so and not changed without good reason, as the people

in the neighborhood become accustomed to it and can distinguish whose machine is giving the signals.

Whistles are sometimes made in chimes of two or more tones that are very pleasing to the ear.

CHAPTER XIV.

OPERATING AND HANDLING OF THE ENGINE.

Reference has already been made to the care of the boiler, and the engine proper, while at work requires as close attention and careful handling. The correct water level, uniform fire and constant steam pressure are to be maintained, as before stated, and, in addition to this, the engine, if on the road, is to be guided and kept clear of stumps and like obstacles. Hills are to be planned for and the fire and water arranged and regulated accordingly. The temperature in which a traction engine works varies from the heat of the southern summer to the intense cold of the northern winter, and these facts must be taken into account in running the machine and keeping it in order.

STARTING THE ENGINE.

Before starting the engine, open the cylinder cocks and let a little steam into the cylinder by opening the throttle slightly; wait until the steam has had time to heat the cylinder and drive out the water from the condensed steam which always forms when the cylinder is cold. This may form in large quantities, and if it gets in between the cylinder head and the piston, its

resistance, if the engine be started suddenly, throws a severe strain on the brasses and connections, and may even fracture the cylinder head.

After the cylinder has been heated up at one end, the reverse lever should be thrown over to admit steam to the other end. If the engine is a compound, the reverse lever should be thrown back and forth a few times to warm up the low pressure cylinder. After the cylinder has been properly heated, which is indicated by steam instead of water issuing from the cylinder cock, the throttle may be opened enough to cause the engine to start slowly. After it has run slowly for a little time, the throttle should be opened enough to run it at full speed.

THE ENGINE ON THE ROAD.

While traveling on the road, the water should be carried as high as practical in the glass to insure the covering of the fire-box and the flues, while the engine is passing over any irregularities on the road. Before starting to ascend long or steep hills, fresh fuel should be added to the fire in time for it to become thoroughly ignited before the steep portion of the hill is reached. Fresh fuel deadens the fire and absorbs the heat of the live coals, thus momentarily checking the generating of steam. If the hill to be ascended is a long or steep one, and the engine has a heavy load to draw, the speed of the engine should be regulated to run only fast enough to use the steam as generated. If the engine is permitted to run too fast when loaded, the steam pressure will be

reduced, and as a result, the engine will be stalled, and there may be trouble in getting it started again while on an incline. The reduction of the steam pressure so suddenly while a hot fire is burning is very liable to cause foaming or priming, and is also hard on the joints and weak portions of the boiler. The proper plan is to watch the steam gauge closely and keep the speed only fast enough to maintain the steam pressure sufficiently high to insure the working of the engine. When the engine is working at its fullest capacity, the reverse lever may be thrown over to the last notch on the quadrant to permit the cylinder to be filled with live steam during the greatest portion of the stroke possible, and thus prevent the engine from becoming stalled.

In passing down hill, the reverse lever may be hooked up near the center. If the hill is so steep that the engine has a tendency to increase its speed, the throttle should be closed and the engine should be reversed; the piston will then cushion itself on the air in the cylinder and so retard the speed. In case this is not a sufficient check, the throttle may be opened slightly to admit a little steam and the reverse lever moved to a point where the desired speed of the engine will be maintained.

While on the road it is poor practice to take off the governor belt and try to control the speed of the engine by the throttle or to run it at a greatly increased rate, as the vibration and jar of the oscillating parts cause strain and undue wear on the connecting parts. If it is desired to change the speed,

it should be done by the governor; this will allow the engine to run at the desired speed without fear of being run too fast.

GUIDING THE ENGINE.

When traveling on the road, the engine is made to turn by swinging the front axle as in a wagon, by means of the guide wheel and steering chain gear. By cramping the wheels more or less, a longer or shorter turn is made.

To find the space required to turn the engine around completely, when the front wheels are cramped at a given angle or position, set the wheels at the required angle and then draw a line on the ground beneath and in a line with the front axle, also draw a line under and in line with the rear axle. The intersection of these lines will be the center of the circle in which the engine will travel when the wheels are set in a given position and double the distance from this center to the engine will be the diameter or width of the circle.

THE FRICTION CLUTCH.

To set the train of traction gearing in motion, and thus start the engine traveling, the flywheel is first put in motion and then the friction clutch is thrown into engagement with it. The motion of the engine shaft is thus transmitted through the clutch and gears to the driving wheels. In using the friction clutch, care should be taken not to throw it in gear too suddenly, as the strain on the gearing and connections

is very severe. The ordinary traction engine weighs from four to twelve tons and to set this great weight in motion suddenly puts an enormous load on the driving mechanism.

The engine should be started slowly. The friction clutch may be then thrown in gradually until the traction gearing is set in motion when the clutch may be sent home and the throttle opened sufficiently to give full speed to the engine.

The friction shoes of the clutch should be just tight enough to insure proper driving of the engine without slipping; if too tight, there is undue strain and wear on the parts which come in contact with the wheel.

SETTING THE ENGINE.

When setting the engine in line with the separator, the flywheel of the engine and drive pulley of the separator should be placed in line and near enough to each other so that the drive belt, when placed thereon, is not too loose. The engine is then started and the friction clutch is thrown in for a moment, causing the engine to travel backwards and tighten the belt sufficiently to drive the separator. The engine is then blocked to prevent it from moving ahead when the clutch is released, as it would otherwise do, owing to the tension of the drive belt.

GEAR LOCK.

If a gear lock is on the engine, it should be thrown in before the engine is started backwards.

The engine should be set nearly even or level for threshing or other stationary work. The rear end

should be somewhat lower than the forward; the engine should never be inclined the other way, as the steam dome is near the forward end of the boiler. The elevation of the front end will give a greater distance from the steam pipe to the water line; this positioning of the engine is perhaps more essential in boilers having little steam space than those having large space.

CHAPTER XV.

TESTS FOR LEAKS.

The cylinder rings and the valve should be occasionally tested to see that they are steam tight. Should the piston or valve leak very much steam the economy or efficiency of the engine will be considerably lessened. The steam that leaks through, besides being wasted, interferes with the free working of the engine by choking the ports and exhaust, thus causing high back pressure. If an engine is allowed to do much leaking the results are far reaching. The ports and exhaust being unduly filled, the engine has to do more work to overcome the back pressure on the piston and this, of course, means that the governor is admitting an extra supply of steam to keep up the speed. We thus have a double loss—the steam leaking through, and the steam used in excess of the normal to overcome the resistance. This excess of steam calls for an extra amount of feed water to be forced into the boiler, an extra amount of fuel to be burned, and an extra high temperature to which the fire-box and plate are subjected. The engine and boiler are thus required to do an extra amount of work, which in some old, worn engines may be nearly fifty per cent of the actual work performed.

The piston and valve may be easily tested as

follows: Place the engine slightly off the center in the direction it is intended to run, a sufficient distance to insure the steam port being open to admit the live steam to the cylinder; take a strong chain and fasten to the rim of the flywheel adjacent to one of its spokes, and secure it to some stationary part of the engine in such a manner that when the throttle is opened, and steam is admitted to the cylinder, the flywheel cannot revolve, but resists the pressure of the steam on the piston. With the engine in this position and the throttle open, we have full boiler pressure on one side of the piston and the other side exposed to the atmosphere through the exhaust ports and pipes. By placing the hand over the exhaust nozzle, at the base of the smokestack, any leakage of the steam through the cylinder rings or valve seat may be easily detected. If much steam is escaping, the valve seats and rings should have attention; however, the most perfectly fitted engines will leak some.

If the engine is found leaking, the next step is to determine whether it is through the valve seat or cylinder rings. This may be done as follows. Place the engine slightly off the exterior dead center in the direction intended to run, which will open the steam port at the crank end of the cylinder. Chain the flywheel as before and remove the cylinder cap. With the engine in this position and the throttle valve open, and steam pressure on the valve and on the piston in the crank end of the cylinder, the point of leakage can be easily detected. If the steam escapes

from the head end steam port leading to the valve seat, it clearly indicates that the valve is leaking; if the steam escapes around the piston head, it is plain that the cylinder rings are leaking.

It is a good plan to test the piston and valve in different positions, as in some positions they are found to leak while in others they are perfectly tight. This is owing to the fact that the cylinder does not wear evenly.

In testing, great care should always be taken to have the flywheel firmly secured, as play of a few inches might break the chain and do injury to the operator.

If the valve is found to be leaking, it may be repaired by planing the valve and valve seat, and afterwards scraping to a true surface by means of a scraper and surface plate.

If the cylinder rings are found to be leaking, they should be expanded or replaced by new ones; cylinder rings in pistons which are constructed with an inside ring and stud bolts for the purpose of forcing the rings outwardly to the wall of the cylinder, are the only ones that can be expanded successfully. In other forms of pistons and rings where a groove is turned in the piston, and the rings are sprung into place and held by their own elasticity, the usual practice is to replace the rings by new ones.

In compound engines the same general plan of testing the engine may be followed, but it is sometimes more difficult to locate the exact point of the leakage, on account of the multiplicity of the ports and working parts.

CHAPTER XVI.

FRICITION AND LUBRICATON.

The rubbing of the surface of one body against that of another produces friction. Friction varies greatly with different materials, conditions of the surfaces in contact and the weight bearing them together. The friction between two pieces of polished steel is much less than between two pieces of brick.

The power expended in overcoming friction is transformed into heat, and the greater the friction between two surfaces the greater the quantity of heat produced.

Friction is caused between two surfaces by the unevenness and roughness of the surfaces in contact. No matter how smooth a journal or box may seem to be, the surface is dotted all over with minute points or projections, with indentations or depressions between them.

When the two metals of the journal come in contact, the points of one of the bodies settle down and fit into the depressions of the other, and when the bodies are moved in relation to each other the points cling fast, and some of them break off, thus wearing the surface away.

By the application of properly shaped particles

between the points or projections of two contacting metals, the pieces may be moved with much less resistance or friction. Lubricating oils or greases are used to supply these particles. The globules of the lubricating material tend to hold the surfaces of the metals apart, permitting the small projections to pass each other without touching, thus reducing the friction and wear. The materials best adapted for lubricating purposes are those whose globules retain their natural shape under the greatest pressure. This property of lubricating oils and greases is called *viscosity*. The lubricant in a revolving journal will lose its viscosity after a time, and permit the surfaces to come in contact; for this reason it is necessary that a fresh supply of oil be fed to the journal to replenish the old oil.

The cylinder rings and valve seats require special lubricating oil, capable of resisting the heat to which the parts are exposed. Cylinder oil should resist a temperature much higher than the steam temperature before its particles become dissociated or evaporate. If cylinder oil is so light or volatile that as soon as it is exposed to the high temperature of the steam the liquid portion evaporates, leaving a dry, sooty like residue, it is valueless as a lubricant and a positive injury to the face of a valve or cylinder ring.

Cylinder oil may be easily tested by putting a small quantity on a steam pipe under boiler pressure, whose heat is therefore equal to the engine cylinder. If the oil boils, smokes or evaporates quickly, it is unfit for cylinder lubrication. Put a little oil such as

kerosene or light machine oil on such a pipe, and see how rapidly it evaporates and disappears in smoke and gas.

The cylinder "lubricators" should furnish a continuous supply of oil to the engine. This supply should be constant although a small quantity will suffice to keep the valve and cylinder rings lubricated. From three to five drops per minute of best grades of cylinder oil will keep the ordinary traction engine well lubricated, while with lighter grades, from five to seven drops should be used.

Gearing which has to withstand a heavy pressure on the face of its teeth should be lubricated with some kind of hard oil or axle grease.

In recent years hard oil has come into general use for journal lubrication.

CHAPTER XVII.

WINTER CARE OF THE ENGINE.

If an engine is not in use it should be stored in a dry shed to prevent deterioration caused by rust and dampness. It should be cleaned of all dirt. The smoke stack and outside of the boiler should have a coat of linseed oil to prevent rusting. The inside of the boiler should be cleaned, the handhole plates should be fastened in again and all valves and connections kept closed, to exclude air. The boiler will not rust or corrode on the inside, if kept air tight.

The piston rod and valve stem should be coated with some non-corroding oil and the engine should be left in position with the piston at the end of the back stroke; this leaves the piston rod housed in the cylinder. The cocks should be kept closed to exclude air and prevent rust.

All pipes and valves should be well drained to guard against bursting or straining by freezing.

If the boiler has formed much scale on its heating surface, the most of it will loosen and drop off during the idle season by the unequal expansion of the iron and the scale from changes of temperature. The loosened scale should be removed from the boiler before starting the engine again.

CHAPTER XVIII.

SOME SEPARATOR AND ENGINE "DONT'S."

Don't use too many concave teeth in dry straw.

Don't run with loose cylinder teeth.

Don't try to thresh tough grain with too few concave teeth, or with the concave set too low.

Don't run belts too loose or too tight.

Don't forget to keep all nuts tight.

Don't run journals too loose or too tight.

Don't have too much blast at the back end of the sieve.

Don't have too little blast at the front end of the sieve.

Don't try to do good work with the separator set out of level.

Don't allow the separator to rock back and forth while threshing.

Don't allow pitchers to overcrowd the separator.

Don't allow the separator to run with too little grain.

Don't use too many sieves.

Don't return many tailings to the cylinder.

Don't have too much end play in the cylinder boxes.

SOME ENGINE "DON'TS."

Don't carry too deep a fire.

Don't allow the ashes to accumulate under the grates.

Don't allow the spaces between the grates to become choked with cinders.

Don't stir the fire enough to cause small particles of unburnt coal to fall through the grates.

Don't allow vacant spaces on the grates.

Don't have the fuel spread unevenly on the grates.

Don't allow mud and scale to accumulate on the heating surface of the boiler.

Don't neglect to keep the flues clean from soot.

Don't pump cold water into the boiler too rapidly.

Don't run with too low water.

Don't carry water high enough to cause priming or foaming.

Don't forget to put out your fire if water gets below crown sheet.

Don't forget to drain pipes in freezing weather.

Don't forget to open the boiler stopcock before starting the pump.

Don't fail to keep your water glass tubes and cocks clear and open.

Don't try to work the pump when the tank is empty.

Don't run the engine with stuffing box glands too tight.

Don't fail to replace old burnt and hard packing with new.

Don't fail to test your piston and valve for leaks.

Don't run an engine with valve set improperly.

Don't fail to adjust brasses and journals.

Don't tinker with valves that are set properly.

Don't fail to keep all wearing parts well lubricated.

Don't fail to keep all other parts clean and free from oil.

Don't run an engine and separator out of line.

Don't run main drive belt too loose.

Don't neglect the rig when not in use.

Don't forget to make the most of your opportunities.

CHAPTER XIX.

A SUGGESTION.

A Suggestion as to soliciting threshing. Go about it in a business-like way. When you meet the man that has a job that you want, ask him for it in a plain, practical manner. Assure him that you will do him a good job in a workmanlike way and save his grain, and do it in as short a time as is consistent with good work. The subject of price usually comes up at this time and this is the best time to lay the foundation for prompt collections.

Let your rule be one price to everybody and the account cash as soon as work is done, unless there is reason for an extension. Be sure to have this understood at the time, just when and how the account is to be paid. This is business and no one ought to take offense at it; but if nothing is said and the work is done, the parties to the transaction may have entirely different ideas as to the price and time of payment. This often leads to difficulties that require some sacrifice to adjust, and the farmer feeling miffed, will resolve to do business with some one else next time, all because the start was not made right.

There is no more reason why a thresherman should wait for his money than anyone else. He has his capital invested and has to pay his help as he goes along.

It is usually the thresherman's own fault if he has poor collections, for not being firm and exact. He would better lose a job now and then than to lose the pay after he has done the work.

TABLE OF THE AREAS AND CIRCUMFERENCES OF CIRCLES AND OF THE SIDES OF SQUARES OF THE SAME AREA.

Diam. of Circle in inches	Circumference of Circle	Area of Circle in sq. in.	Sides of Sq. of same Area in sq. in	Diam. of Circle in inches	Circumference of Circle	Area of Circle in sq. in.	Sides of Sq. of same Area in sq. in
1	3.14	.785	.89	21	65.97	346.36	18.61
1½	4.71	1.767	1.33	21½	67.54	363.05	19.05
2	6.28	3.142	1.77	22	69.11	380.13	19.50
2½	7.85	4.909	2.22	22½	70.68	397.61	19.94
3	9.42	7.069	2.66	23	72.25	415.48	20.38
3½	10.99	9.621	3.10	23½	73.82	433.74	20.83
4	12.56	12.566	3.54	24	75.39	452.39	21.27
4½	14.13	15.904	3.99	24½	76.96	471.44	21.71
5	15.90	19.635	4.43	25	78.54	490.88	22.16
5½	17.27	23.758	4.87	25½	80.10	510.71	22.60
6	18.84	28.274	5.32	26	81.68	530.93	23.04
6½	20.42	33.183	5.76	26½	83.25	551.55	23.49
7	21.99	38.485	6.20	27	84.82	572.56	23.93
7½	23.56	44.179	6.65	27½	86.39	593.96	24.37
8	25.13	50.266	7.09	28	87.96	615.75	24.81
8½	26.70	56.745	7.53	28½	89.53	637.94	25.26
9	28.27	63.617	7.98	29	91.10	660.52	25.70
9½	29.84	70.882	8.42	29½	92.67	683.49	26.14
10	31.41	78.540	8.86	30	94.24	706.86	26.59
10½	32.98	86.590	9.30	30½	95.81	730.62	27.03
11	34.55	95.03	9.75	31	97.38	754.77	27.47
11½	36.12	103.87	10.19	31½	98.96	779.31	27.92
12	37.69	113.10	10.63	32	100.5	804.25	28.36
12½	39.27	122.72	11.08	32½	102.1	829.58	28.80
13	40.84	132.73	11.52	33	103.6	855.30	29.25
13½	42.41	143.14	11.96	33½	105.2	881.41	29.69
14	43.98	153.94	12.41	34	106.8	907.92	30.13
14½	45.55	165.13	12.85	34½	108.3	934.82	30.57
15	47.12	176.72	13.29	35	109.9	962.11	31.02
15½	48.69	188.69	13.74	35½	111.5	989.80	31.46
16	50.26	201.06	14.18	36	113.0	1017.88	31.90
16½	51.83	213.83	14.62	36½	114.6	1046.35	32.35
17	53.40	226.98	15.07	37	116.2	1075.21	32.79
17½	54.97	240.53	15.51	37½	117.8	1104.47	33.23
18	56.54	254.47	15.95	38	119.3	1134.12	33.68
18½	58.11	268.80	16.40	38½	120.9	1164.16	34.12
19	59.69	283.53	16.84	39	122.5	1194.59	34.56
19½	61.26	298.65	17.28	39½	124.0	1225.42	35.01
20	62.83	314.16	17.72	40	125.6	1256.64	35.45
20½	64.40	330.06	18.17	40½	127.2	1288.25	35.89

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