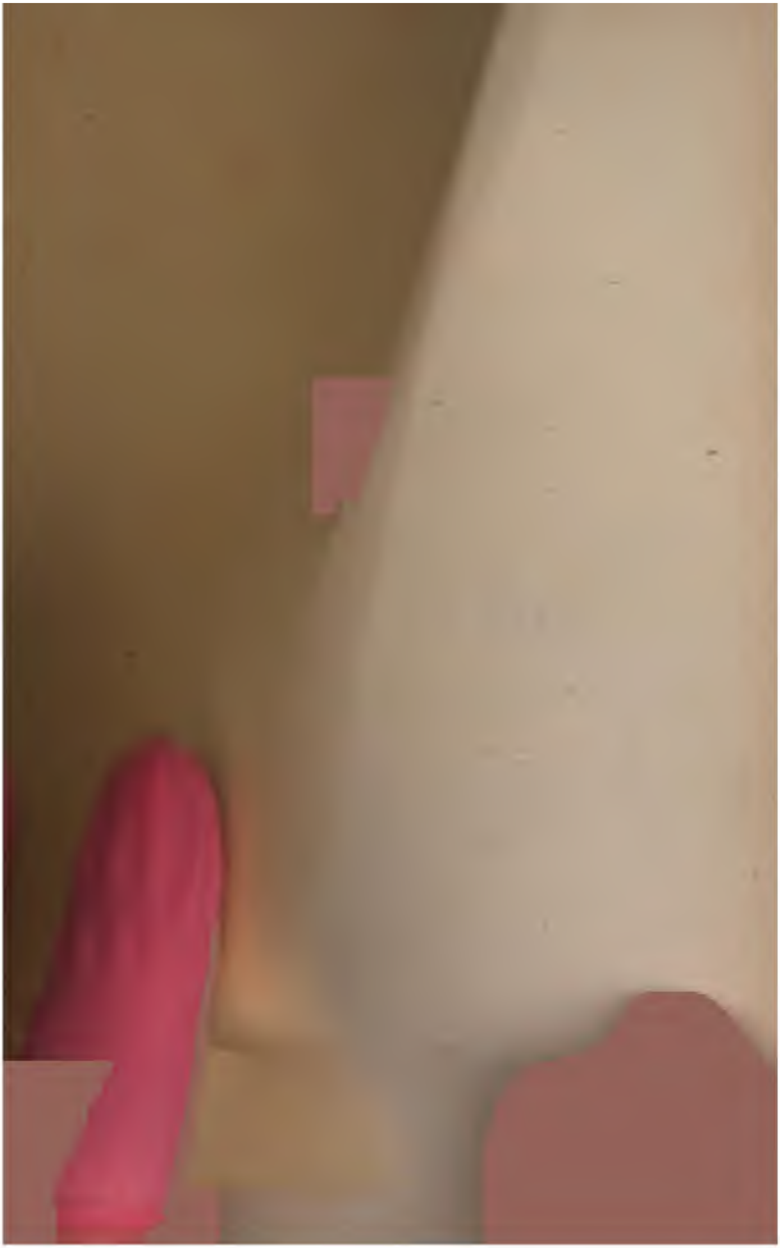
STEAM Engineering

ON

SUGAR PLANTATIONS,

Steamships & Locomotive Engines.



STEAM ENGINEERING

ON

SUGAR PLANTATIONS,

STEAMSHIPS,

AND

LOCOMOTIVE ENGINES.

BY JAMES STEWART.

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TO

JAMES BOGARDUS, Esq.,

The Eminent Mechanician,

ORIGINATOR AND CONSTRUCTOR OF IRON BUILDINGS;

THE DONOR, TO SCIENCE AND ART, OF MANY VALUABLE IMPROVEMENTS;

THE FRIEND OF MECHANICS AND WORKINGMEN;

This Book is respectfully Dedicated,

AS A TESTIMONIAL OF THE HIGH ESTEEM

IN WHICH HE IS HELD BY

THE AUTHOR.

This book contains enough for all practical purposes, and being written in the style of language used by mechanics at their work, it will be easily understood by an intelligent man; and there is no need of engravings to show the various parts, as the actual machine is the best illustration.

PART I.

SUGAR MANUFACTURING.

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ERRATA.

Page 30, first line: For "*off* wrought iron flanges, when *they* get broken," read—"*on* wrought iron flanges, when *others* get broken."

Page 45, eighth line: After "to purge the sugar." insert "The top of the mould is covered up with clay."

hoed the same as co..., ... e planted in good land will be ready to cut down and send to the mill in one year after it is planted.

The cane is cut about one foot above the surface of the ground, and the roots are left to grow up again for the next year.

The second year's cane, from the same roots, will be better than the first.

There are some plantations, in the islands of Cuba and Porto Rico, where the cane grows fifteen feet high and over two inches thick.

When the cane is ready for grinding, it is cut down, the leaves are taken off, the top part is cut off about one foot from the end; these pieces that are cut off, and also the leaves, are used for fodder for the cattle; the canes are then cut in about four feet lengths and carted to the mill.

The fields are divided off into sections, and spaces are left, at convenient distances, for carts to get in to take the cane away.

In good land the cane does not require to be replanted for four or five years.

There are various kinds of cane: the red cane has a red hard skin, the white cane has a soft skin, the crystalline cane has a light skin, and appears to have a coat of varnish on it. There is a kind called Tampico cane. Each kind of cane is planted in the ground that is best suited for it.

The cultivator distinguishes three kinds of cane: the Batavian cane, with dense foliage and covered with purple stripes; the Creole cane, with dark green leaves and a thin and knotty stem; the Otaheite cane, which is very juicy and yields much sugar.

Good land, in Cuba and Porto Rico, will produce four hogsheads of sugar to the acre, while poor land will not produce more than from one and a half to three hogsheads of sugar. The hogsheads contain one thousand and seven hundred pounds average; the hogsheads in Louisiana are not so large, they average one thousand one hundred pounds.

The cane harvest in Louisiana is gathered sooner than it is in the West Indies, on account of frost, and the cane does not get time to grow so large. The cane in Louisiana is all ground up before the month of December is out, and in the West Indies the cane grinding does not commence until about the end of December, and is not finished until the first day of May—the time intervening is occupied in cultivating and preparing for next crop.

THE CANE MILL ENGINE.

The steam engines in common use in the West Indies and Louisiana for driving cane mills, are mostly of the high pressure, walking beam kind. A common size is about eighteen inch diameter of cylinder, and four feet stroke. In the West Indies and Louisiana the climate is damp, and in the dead season, as it is termed, or the months when the crops are growing, after the former crop has been finished and made into sugar, the engine is dismantled, the bright work is taken off, and cleaned and packed into boxes filled with hot lime; the inside of the cylinder is served with a coating of white lead and tallow mixed, and the beam centers and crank shaft and crank pin, and the rollers of the mill, and all the parts of the machinery that cannot be taken down and packed in lime, are served with a coating of this mixture of white lead and tallow.

Therefore, before erecting the engine, all these parts must be carefully cleaned.

Examine if every piece is ready to go in its place —see if all the parts are level.

Examine the timbers and brick work of the foundations; these foundations often settle, on account of the heavy rains that fall in the dead season.

Plumb and level the cylinder and bed plate, the beam at the main centre also; adjust the valves; this is an important matter at the beginning of a long crop.

HOW TO SET THE VALVES.

First find out the way which the engine is required to turn; that will be easily seen by tracing the wheels from the crank shaft to the rollers of the mill. The piston may be put in the cylinder; but do not put in the packing rings, as it will be lighter to turn the wheel without them. Turn the wheel around until the crank is on the top centre; and to find out when the engine is on the dead centre, turn the fly wheel slowly—always turning the same way the engine is required to go; when the piston stops moving, make a slight mark, with the point of a knife or a scriber, on the piston rod or slides; make a trammel out of a piece of three-eighths of an inch iron rod; sharpen both ends to a point; bend the rod so that the points will be at right angles with each other; make a centre mark with a punch in the frame, in front of the fly wheel; put one of the points of the trammel in the centre mark, and make a mark on the face of the fly wheel with the other point of the trammel; turn the fly wheel slowly until the piston rod or slides begin to move, visible from the mark made on the piston rod or slides; mark another line on the face of the fly wheel with the trammel; then the centre between the two marks that have been made on the fly wheel with the trammel is the true centre. It is best to find the centre in this way, as there are some engines that the wheel will turn about two feet when the crank is on the centre, and the piston will not travel any.

Make a centre punch mark in the centre, between the two lines drawn on the face of the fly wheel, with the trammel, and let the centre punch mark remain in the fly wheel; keep the trammel, so that the centre can be found at any time when required; in like manner, turn the wheel and do the same with the crank on the low centre; having found the centre, proceed to set the valve.

The valve may be a long slide valve, that is, having a steam and exhaust port at each end of the cylinder; that is the kind in most common use in this class of engines.

Connect all the valve gear, eccentric rod, &c.; turn the fly wheel until it comes to one of the centre marks, so that the trammel will match into it. By turning the fly wheel the same way the engine is intended to run, the lost motion of all the connections from the eccentric wheel to the valve is taken up, and if the wheel should overrun the mark by the trammel, when setting the valves, the wheel must be turned back some distance, and then brought up slowly to the mark by turning again slowly the way the engine runs. Having got the wheel to the right position with the crank on the top centre, and the trammel in the centre punch mark on the face of the fly wheel, then the port at the bottom of the cylinder must be open about one-tenth of an inch, to admit steam; if the valve is not in that position, slack the screws in the eccentric wheel, and turn the eccentric wheel until the valve comes right; then tighten up the screws again, and turn the fly wheel until the engine is on the low centre by the trammel, and see that the valve is in the same position at the ports of the cylinder as it was on the other end of the cylinder; if the valve is too far over, or not enough, then the eccentric rod must be lengthened or shortened, as the case may require; the eccentric rod is furnished with screw and check nuts, to regulate the length of the rod.

The one-tenth of an inch that the valve is open before the engine is over the centre, is given for the purpose of filling the ports, and having the steam ready up to the piston as soon as it begins to travel on the other stroke, and also to act as a cushion against which the piston may strike as it turns the centre; this is termed the lead of the valve, and when the engine travels fast, as a locomotive engine does, the valve requires more lead.

REGULATING THE PISTON.

The piston packing mostly in use for sugar mill engines, is double rings with springs. These springs are furnished with screws to set them up when the piston is slack.

Take a piece of stout wire; make it the right length to measure from four points from the inside of the cylinder to the piston rod. Tighten the screws up gently until the rod is in the centre of the cylinder.

This wire measure is used to ascertain if the piston rod is in the centre of the cylinder, and the springs set up with equal pressure all around.

Screw down the follower bolts as tight as possible; screw down the cylinder cover, then pack all the glands with packing yarn, plaited either square or with three strand flat; there is prepared packing with rubber and canvas; the packing should fit the space that is to be packed; drive the packing in the space with a piece of hard wood and a hammer; if the rods or spindles are much worn and uneven, it will be well to cut a ring out of soft rubber, leaving space enough to wrap it around with hemp or cotton; cut the one side open, so that it will go over the rod or spindle; put two of these rings in first at the bottom of the space; let the one be put on the top of the other, with the joints crossed; that is, put the cut side of one ring against the whole side of the other; then pack on the top of those rings until the gland is full in the space; tighten the gland down regular, so as to keep the rod in the centre of the gland; soak the packing in oil or melted tallow before it is put in.

THE STEAM BOILERS.

The steam boilers in common use for those places that make open kettle sugar, are boilers with two flues inside and built into brick work—the fire passing under the bottom of the boier and returning through the two flues inside the boiler, and thence to the chimney. These boilers are the same as most that are in common use in any factory where there is plenty of room.

The engineer must examine the brick work of his boilers; in the dead season the brick work gets damp and crumbles away; the engineer should go into the furnace and examine the built work; see that the bridge walls are high enough up, or near enough to the bottoms of the boilers; in the event of their being too far away from the bottoms of the boilers, the flame will pass through under the boilers without having the desired effect; the fire may have burned or the damp might have crumbled the top of the bridge walls; let that be looked to, and build them up until the tops of the walls are about seven or eight inches from the bottoms of the boilers; or, in other words, there should be a space of seven or eight inches between the tops of the bridge walls and the bottoms of the boilers, to let the flame pass through with good effect.

Care should be taken that the brick work is gathered in, or built up close to the boiler (to the outside of the boiler), three or four inches under the water line. Some boilers may have the brick work so damaged as to leave a space between the brick work and the boiler, so that the flame will pass up above the water space and damage the boiler. It is always safe to have the gauge cocks or water guages sufficiently high so as to have the water five or six inches above the flues, that is, to have the flues covered with water about five or six inches deep at the lowest gauge cock, as the engineer has to sleep, and then the engine and boilers are left to the care of the inexperienced. This kind of boilers make more steam when the water is kept high. A number of these boilers in the West Indies have their gauges placed too low for that country; so that if the engineer finds that his lowest gauge is too near the top of the flues, let him put another above the highest; that will then be the steam indicator—the other three below will indicate water.

The engineer should go inside the boilers and examine every plate; sound all along the boiler with a hammer, to find out if there is any flaw or weak part in the plates; if any part sounds soft, or if he finds a thin part, have a patch put on by cutting out the bad piece and riveting on a new piece of plate; or if he cannot get at the place to work at it in that way, then let him put on a soft patch, by drilling holes all around the bad place and bolting on a piece of plate, fitted to the place and screwed on tight, with a mixture of white lead, red lead and cast iron turnings, fine sifted, and mixed into a stiff putty, and put between the boiler and the plate. The mixture will force its way into the bolt holes around the bolts and make a strong sound place of it.

The boilers should be crusted inside—all the scale taken clean off; there are hammers made for that purpose; these hammers are shaped at the face like cold chisels. The men who hammer off the scale should strike lightly, not to damage the iron. The water used for boilers in the West Indies creates a scale, and it should be cleaned off so as to get steam, and also to prevent the fire from burning the plates. These boilers are provided with braces riveted on to the shell of the boiler, and passing at an angle to the boiler head, where they are secured to eyes with pins and lock pins. These pins should be taken out and examined, and, if they are eaten away with rust, they should be replaced with new ones. These braces are intended to prevent the boiler head from blowing out, and if the pins are so corroded that they are loose, and do not fill the hole, that will prevent the stay from bearing part of the strain when the pressure of steam comes on the inside of the boiler head.

PIPES AND CONNECTIONS.

Having examined his boilers and furnaces, the engineer will next look to his pipes and connections. The feed pipes should be disconnected at the joints, and new rubber joints put in; see that the feed pipes are not obstructed by sediment from the bad water, the check valve at the boiler should be ground in with fine emery or sand; fill the chamber with water, to prove if the valve is tight, after grinding it in, and be sure that the valve or clack, as it is termed, lifts and falls easy, and care must be taken that the valve does not lift too high.

These valves or clacks are cast with a piece, or pin, on the back, to prevent them from lifting too high up —when they are lifted up by the force of the water passing from the pump into the boiler; if that pin is worn down, a screw can be put through the cover of the chamber for the valve to strike against; in the event of the clack lifting clear above the passage or opening in the pipe, it might become gagged and stay there, the hot water from the boiler would then come back on the pump and prevent it from acting.

HEATER FOR FEED WATER.

The heater must be examined to see if all the pipes are sound and the joints good; find out if the tubes need cleaning; if a coil of pipe is used as a heater, it will be well to have it taken out and attached to a steam pipe from the boiler, and blow it through.

Some boilers are provided with an arrangement for the purpose of blowing obstructions out of pipes; the pipe, or heater, or whatever it is, after being attached to the nozzle on the boiler, the screw valve is opened, and a jet of hot water and steam blows through the pipe, which cleans all the obstructions out.

Examine the safety valve; grind it in, if required, and see that it works loose and easy; have the gauge cocks and all the brass work about the boilers cleaned and polished bright, and kept bright; examine the damper in the chimney or flues—see that it works free, and regulate the length of the chain, so that it will be convenient.

THE CANE MILL.

The mill for crushing the cane, to express the juice, has the hardest strain to bear, and is most liable to break down, and it must be carefully attended to.

The mill is furnished with three rollers; common size of rollers, two feet six inches in diameter, and six feet long; there are two rollers below and one on the top, between the two. The rollers are set in a strong frame of iron, and the whole mass rests upon two large square timbers; these timbers are set upon a solid foundation. The mill goes slow, making about one turn for fifteen turns of the engine.

On the engine shaft there is a pinion about eighteen inches in diameter, which drives a spur wheel about eighteen feet in diameter. This spur wheel is connected on the shaft that turns the top roller of the mill, and on the end of each roller there is a crown wheel; each of these wheels gear into the other, so that the whole three rollers move around at a little over two turns per minute. The two low rollers lay level in their journals. The top roller is held down by four large screws, that pass down through the frames and through the square timbers or spring beams below; there is a key through each bolt, and a plate of iron under the spring beams for the keys to bear against; these bolts are screwed down very hard with a long wrench.

The rollers must be level, and when the vertical screws are screwed down there should be about one-tenth of an inch of space left open between the bottom of the top roller and the top of the last roller, or bagasse roller, as it is termed. It is best to have an iron gauge to put between the rollers, and screw down until the rollers touch the gauge. At the front of the mill, where the cane enters, there should be a space of half an inch or more between the rollers. There are two horizontal screws at the front of the mill that act directly on the bearings of the first low roller; these must be screwed up and secured, to prevent them from working loose when the mill is in motion. These screws keep the roller up to the pressure, and regulate the roller, to keep it in a parallel line with the other rollers. There are two screws on the other side of the mill that answer the same purpose for the other roller. These rollers must be kept parallel to each other. In the event of their being out of line, the teeth of the crown wheels will not bear on each other fair, but they will touch at each end only; that will break the teeth out.

The mill has to be attended to every day—the screws tightened up, as may be required; there being a heavy strain on the mill, it is continually getting out of order, and must be regulated to crush the cane hard enough and make the bagasse fine and dry. There is a knife or scraper that is placed below the top roller, and is fastened through both sides of the frame of the mill. This knife is put there to keep the cane from passing down and to guide it through the mill. It is made of cast iron, although some are made of boiler plate, bolted on a square timber. The sharp side of this scraper must be kept close up to and scraping the face of the first roller; and, as the roller sometimes springs back, with the unequal pressure of the cane, as it passes through, the scraper must be wedged in its place, so that it will spring back, and follow the roller, and always be close up. If the scraper stands still, when the roller springs back, there will be a space left, and the leaves and trash will get in and choke the mill, and may cause a breakdown. Wedge the knife into its place, so that the bolts that hold it down will strain and spring it down to the face of the roller when the roller springs back; but it must not be strained too hard, or it will wear away the knife.

It is of great importance to have this knife set right.

CANE CARRIER.

The conductor or cane carrier is an arrangement to convey the cane from the yard up into the mill It is constructed of two endless chains—one at each side, and boards or slats fastened on the chains. The sides of the conductor are made of planks built on uprights, and the sides are stationary. The chains pass over and around a drum in the yard, and they also pass around a drum at the mouth of the mill, where the cane falls in as the conductor revolves around. There is a coupling, or clutch, at the mouth of the mill, with a lever to ship and unship it, as the mill requires to be fed. When there is too much cane in the mill the clutch is unshipped, and the conductor is stopped for a few moments, until the mill is relieved of some of the cane; the clutch is then shipped again, and the conductor travels on.

The conductor must be kept in oil, and the drum in the yard must be watched to see that no cane gets inside of it to jam the slats, and keep the conductor from working.

The sides between which the conductor slides along are about one foot high; that space is nearly filled with cane, and is a good gauge to regulate the quantity of cane to be passed along to the mill. There is also a conductor at the other side of the mill, that conveys the bagasse up to a point high enough up for a cart to get under, to receive it as it comes out; this is bagasse carrier.

RAISING STEAM.

In raising steam, to prove the engine and machinery, the safety valve being gauged up to let out the air, put in a slow fire at first, in order to dry all the brick work about the furnace. When every part gets warm, and when the steam begins to blow off, put down the safety valve, and put the weight out to the proper notch on the lever; then go around and tighten up all the joints, the man head, the pipe connections also; let a little steam into the cylinder; tighten up all the joints around the engine, when they are warm; the bolts will screw up some, after the heat gets around them, although they have been hard screwed up when cold—but care must be taken not to strain hard upon any nuts, or tighten them up when there is a pressure of steam on the joints; accidents have happened in that way, by bolts breaking.

STARTING THE ENGINE.

Before starting, the journals must be all keyed up. Strike the keys in with a copper hammer, or an iron hammer with a piece of sheet copper held on the head of the key; then give them a slight tap on the point back, to ease the journal, by driving the keys tight in; the shâke is all taken up; then the tap back will ease the journal and keep it from heating. Tighten up all the set screws, so that the keys will not work out; see that every journal is properly oiled, but only put a few drops on each; put the covers down on all the oil cups, and those that have no covers, put wooden plugs in the oil holes, to keep out dust from the journals. Open the regulator valve, to let steam into the steam chest; the eccentric hook being out of gear, take the starting bar and lift up the valve. The engine will move; but, before the crank gets on the centre, reverse the valve by the starting bar, and the engine will move back. After having done this a few times, until the cylinder and pipes are warm—the cylinder cocks being open to let the water from the condensed steam pass out, then let the crank pass the centre before reversing the valve; then reverse and hook the eccentric rod in gear, and unship the starting bar, and the engine will go along. After the engine has gone a few strokes, and all the water is out of the cylinder, shut the cylinder cocks, and oil the inside of the cylinder. There is an oil cup on the steam chest, and some engines have them on the cylinder also.

The oil cups are constructed with three cocks, mostly; in giving oil, shut the low cock, open the centre one, to let the steam out that has collected in the chamber; pour the oil into the cup; open the top cock, to let it down into the chamber; shut the top cock, and the small one in the chamber; then open the lower one, and leave it open, and the oil will find its way into the valve, and through the piston in the cylinder. It will be well to open all three cocks, at times, to blow the passages clear, as they sometimes get choked up. It is best to oil the cylinder often, and only put in a little at a time—once every hour will be plenty. There is danger of the cylinder being cut by the piston, if the oil is neglected.

When the engine is running, the safety valve should be lifted up at times, to see that it works loose. If any of the journals get hot, put a little powdered sulphur around the heated part; but if it still gets warmer, then the engine must be stopped, and slack the keys or bolts in the journal, and cool it down with water, and begin, fresh oiled and cool. The engine must not be stopped with cane in the mill. Before stopping the engine, unship the clutch, and stop the cane carrier, and let all the cane that is in the mill pass through—then stop the engine. If the engine is stopped when the mill is full of cane, there will be danger of breaking something in starting again.

If the mill gets choked with cane, and the engine stops, then stop the carrier and take the bagasse away from the last roller, and back the engine slowly, by the starting bar. Only a little steam must be given when backing, and if the mill is so hard choked that the engine will not back, the mill must be slacked up a little. This will not happen, unless the steam is low; or if the conductor has been neglected, and too much cane allowed to pass through into the mill, or if the knife or scraper is out of order.

The furnaces for the steam boilers are fired up with wood, and on some plantations, where wood is scarce, coal is used. When the clarifiers, or tanks for holding the cane juice, are all full, the engine is stopped until more cane juice is wanted in the boiling house. The fire must be regulated, so that the steam will not blow off when the engine is standing still. When the tanks are nearly full, feed up the boilers—let the fire burn out, then shut the damper some. The steam will hold in the boilers, at a lower pressure, and it will be easily raised, when the engine is required to be started again.

When the engineer thinks proper to stop the engine, to examine the piston—to set up the packing, if required, after it has run some time, the best way to take up the cylinder cover is to lift it by the steam.

Unscrew the cylinder-cover bolts about one-tenth of an inch; then let a little steam slowly under the cylinder cover. The pressure of steam will lift the cover, and the bolts will prevent the cover from flying off—the nuts being loose only one-tenth of an inch; this will break the cover away from the joint at the cylinder top. Then shut the steam off, and unscrew all the nuts, and take the bolts out. Screw two eye-bolts into the cylinder cover, and make a rope fast around the cross-head, and through the eyes in the eye-bolts; the piston then being at the bottom of the cylinder, let a little steam under the piston, and it will rise up slowly, and as the cross-head ascends, it will take up the cylinder cover with it. Then when the piston is clear up to the top of the cylinder, it will be in the right position to slack the bolts in the piston.

The engine is stopped every two weeks, to clean boilers, and to haul a stock of cane, to give a good start; and at these times the piston should be examined, and also the straps, and brasses, and bearings; and covers should be taken off and cleaned, and the oil-holes cleared. The engine should be wiped down once a day at least, and freshly oiled every time before it is started, and kept cool and oiled while running.

CRUSHING CANE.

Cane grinding is a pleasant part of the engineer's duty, when everything goes right, and very disagreeable when he is troubled with breaking down. If every part is well cared for, a break down will seldom happen.

Keep the engine running steady—not too fast nor too slow. The way to do that best, is by keeping the steam always nearly at the same rate of pressure. If the steam is likely to rise too high, take that chance to feed up the boilers; do not let any steam blow off, if possible, to prevent it from rising. When the steam begins to fall, stop the feed water—keep the fires regular—keep always the same quantity of cane on the carrier; the sides of the conductor will always be a good guide.

See that the cane is laid on the carrier equal and regular, and not in bunches. The engine then will run steady.

When grinding cane that is hard—such as red or crystalline cane—there will have to be a lighter feed on the carrier. It will be easily seen, if the feed is right, by taking notice if the engine is not burdened or running too light or irregular, and also if the bagasse is coming out fine enough, and the cane is getting properly crushed.

The crown wheels must be watched when the mill works. Paint the teeth with tar and tallow, mixed; paint them with a brush as they revolve, or have a box below the wheels, so that they dip among the tar as they turn—the box being half filled with this tar and tallow mixture.

The mill must be washed down, with water from a hose, or buckets, once a day; and clean the canal that conveys the juice from the mill. If the mill is not kept clean, the juice, while running down, gets soured, and spoils the sugar.

The rollers, by constant wear, get smooth and slip around without taking the cane in. This is liable to loosen the keys. When the rollers slip in that way, the engine must be slowed down for a minute, until the cane takes again. The conductor must be stopped at the same time.

BREAKING DOWN.

The parts most likely to break down are the crown wheels, the spur wheel, and the shaft in the top roller.

There should always be on hand one spare shaft for the top roller, one set of crown wheels, some segments for the spur wheels, one pinion for the crank shaft, and it would be well to have a spare roller complete, with the shaft keyed in it splace. If a shaft should break, at the time when there is a great stock of cane in the yard, the cane would be spoiled by the heat of the sun before a new shaft could be ordered and made.

The cane mill rollers become less in diameter, by the friction of the cane passing through them. The crown wheels are then too large in diameter, and have to get the points of the teeth cut, or turned off, to allow the rollers to be screwed close together; therefore, the engineer must look to the set of spare crown wheels, and have the teeth cut to the right depth, so that there will be no delay in the case of a break-down. If the top roller shaft should break, the engineer must put up a derrick, or some means of lifting out the roller. Blocks and tackle are kept on most of the sugar plantations. When the roller is got out of its place, take it out in the yard; block it up at each end of the shaft—about one foot clear of the ground; put clay all around the keys and the shaft; pile a fire of wood around the roller: take care that the fire is kept regular, and also watch the opportunity when the weather is favorable; place the roller in the right position for the wind to blow the fire regular all around it; one part of the roller must not be heated higher than the other; see that the roller is protected from rain, when it is warm; when the heat has expanded the outside of the roller so that the keys are loose, then take a long stick of wood and strike the end of the shaft, and the shaft [illegible] keys and all will slack and drive out. When the shaft is out and the roller cool enough, clean up all the key beds and the keys, and hang the roller [illegible] the new shaft. Some rollers work loose on the shaft while the mill is running, and they move [illegible] along the shaft, taking keys and all [illegible]. This is dangerous, as the flanges on the other rollers generally get broken off, as the roller travels on [illegible] and bears hard on to them. If the engineer has not time to spare to take out the roller, and take out the shaft that is in the roller, and fit the keys over anew, he can prevent the roller from going any further in the following manner: fit a key in a square on the shaft at each end of the roller; make the key with a gib head; fit the gib head close up against the [illegible] of the roller, cut a recess in the shaft at an angle from the roller, warm the head of the key and [illegible] in its place, and set the head part down [illegible] the recess that has been cut in the shaft; then [illegible] the head of the key being firm in the recess and bearing against the square end of the recess it is prevented from moving, and the roller bearing against the gib head the roller is prevented from moving [illegible] further.

If a chain of the [illegible] should break, stop the [illegible], and haul the two broken ends of the chain together, and put in a connecting link. The engineer should have some spare links made for that purpose, so that he can open the end of the link, and connect it again to the chain, by closing the ends with a hammer. A small block and tackle is a good thing to haul the two ends of the chains together with; or, if the engineer has not a tackle, he can use a rope, and twist it with a short lever, and keep the rope far enough away from the ends of the chain, in order to give room to connect the link.

When the rollers are worn smooth, they should be turned off. This is generally done before commencing the crop. A temporary rest may be bolted across the frame of the mill, and fastened with cramps and bolts at each end. A stick of hard wood will answer for a rest. Holes must be bored in this rest, to hold the turning tool; the tool may be made one and a half inches wide at the cutting edge, and the edge made like a chaser, or comb, for cutting screws; that is, the tool will have teeth like a saw, at the cutting edge. In this way ridges may be cut in the roller, by running the engine slow, and the tool will cut as the roller turns around. The tool can be fed up by a temporary screw. After the ridges are cut deep enough—about one-eighth of an inch deep, and three-sixteenths apart—but not sharp at the top, then put the tool farther along into the next hole in the rest, and turn away, until the whole length of the roller is marked with ridges. If the first roller is ridged in this way, the cane will go through without slipping, and there will be no necessity of making ridges in the top roller, or bagasse roller.

This way of fixing up a temporary rest can be done to turn off the rollers when they get uneven, and also to turn off the teeth of the crown wheels, and to turn down the ends of the rollers, to take off wrought iron flanges, when they get broken. When this happens, which is caused by the roller moving on endways on the shaft, then the engineer must turn the ends down with a little taper inside; that is, the recess will be smaller in diameter—about one-sixteenth of an inch inside—than what it is at the outside of the roller; a wrought iron flange must be made, with taper, to fit the recess; but make it one-tenth of an inch smaller than the turned part on the roller; then warm the flange, and let it shrink on its place, on the end of the roller; when cold, it will hug the recess tight, and the taper that is on it will prevent it from coming off. The flange must not be cooled with water, but left to cool by the air.

PROCESS OF SUGAR MAKING.

As the cane juice falls from under the rollers, into a pan under the mill, it runs down through a canal, and passes through a strainer of fine wire cloth, to clean it; it is then received into a large tank.

THE SACCHAROMETER.

This is an instrument for testing the density of the cane juice. The saccharometer is a glass tube, about ten inches long and half an inch in diameter. It is closed at both ends. The bottom end is formed in the shape of a globe, about one inch in diameter, and is filled with shot to make it heavy, so that it will sink and leave the small end on the top. There is a slip of paper on the tube, with figures to indicate the different degrees. If the instrument is inserted in pure water, it will sink until the top of the tube is level with the water. When it is inserted in cane juice, it only sinks as far as the density of the juice will allow it. Some canes produce juices that indicate ten, eleven, and twelve degrees. By this the sugar maker can ascertain what quantity of saccharine matter the juice contains.

THE CLARIFIERS.

There is a row of six or eight oblong shaped tanks, that hold about seven hundred gallons each. The juice is let into these tanks, or clarifiers, out from the tank, with the strainer in it; the clarifiers are placed on the top of the flues that lead from the furnaces of the trains, and in some places they are provided with steam pipes to heat them. When a clarifier is about to be charged with juice, there is a quantity of hot lime put into it; the gate is then opened to let the juice run in; the clarifier is filled up to within a few inches of the top; the juice is kept there until it comes to the boiling point, and no more. The impurities accumulate on the top; in some places the sugar maker skims the top off, and in other places the top is not broken, but the juice is let run off from below, and when it is all out, the clarifier is washed out at the bottom; but this is done only when the clarifiers are heated with steam pipes, as the steam can be shut off when washing out; but when they have fire under the bottom, the top is skimmed of; the lime is used to clean the juice of impurities; the juice is then ready to be boiled.

THE TRAINS.

There are from one to six or more trains in a sugar boiling house, according to the amount of business done. Each train consists of four round bottom open top kettles, placed in a line, and built into brick work. The kettle that receives the juice first, as it runs from the clarifiers, is the largest; the others diminish in size to the end of the train. The last kettle is the one in which the sugar is made; it is the smallest kettle. The juice, as it boils, is laved up from one kettle to the other, until it is boiled up and finished in the last kettle. When the sugar is ready for drawing, it is scooped up out of the kettle and put into coolers; it is left there until it grains or granulates, as it is termed; that is, when it gets hard and takes the form of particles. The sugar is then taken from the coolers and put into hogsheads; the hogsheads are perforated in the bottoms with small holes, and placed in the purging house—that is a large room with beams across the floor, on which the hogsheads are set—the molasses drips out of the holes in the bottoms of the hogsheads into the cellar below. The cellar has a cement floor; by this means the molasses is kept clean. The molasses is pumped up out of the cellar into casks, ready for the market, and the sugar in the hogsheads gets dry as it gets purged of the molassess, and it also gets ready for sale.

BAGASSE.

The fuel used for the furnaces under these trains of kettles, is the bagasse. This bagasse is that part of the cane that is left after it has been crushed and gone through the mill, and the juice has been all pressed out of it. It is spread in the sun, in a wide space of ground; the sun bakes it, and it then is like fine chips from a carpenter's shop; it burns furiously, and makes a very hot fire. The furnace mouth of the train is under the smallest kettle; that brings the greatest heat under the kettle that the sugar is finished in. The flame passes along under all the kettles of the train, and passes out through flues, under the clarifiers, to give heat to them, and from there into the chimney. The furnaces are built so that the flame will fly all around the bottoms of these kettles in the trains, and the flues are provided with dampers to regulate the heat under the clarifiers.

BAGASSE BURNER.

In Louisiana the bagasse cannot be dried in the sun, as it is in the West Indies, because the heat of the sun is not strong enough.

The bagasse carrier conducts the bagasse direct from the mill up into a furnace, built high up. At the top of the furnace there is a square chamber, into which the bagasse drops; there are two doors in this chamber, one above the other. These doors are made of iron, and have iron bars, one through the length of each door; the doors are hung on these bars. There is a weight and lever fastened on the end of each bar, outside of the chamber; this is for the purpose of keeping them shut. The bagasse carrier is provided with a drum at the top of the chamber, around which the carrier revolves. As the carrier travels around, it empties the bagasse into this chamber. The weight of bagasse counteracts the weight and lever, and the door opens and empties the contents of the chamber down on the other door. As soon as the bagasse is emptied, and the door is relieved of the weight of the bagasse, the door shuts; the other door receives its weight, and gets clear of it as quick as the top door, and by this means the flame from the furnace is prevented from flying out. The bagasse falls down on the top of an arch in the furnace—a skeleton arch, built of fire brick. The bagasse gets dried as fast as the next lot falls down. When the doors open again, the wet bagasse that falls down displaces the dried bagasse, and it falls into the furnace below from off the top of this skeleton arch, and the flames pass under the steam boilers. The furnace is provided with air flues from the top to carry all the damp up the chimney. This furnace requires a great current of air, else the bagasse cannot be burned.

If the bagasse gets collected on the top of the arch, it must be displaced by the use of a long pole, and a few sticks of wood must be put in the furnace below, at the doors, to burn out the bagasse that has collected on the arch.

Steam is raised by firing up with wood, in by the low furnace doors, before the mill has started; and when the mill is going, the bagasse is fuel enough. The furnace must be heated up good before the bagasse will burn well. In starting with a damp furnace, at the commencement of the crop, a light feed of cane must be kept on the carrier, and some wood must be used, and the skeleton arch must be watched so that the bagasse does not collect on the top of it.

REFINED SUGAR PROCESS.

Making refined sugar from the cane juice requires a great deal more machinery than the Muscovado or open train sugar. The juice and syrup are boiled in evaporating and vacuum pans, and before proceeding further it will be necessary to explain what is meant by a vacuum.

A VACUUM.

A vacuum means an empty space. The atmosphere that surrounds the earth exerts a pressure of nearly fifteen pounds on every square inch of surface of every thing that it comes in contact with. Therefore, in order to form a vacuum, in any vessel, it is necessary, first, to force out the air, by steam, or draw it out by pumps.

If a jet of steam, of greater force than the atmospheric air, is let into a vessel—the vessel being furnished with a valve to let the air escape, the air having been all blown out by the greater force of the steam—the steam has taken the place of the air. Let a jet of cold water on the steam in the vessel; that will condense the steam that is inside of the vessel; there will then be neither air nor steam inside, but there will be what is termed a vacuum formed inside the vessel.

THE VACUUM PAN.

The vacuum pan is a large globe-formed boiler, and flat on the bottom; there are several rows of brass tubes, and also a coil of copper pipe, all inside and at the bottom of the pan; these pipes are filled with steam when the pan is boiling. There is a large pipe, the mouth of which is set high up to the top, inside of the pan; this is the suction pipe, and is set high up, in order to prevent the sugar from getting into it. This suction pipe is connected with a condenser and two large brass-lined pumps, worked by the engine. The condenser is a vessel that has a jet of cold water rushing through it; the pumps draw the water from the condenser, and as the heat of the steam pipes inside of the pan boils the syrup, the vapor from the pan rushes into this condenser, the water condenses the vapor, and the pumps draw the contents out of the condenser and discharge them in the street.

This method of boiling is superior to boiling in open pans, because the syrup is relieved of the pressure of the atmosphere, and for that reason it boils with a less degree of heat, and the pumps draw off all the noxious vapor from the syrup; the sugar also granulates in the vacuum pan, whereas the open train sugar does not granulate until it is in the coolers for some time. The vacuum process is much quicker done. White sugar may be ready for the market, made in eighteen hours from the time the cane is put through the mill.

By the use of evaporating apparatus, vacuum pan, and centrifugal machines for drying, the kettle sugar would require three weeks for the same process, as the hogsheads require to stand a long time, to purge the molasses out of the sugar that is in them.

EVAPORATING VACUUM PANS.

There are various kinds of these pans, but the following description will answer for those in common use. The cane mill engine is the same kind used in the open train process, with the exception of a weighted valve on the exhaust pipe. This valve has a weight of about ten or twelve pounds on the square inch. The steam, as it escapes from the cylinder, is prevented from blowing out of the exhaust pipe, and is forced under the pans, to heat the pipes, for boiling purposes. The cane juice runs from the mill, through fine wire cloth, into the clarifiers.

STEAM CLARIFIERS.

These clarifiers are eight in number, and about the capacity of four hundred gallons each. There is a double row of steam pipes placed in the bottom of each clarifier; the pipes are hung by a joint, at one side of the rows, so that the joint can be slackened up at any time, and the pipes swung up, in a vertical position, for the purpose of having them cleaned; they require cleaning often, as the lime that is used for clarifying gets cemented on them. There is a screw valve to each clarifier, so that the steam can be let on or shut off, as it may be required. When a clarifier is about to be charged with juice, it is let run in until it covers the pipes in the bottom; the steam is then turned on, and the lime is put in; the quantity of lime used must be regulated by the kind of juice that is coming from the mill, and is best known by experience. Some cane juice requires about twenty cubic inches of lime to three hundred gallons of juice. The engineer must have the pipes in the bottom of the clarifiers kept clean. The water from the condensed steam, that comes from the heating pipes in the clarifiers, runs into a cistern, which receives all the water from condensed steam from the pipes in the heating apparatus, and of all the pans as well. This cistern is connected with the force pumps, and the water is all forced back into the steam boilers, to feed them up.

This condense box is furnished with a small self-acting valve, to let out the steam that collects in it. If the steam is not let off, the pumps will not get the water to force it into the boilers.

THE DEFECATORS.

When the clarifier is full of juice, and after it has stood long enough to come to the boiling point, it is let run into the defecators. These are tanks similar to the clarifiers, but larger, about double the capacity of the clarifiers, and fewer in number. The defecators have steam pipes in the bottoms for heating, the same as the clarifiers. The pipes must be scraped, and kept clean. The impurities on the top of the juice, in the defecators, are skimmed off, and the juice, when it is defecated properly, is run down through the filters.

THE FILTERS.

These filters are cylindrical tanks, about five feet in diameter, and eight feet deep. They are eight in number. Each filter is provided with a cross, which fits into it, near the bottom. There is a woolen cloth covered over this cross. There is another woolen cloth covered over the top of the filter. The space that intervenes, between the two woolen cloths, is filled up with bone black. The juice, hot from the defecators, runs on this woolen cloth, and finds its way through the body of bone black, and through the other woolen cloth, and runs out by a cock at the bottom of the filter. The juice runs out at the bottom of the filter in a pure clear form, and is collected below, ready to be taken into the apparatus, for evaporating and boiling into syrup.

BONE BLACK.

This bone black, that is used in the filters, for purifying the cane juice, is made of the bones of animals. The bones are burned black, and ground up into small pieces, about as fine as rice. The dust, is all sifted or blown out of the bone black, and only the particles are used. After the bone black has been in the filters for some time, it has to be taken out and washed; and, after a little longer use, it has to be taken out and re-burned, and cleaned again. While five filters are in use, the other three are in process of renovation. The juice is now ready to be made into syrup. It is pumped up into the apparatus.

THE APPARATUS.

This arrangement consists of two oblong-shaped pans, which are worked in the manner of vacuum pans, having pipes inside, for steam to circulate through, for heating purposes. One of these pans is provided with a suction pipe and condenser, that are attached to the vacuum pumps, the same as a vacuum pan. The two pans that constitute the apparatus are joined together by a pipe from below. This pipe conveys the juice from the first to the second pan, as it gets boiled. The first pan (or the pan that receives the juice from the tank below, after it has left the filters) is not connected to the vacuum pumps, but is furnished with a small pump, detached from the others, and not in connection with the condensers. This pump is continually drawing off the vapor from the first pan, as it boils. This vapor is carried through pipes, under the second pan. This is for the purpose of giving the heat of the vapor to the second pan, to assist the boiling process. By the time the vapor has reached the suction pump, it has been condensed into water, by coming in contact with so many cold surfaces. The vapor reaches the pump in the form of very noxious smelling water. The pump discharges this water into a ditch outside.

These pans are provided with bull's eyes; these bull's eyes are thick pieces of glass set into a recess—one in each end of the pan. They give light inside of the pans, so that the man who tends the pans can look in and see if the boiling is going on right. When he wants more juice in the first pan, to cover the tubes, or if he wishes the juice to pass from the first to the second pan, he has screw valves that he regulates that with.

There is an arrangement for drawing off the syrup, as it gets boiled enough; it is pumped out of the second pan and discharged into a cistern. The syrup is tested by inserting the saccharometer. When it indicates twenty-seven degrees, it is ready to be boiled into sugar, in the vacuum pan. These pans are all furnished with valves, to admit steam direct from the boilers, when the exhaust steam from the engine is not strong enough. There are pipes connected to these pans, to convey the water made from the condensed steam into the tank that feeds the boilers. It is the duty of the engineer to attend to these pipes and valves, and stop all leaks, and keep the joints in order.

SUGAR BOILING IN VACUUM PAN.

The next process is the boiling of the syrup in the vacuum pan, until it granulates and turns to sugar. When there is plenty syrup collected in the tank below, to make a strike of sugar, as it is termed, the suction pipe valve is opened to the pumps, and the pumps exhaust the air out of the pan. The valve is opened to the syrup tank, and the syrup rushes into the pan; the steam is let on the pipes, and the boiling begins. There are bull's eyes to look through inside; the pan is also furnished with a small nozzle into which a rod is inserted. When the sugar master wishes to test the sugar, to ascertain if it is ready to be drawn, the proof rod is put in through this nozzle into the pan, and turned around and drawn out with a little of the sugar sticking to the point of it; the nozzle is arranged so that the air cannot get into the pan to spoil the vacuum, when the proof stick is being used.

Some vacuum pans boil up twelve hogsheads of sugar in four to five hours. When the sugar is ready to be drawn, the valve is opened, to let air into the pan, to spoil the vacuum. The steam is shut off the pan, and, if not regulated, will get strong in the boilers, and blow off out of the safety valve. When the pan is done boiling, and the steam shut off suddenly, the steam can be used to boil molasses, as there is an arrangement, termed a blow-up, for boiling molasses, that is not used regularly, but at times only. The surplus steam can be used at that time, or the furnace doors may be kept open, to damp the fires. There is a large wagon brought directly under the pan, and a gate is opened to let the sugar run out of the pan into the wagon. There is a small screw valve for letting steam into the pan, after the sugar has all run out. This steam cleans off all the sugar from the pipes and from the sides of the pan.

The wagon, with the strike of sugar, is moved into the purging house, and the sugar is dried by the use of the

CENTRIFUGAL MACHINES.

There are ten or twelve of these machines. The centrifugal machine is an open mouth cylinder, with an upright shaft in the centre, by which the machine is turned with great velocity. The outside of this cylinder is covered with fine brass wire cloth. Outside of the cylinder there is a casing of iron, and there is a space left between the cylinder and the outside casing. The sugar is put into this cylinder, about seventy or eighty pounds at a time; the machine is put in motion, and the force with which the machine flies around causes the sugar to mount up and adhere to the sides of the cylinder. By the centrifugal force created, the molasses that is in the sugar flies out through the wire cloth into the space between the outside casing and the cylinder, and runs into a tank. The sugar gets dried by getting clear of the molasses, and also by the current of air rushing on it, caused by the velocity. If the sugar is wanted very white, there is a watering can used to sprinkle water or syrup on the sugar, as it flies around in the machine. This watering can is similar to those used for watering flowers. It has a nozzle perforated with small holes. As the water is sprinkled on the sugar, it flies out into the space amongst the molasses, and carries the molasses through the sugar with it. If too much water is used, the quantity of sugar will be reduced, and more molasses will be made. It depends upon the quality of the sugar required, whether much water should be used. If the sugar is wanted pure white, then plenty of water must be used; and although it makes more molasses, still the loss is not great. The molasses may be boiled up and made into good brown sugar, which is often done on these plantations.

This process of drying is very quick, and is convenient for the planters, who sell their sugar by sample, as it can be manufactured to a sample at eighteen hours' notice—that is, from the time the cane enters the mill until the sugar is taken out of these centrifugal machines.

From five to eight minutes is plenty of time for the sugar to purge and dry in the centrifugal machine. The time required depends upon the speed of the machine—the quicker the machine runs, the sooner the sugar will be purged and dried.

The engineer must keep a close watch on these centrifugal machines. There is a steel step at the bottom of the shaft; that step supports the shaft, and is liable to get hot, on account of the great speed with which it turns. The oil tube is liable to get stopped up with sugar. These machines must be examined often. They are easily taken apart. They are driven by friction cones, made of pieces of leather bolted together. The engineer should have some of these pieces of leather cut and ready, and some spare pieces of hardened steel, for the bottoms of the steps, and also some pieces of wire cloth for the cylinders.

SUGAR MOULDS.

There is a process of purging and drying sugar, by keeping it in moulds for some time. These moulds are made of sheet iron; they are wide at the mouth and taper to a point; they are filled with sugar, when it is soft, from the coolers; the small ends of the moulds are placed down, and into steady seats, to keep them from falling; there is a small hole in the lower end of the mould, through which the molasses drips into a tank. There is some syrup poured on the top of each mould, to purge the sugar. After the sugar has been kept in the moulds for over two weeks, the loaf is taken from the mould, and cut in two pieces—the top part of the loaf is white, the lower part is brown. These pieces of the loaf are ground up into two kinds of sugar, the white and the brown. The sugar is spread out and dried in the sun, and packed in boxes. Some places have ovens for drying the loaves.

THE VACUUM ENGINE.

On plantations where refined sugar is made, there is a separate engine for the pumps alone. The engine is a beam engine, and has the air pumps placed one under each end of the beam, but not under the extreme end. The cylinder is placed at one end, as in other engines, and a crank and fly wheel at the other end. The air pumps are placed, one between the cylinder and main centre, the other between the crank and main centre, so as to balance. The pumps are about twenty inches diameter, and eighteen inches stroke. They are lined inside with brass; the pump buckets and valves are made of brass, and the pump rods are iron, covered with brass. It is necessary to have these things made of brass, as the acid from the sugar would eat the iron away. The pump bucket fits the chamber of the pump. The bucket is furnished with two valves, that work on a rod, like a hinge. The valves open with the down stroke of the pump, and shut as the bucket ascends; the water is drawn out of the condenser in that way. There is a hinge valve, between the condenser and the air pump, that opens with the up stroke of the pump, and shuts with the down stroke. This is the foot valve, and it prevents the water from returning back to the condenser at every stroke the bucket makes down. There is another valve, just like the foot valve. It is placed above the air pump bucket, and opens to admit the water that the bucket brings up, and shuts when the bucket begins to descend, and prevents the water from going back with the down stroke of the bucket. This is the delivery valve; it is placed at the entrance of the hot well. This hot well is a cistern that receives the water at every up stroke of the pump. There is a discharge pipe on the hot well, where the water escapes into the street or into a ditch. These pump buckets are packed with gaskets, made of plaited spun yarn, or packing yarn as it is termed. The gasket is plaited square or flat, and is made the size of the space between the body of the pump bucket and the chamber of the pump. The gasket is soaked in melted tallow, and coiled into the space, and driven in with a piece of hard wood and a hammer. It is best to cut the gasket, and put in a turn above a turn, always crossing the joints; where the ends of the first turn meet, put the ends of the next turn farther around. When the space is full, the follower or junk ring is screwed down. This ring is bolted down with six or eight bolts. In order to have a good vacuum, these pumps must be kept well packed. After the pumps have been working a day or two, the pump covers should be lifted up and the follower unscrewed, and another turn of packing put in, if the space will admit of it; then screw down the ring again tight, but do not strain down the packing too much, as it might cut the pump chamber or burden the engine. The foot valve and delivery valve must be looked at before the commencement of the crop.

The injection water should be got to come to the condensers as clean as possible, and as cold as it can be got. The injection water is that stream or jet that flows through the condenser, to condense the vapor that rushes into it, from the boiling syrup in the vacuum pan. There is a strainer at the mouth of the pipe, in the pond, where the injection water enters. This strainer must be kept clear of trash, and a good supply of cold water always there. If the water is mixed with sand and trash, the pumps will get cut and the packing will wear out quick.

There are other pumps that are worked by the vacuum engine. There is the juice pump, that pumps the cane juice into the first pan of the apparatus; the hot water pumps, that pump all the hot water made from the condensed steam from the cistern into the steam boilers; the pump that draws that noxious vapor from the first pan of the apparatus; a pump for drawing the syrup from the second pan, after it is sufficiently boiled All these pumps, and their connections, must be traced by the engineer, so that he may become familiar with them, and be able to get at them, without delay, in the event of anything getting out of order.

TRACING CONNECTIONS.

The steam pipes may be traced from the boilers down to the cylinder of the engine. The throttle valve lets the steam into the steam chest; the slide valve admits the steam to the cylinder, and the steam escapes through the recess inside of the valve, thence to the exhaust pipe. If the sugar is refined, or if the juice is clarified by steam, there is a valve with weights to prevent the steam from escaping, and it is forced under the clarifiers. There is a pipe that runs along the front of the clarifiers, and there are screw valves to let on or shut off the steam from each clarifier, as it is wanted. There is a branch of the exhaust pipe that leads the steam to the evaporating and vacuum pans. There is a steam pipe that leads from the boiler direct to the vacuum engine, and a branch to the evaporating vacuum pans; there are small pipes to convey the water from these clarifiers and pans, and these pipes lead into the condense box, where the feed water is taken to the force pumps; the suction pipes from the vacuum pans lead through condensers and into the air pumps. The water is discharged through the pumps and delivery valves into the ditch; the syrup is drawn from the pan through a pipe and discharged into a cistern; the juice is drawn from a tank and forced through a pipe in to the first pan. The water pipes lead from the condense box to the force pumps, and pipes lead into the bottoms of the boilers, where check valves are placed to prevent the water from coming back on the pumps; the cold water pumps are furnished with pipes from a well or reservoir, and the discharge pipes lead into tanks. The steam pipes may be traced from the boilers to the centrifugal machines. The pipes that convey the cane juice from the mill to the clarifiers and defecators and filters into the tanks, are easily traced.

PART II.

STEAMSHIPS.

INTRODUCTORY REMARKS.

An engineer at sea has some duties to perform that are not required of engineers on land, and some peculiarities about his engines and boilers, and the working of them, that do not occur to engineers for machinery on land.

The engines of a steamship are influenced in their motions by the weather. The boilers are fed with salt water, in some ships, and in others the boilers are fed by the water from the condensed steam; but these steamship boilers require some salt water to keep up the waste.

Steamship engines are low pressure, or condensing engines. All these things must be considered by the engineer.

There are a great many different kinds of engines in steamships; but the principle is the same. The power is got by the pressure of the steam on the piston of the cylinder, and the forming of the vacuum on the opposite side of the piston. It matters not whether the engines are horizontal or upright engines, beam engines or oscillating engines, or engines with long stroke, or engines with short stroke. There is no power got but by the force of the steam, and the vacuum. If an engine has a short stroke, it will make a greater number of them, and use the steam; and in using the steam, the force has been used. An engine with a long stroke makes a less number of strokes, and does not use any more steam than the short stroke engine, and, therefore, does not exert any more force. If the pistons are the same size, and travel with the same speed, there may be a little loss by turning the centres often in a short stroke engine, but it does not amount to much.

The plan of an engine, and the length of the stroke, are regulated to suit convenience, and sometimes to suit the fancy.

The engines of a propeller ship require to turn quicker than those of a side-wheel ship, as the propeller must turn quick to be of service. The engines of a side-wheel ship do not require to turn quick, as the wheels are large in diameter; but still, it takes a great force to turn the wheels. The propeller ship, with engines of shorter stroke, may have made three strokes while the side-wheel ship made one, and both ships sailing at the same speed, and both using the same amount of steam and fuel.

PROPELLER SHIP.

Some propeller ships are furnished with one engine and a surface condenser. It is best to have two engines in a ship, as the one helps the other over the centre; but a great number of ships have a single engine, and the engineer has no choice but to go to work at his engines and boilers as he finds them.

The propeller engine is commonly constructed with an inverted cylinder; that is, with the cylinder bottom end up.

Some of them are furnished with two piston rods attached to the cross head and the connecting rod in the centre, between and leading down to the crank.

Some engines are furnished with gear wheels, which intervene between the crank and propeller shaft, for the purpose of giving greater speed to the propeller, and allowing the engines to run slower. The propeller shaft is laid through a tunnel, and supported on bearings, clear to the stern of the ship, and then through a stuffing box packed with hemp packing, and made water tight; and outside in the sea, the propeller is keyed on the end of the shaft.

The cylinder is the same as other steam cylinders, with piston packing that requires to be set up and kept tight. The valve is a slide valve, with link motion, worked by two eccentrics, from the shaft below.

SURFACE CONDENSER.

The surface condenser is a large iron box. Inside of this box there are placed a great number of tubes, The water of the sea circulates through among these tubes; and the steam, as it exhausts from the cylinder, passes through inside of the tubes. Some surface condensers are furnished with two air pumps—one to circulate the sea water through amongst the tubes, and force it out into the sea again, and the other air pump to draw out the fresh water from the compartment in the condenser, that communicates with the insides of the tubes—that being the chamber where the steam circulates and where the vacuum is formed by the steam getting condensed. This second air pump forces the water (which is made from the condensed steam) into a hot well, inside of the condenser, where it is led to the feed pumps by a pipe. Some surface condensers are furnished with one trunk pump only, which answers the same purpose as the two air pumps.

There is a large valve that opens to let the sea water to the circulating pump; this is termed the injection valve. This valve is shut, if any accident happens to the pump, or when the ship is in port, it is kept shut.

There is a discharge valve, at the top of the condenser, where the water is discharged into the sea, after it has passed all through the condenser, by the force of the circulating pump. The water at that discharge valve is warm—having become heated in passing through the condenser.

In a separate compartment, in the condenser, the exhaust steam of the cylinder enters. The condenser is arranged so that the steam that exhausts into the condenser, and the cold water that circulates through the condenser, are kept separate—the steam being on one side of the tubes and the water on the other side, the steam coming in contact with the cold surfaces of the tubes, made cold by the sea water circulating through amongst them. By this means the steam is condensed, and a vacuum is formed, and the valves of the engine being always open to the vacuum, on the side of the piston opposite to that which is receiving steam, there is then always a vacuum on the one side of the piston, when the steam is pressing on the other side.

If this engine acted like a high pressure engine, having no condenser, but blowing the steam out of the exhaust into the open air, at every stroke of the engine, the steam thus blown out of the exhaust pipe would have to blow against the pressure of the atmosphere; and, as the atmosphere exerts a pressure of nearly fifteen pounds on every square inch of surface that it comes in contact with, therefore, by exhausting the steam in the open air, the piston would be subjected to a force against it of nearly fifteen pounds on every square inch of its area; but by exhausting into the condenser, there is a vacuum formed, and the piston is relieved of this pressure. If the vacuum gauge shows twenty-six inches of mercury, which is a very good vacuum, that will be thirteen pounds of pressure saved on every square inch of the piston.

FEED PUMPS.

The water made by the condensed steam is drawn by two feed pumps from the hot well, at the temperature of one hundred degrees, and heated to a higher temperature, then forced into the boilers again.

When all the tubes in the condenser are sound, the water is fresh; but if any of the tubes leak, the salt water will get in and taint the fresh water. If the tubes are all sound, there will not be any other water required to keep the boilers going, except to make good that which is wasted—such as blowing off steam from the safety valve, or the whistle, or any joints that leak steam, about the engine or boilers. That is all lost, as it blows in the open air; therefore, to supply the deficiency of water in the boilers, there is a valve, termed the salt water feed, which must be opened to let the warm salt water from the condenser to the pumps.

BILGE PUMPS.

Besides the feed pumps for forcing water into the boilers, and the large circulating pumps for the condenser, there are two bilge pumps. These pumps are worked by the engine, and their duty is to pump the water out of the bilge of the ship, and discharge it into the sea. All the water that comes in through the bottom of the ship, by leakage, and all water spilt below, runs into the bilge, and is pumped out by the constant working of the pumps.

There are two iron or copper boxes perforated with small holes. These boxes are placed in a low place in the bilge. The suction pipes from the bilge pumps are placed in these boxes. The holes in the boxes are intended to let in the water to the pipes and to act as strainers, to keep out trash, chips and anything that would be likely to choke the pumps. These strainers must be kept clean and clear in the holes; the pumps are furnished with pet cocks, which, when opened, will indicate if the pumps are drawing water. If the pumps are working, water will fly out at the pet cocks. There are holes under all cross timbers to let the water run through to the strainers in the bilge; these holes must be kept free.

BILGE EJECTOR.

The bilge ejector is an arrangement for forcing the bilge water out of the ship into the sea, by means of a jet of steam, without the aid of a pump. There is a pipe attached to the steam drum of the boiler; this pipe leads down into the bilge, and has a small nozzle on the end of it.

There is a coupling that screws on to the end of the pipe; this coupling is large enough to leave a space all around the small nozzle. There is a suction pipe, that is put down into the water in the bilge, and the top end of it is screwed into the coupling. There is a discharge pipe screwed on to the coupling in a line leading from the small nozzle. There is a screw valve on the steam pipe at the boiler; when this valve is opened, the steam rushes down the pipe and through the small nozzle, out through the discharge pipe. The steam forcing out of the small nozzle creates a partial vacuum in the space in the coupling; the water from the suction pipe rushes up into the space, and is forced by the jet of steam from the nozzle, through the discharge pipe up into the sea. There is a cock on the discharge pipe that may be shut to blow the steam into the bilge, to clear the suction pipe of small coal or any obstruction that will choke it.

BILGE INJECTION.

All sea going ships are furnished with the bilge injection arrangement, which is only used if the ship springs a leak, and the bilge pumps and donkey pump are not sufficient to keep the water down. When this happens, the injection valve that lets the sea water to the condenser is shut, and the bilge injection valve is opened—that is a valve fixed on a pipe that is carried down into the bilge. The bilge water is used instead of sea water; it rushes into the compartment in the condenser, and is discharged into the sea by the air pumps or circulating pump. The strainer at the end of the bilge injection pipe must be kept clear, when using this arrangement, as there is a great suction from the condenser, and the strainer is liable to get choked; and as this arrangement is seldom needed, care must be taken that the valve is kept in order, so that it can be opened at a moment's notice, and the strainer and everything connected with it working perfect. It is sometimes necessary to work the bilge pumps, the donkey bilge, and the bilge injection, to keep a ship from sinking, when the leaking is on a grand scale.

THE DONKEY ENGINE.

This is a small engine, getting steam from the boilers. Some donkey engines are furnished with a separate boiler; then steam can be got up at any time, and when the other boilers are not making steam, when the ship is in port. The donkey is arranged so as to act as a fire engine, in case of fire aboard ship, or if the feed pumps give out, and water is wanted in the boilers, or in the event of the ship springing a leak. The engineer should trace all pipes leading from and to the donkey.

There is the steam pipe, and exhaust pipe.

There is a suction pipe leading to, or connected with the bilge. A suction pipe from the sea, and a branch pipe to get the water from the hot well, if it is wanted, as the feed pump may give out. The delivery pipes lead, one into the sea, and one into the boilers, and one on deck, connected with the fire hose. All the valves connected with the donkey should be kept shut when it is not working, then the engineer will know at once where to begin, which valves to open, and which valves to keep shut.

If the feed pumps worked by the large engines give out, and the warm water from the hot well cannot be got into the boilers, the donkey must have steam turned on to it, and set in motion; then open the valve that is connected with the suction to the donkey, open the discharge pipe valve connected to the feed pipes of the boilers—all other connections being shut, the water will be forced into the boilers If the ship spring a leak, open the suction to the bilge; open the discharge that leads overboard to the sea; all other connections being shut, the water from the bilge will pass through the pump into the sea.

If a fire break out aboard ship, open the suction from the sea, open the discharge that leads on deck to the fire hose; all other connections being shut, the water from the sea will pass through the pump, and be forced up on deck to the hose. The hose should be kept in readiness, and in good order. See that the couplings are sound, and not damaged in the screw. Every thing connected with the fire department should be kept in good order. The donkey should not be used for pumping out bilge water, except when the bilge pumps are out of order, or when the vessel arrives in port, and the engine is not working. Before blowing the water out of the boilers, it may be necessary to pump out the bilge water with the donkey; then, after the bilge water is out, shut the suction to the bilge, and open the suction to the sea, and pump some sea water, and let it discharge overboard. The sea water passing through, will cleanse and purify the pump of the effects of the bilge water.

When that is done, the valves must be all shut and left shut.

THE GOVERNOR.

The governor used on propeller ships is the same kind of governor used on engines on land, with an arrangement which prevents the motion of the ship from throwing the spindle (that carries the balls) out of plumb. The spindle is stepped in a bracket with a universal joint, and the spindle and balls always hang plumb, however much the ship may list. The governor is driven with pulleys and belts from the propeller shaft, and is used only when the sea is rough, the vessel rolling and the engine running irregular. The rod from the governor is attached to the throttle valve lever.

When the governor is used the engine must not be cutting off steam, because, if the engine should slow down suddenly, the balls would fall and open the throttle valve; but if the slide valve, on the face of the cylinder, was in the position cut off and shut, the steam could not get to the piston to force it on, and the engine would stop.

STEAM GAUGE.

There is a steam gauge placed in the engine room: this gauge has a dial, with a finger pointing to the figures that are marked around the face of it. These figures indicate the pressure which the steam exerts on every square inch of surface that it comes in contact with. If the finger points to fifteen or twenty, or whatever number it points to, that number indicates the amount of pressure per square inch. There is a small tube leading from the gauge to the steam dome of the boilers, and a cock to shut steam off the gauge when required, and another cock close to the gauge, to let off the water that collects from condensed steam. When the boilers are cold, not having steam on, the finger will be down, pointing to the cipher on the dial.

The boilers are tested, and calculated to stand a certain amount of pressure with safety; and when the steam gets to the limited amount it will lift up the safety valve and escape into the open air. If the boilers are allowed to carry twenty pounds on the square inch, when the steam gauge indicates twenty, and just when the finger points a little above twenty, the steam will be blowing out of the safety valve.

THE SAFETY VALVE.

This valve is situated on the top of the boilers, and is a circular conical valve, with its seat in a cast-iron chamber. The valve stem stands out above the chamber, and there is a lever and weight that bears on the valve stem and keeps the valve down. The weight is calculated so that when the steam reaches the pressure that the boilers are allowed to carry, the safety valve lifts up by the force of the steam from the inside, and the steam blows off and escapes. There is a chain or rod leading from the safety valve lever into the engine room. The engineer can lift the safety valve by pulling this chain. It is necessary to lift the safety valve at times, to see if it is not stuck; or when the engine is stopped with great fires in the furnace, then the safety valve lever is hooked up, and the steam escapes free.

THE DAMPER.

There is another chain or rod that leads into the engine room, which is attached to a damper in the chimney. This is a flat plate of iron, made to fill up the space in the chimney. There is a rod fastened through the centre of the damper; on the end of the rod a lever is keyed on the outside of the chimney; the chain that leads into the engine room is attached to this lever; by the lever being lifted up or let down, the damper is shut or opened. When the fires are strong, and too much steam on, the damper is shut to prevent the air from rushing through the chimney, or to stop the draft. This keeps the steam down. Care must be taken not to have the damper too close shut up when there are strong fires in the furnaces, as there will be danger of the heat of the fires striking down and melting the grate bars, and letting all the fire in the furnaces fall down into the ash pits. This would be a bad position to get into, but it has happened in many instances.

THE VACUUM GAUGE.

The vacuum gauges in common use resemble the steam gauge. There is a pipe leading into the condenser, and the strength of the vacuum is indicated by figures on the dial of the gauge, and a finger pointing to the figures and rising or falling according as the vacuum is strong or weak. Some steamships are furnished with mercury gauges. Two inches of mercury counts one pound pressure; if the gauge indicates twenty-four inches, that will be twelve pounds of pressure.

The vacuum is affected by the quantity of steam that enters the condenser from the cylinder. If the steam is strong, and the engine is not cutting off, and a great force of steam entering the condenser—if the condenser is not a very large one, the vacuum will not be so good. It may not indicate more than twenty inches—ten pounds; so that it will be seen that there is no advantage gained in raising too much steam in the boilers and exhausting it into the condenser, as the force gained by the strong steam will be lost by the spoiling of the vacuum, and there will be a loss of fuel. If the fires were kept lighter, and less coal consumed and less steam raised, the power would be the same gained, as the vacuum would be better.

THE REGISTER.

This is an arrangement for counting the number of turns the engine makes. There are six or seven small rollers, with figures marked around the outside of them; they are set in a dial, in a row, and they revolve independent of each other. They get their motion from a connection to the cross head or valve stem; every turn the crank makes, the first roller turns up one figure; the next turns up one figure every time the engine turns ten; the next, one to a hundred; the next, one to a thousand; the next, tens of thousands; the next, hundreds of thousands. Thus, an engine making forty-five turns per minute, will indicate on the register two thousand seven hundred per hour, sixty-four thousand eight hundred per day, and six hundred and forty-eight thousand in a trip of ten days.

The rollers or cylinders are set with the cyphers all shown when the ship starts on her voyage.

THE SALINOMETER.

The salinometer is an instrument used for the purpose of testing the saltness or density of the water in the boilers. Although these engines are furnished with surface condensers, and all the fresh water from condensed steam is forced back into the boilers, still there is a deficiency of water in the boilers, caused by that which is wasted (as has been explained in another page); therefore, the salt feed must be used. This salt feed taints the water in the boilers, and on a long voyage the water in the boilers will become quite salt; and when it is as salt, or more so, than the sea water, it will be necessary to blow out some and feed up from the sea water.

The salinometer is the same kind of instrument as the saccharometer. It is a tube half an inch in diameter, closed at both ends, and ten inches long. The lower end is a globe, filled with shot, to make it sink. The tube is marked 190, under this $\frac{1}{32}$ is marked; a little below this there is $\frac{2}{32}$, and a little lower $\frac{3}{32}$ is marked. Turn the tube around, and the same figures will be seen, but a little higher up on the tube, and 200 marked on the top of the column. Turn the instrument around a little farther still, and the same figures will be seen with 210 marked at the head of the column—the figures being a little higher up on the tube than the others.

Sea water is said to contain $\frac{1}{32}$d of its weight in salt; the salinometer is marked accordingly, and between the figures $\frac{1}{32}$ and $\frac{2}{32}$ there is marked the limit—that is, blow out some water from the boilers, and feed up from the sea water. The way the salinometer is used to test the salt water is to draw some water from the boilers into brine pots, that are fixed up near the boilers or in the engine room. There is a small pipe, with a cock to open from the boiler; the hot water runs into the brine pot and fills it up; [illegible] is a pipe and cock at the bottom of the brine pot, to let the water run out; this cock is left open to let the water run out, until the brine pot gets heated; then shut both cocks, and put the salinometer in the hot water in the pot; put in a thermometer also, to ascertain the temperature of the water. If the thermometer indicates 190, then see how far the salinometer has sunk on the column 190; if the thermometer shows 200, then the column under 200, on the salinometer, is the guide to go by. If the thermometer shows above the 200, then the 210 column is the one to go by. The salinometer is marked at three different degrees of heat, and whatever is marked on the salinometer, at the surface of the water, that is the mark to go by.

Some salinometers are arranged for water at sixty degrees only.

THE INDICATOR.

The indicator is an instrument for testing the force that is exerted on the piston, inside of the cylinder. It shows the exact force of the steam and the vacuum at all parts of the stroke, and shows any defect in the working of the valves.

The instrument is constructed with a small brass tube, about one inch in diameter. This tube has a piston that fits steam tight inside of it. The tube is arranged so as to screw on to a small nozzle on the steam cylinder of the engine. The nozzle is furnished with a cock that opens the communication between the steam cylinder and the small piston in the tube; the tube is open at the top end, where there is a spring, against which the small piston bears;

there is a barrel placed around the outside of the tube; a piece of paper is fixed on this barrel; there is a lead pencil put in motion by the small piston in the tube; the barrel is put in motion by a small rod with levers worked from the cross head; when the cock is opened to the steam cylinder, the small piston in the tube moves by the force of the steam from the cylinder or the force of the vacuum and the small spring on the other side; the barrel revolves at the same time, as it receives its motion from the cross head of the engine. The pencil is arranged with a joint, so that it may be placed in the position to make a mark on the paper; as the small piston moves up or down, the barrel revolves at the same time, and the paper has an irregular line drawn on the face of it.

The cock that opens the communication from the steam cylinder to the small tube of the instrument, is arranged so as to let air in at the bottom of the tube; when the cock is shut off from the steam cylinder, the small piston in the tube then stands still—there being air admitted at each end of the tube—the barrel alone works, and the pencil draws a straight line along the paper; this is the atmospheric line or zero; from this line the pressure is marked off on the paper—to the one side for vacuum, and to the other side of zero for steam; by this means the exact force on the piston is ascertained, so that the power of the engine can be calculated; the engineer can also tell by the shape of the lines drawn on the paper, if the valves are in good working order. Some skill is required in using the indicator, and that must be learned by practice.

THE STEAM BOILERS.

These single engine propeller ships are commonly furnished with two boilers, and three furnaces in each boiler. These boilers are square, with arch tops, and a steam pipe above that connects them both together. There is a branch of the feed pipe that leads from the pumps into each boiler separate. The fire from the furnaces strikes on the water spaces, and the flame passes through flues that are situated so that the flame has to pass and return back before the smoke enters the chimney.

Some boilers are constructed with small flues or tubes, as well as the common flues. The fire box is arch-shaped at the top; the fire strikes on this arch and passes through the flues, then returns through a series of small tubes that are placed above the top of the fire boxes. These tubes are placed close together, the fire passes through them; the spaces between the tubes being small, the water that is in them is easily heated. There are doors or man heads in the spaces above the tubes, for the purpose of getting inside to clean off the scale when the ship is in port. There are large doors that open in the front of the boilers, opposite the ends of the tubes; these doors, or flue connections, are arranged so as to open when the tubes want brushing or sweeping inside; these doors are also opened at times, to stop the draft and keep down the steam. There are two iron tunnels that lead from the fire room up on the upper deck, where there are bell mouth-pieces on each tunnel that swing around to let the air down into the fire room. In these tunnels the ashes are hoisted up on the main deck to be thrown overboard.

WATER GAUGES.

Each boiler is furnished with three gauge cocks—two indicate water, and the top one steam. There is also a gauge cock on each boiler, out towards the ship's side. This cock is placed near the top of the flues, and is used for trying the water when the others may be doubtful, and when the ship is listed over very much.

The gauge cocks are opened, at regular intervals, to see if the water is high enough in the boilers. The top gauge is steam; the other three are water. It is best to open the lower gauge cocks, as well as the top one and the second; at least they should be opened sometimes, to keep them from getting salted up. There are pipes fastened temporarily under the gauge cocks, to convey the water from the gauges down into the ash pits; this keeps the water from corroding the boilers.

GLASS GAUGE.

There is a glass gauge on each boiler, placed near the gauge cocks. There is a hole pierced in the boiler, at the low water gauge mark, and another at the steam space above the water. In these holes there are plugs, fitted with cocks to shut or open.

These plugs are arranged so as to admit a glass tube that is fastened at the top and bottom plugs, with small rubber joints and nuts to tighten the joints up, to make them steam tight. When the cocks are opened, the water in the boiler will rise in the tube up to the level; the height of the water in the boilers can always be seen.

It is necessary to open the cocks in the glass gauges at times to let the water blow out and change the water in the tube. If a glass tube should break, the steam and water will fly out. The cocks must be shut, the nuts unscrewed, and a new tube inserted, with a rubber ring cut to fit the tube at each end. The rubber rings are put on the ends of the tube, and it is put in and the nuts screwed up gently. The tube must not bear against the side of the nut, or it will break. Keep the tube in the centre, and clear of the nut, the rubber joint only pressing the tube. There are always plenty spare tubes carried in steamships, as the glass tubes are often broken.

THE CHECK VALVES.

These valves are placed on the boiler low down, and in the pipes that convey the water from the feed pumps into the boiler. Their use is to prevent the water from the boilers getting back upon the pumps.

The check valves are circular conical valves placed in chambers, and the pressure of the steam that is in the boilers bears against the tops of the valves and keeps them shut. The water from the pumps enters under the valves, and by every down stroke of the pump the water is forced into the boiler, against the force of the steam on the top; and as the plunger of the pump returns on the up stroke, the steam on the back of the valve shuts it. There should be a screw valve or cock between the boiler and the check valve, to shut, if anything goes wrong with the check valve. If the valve gets stuck and stops acting, then the screw valve must be shut, the feed water shut off first, the cover taken off the check valve, and the valve fixed.

BLOW VALVES.

These valves are placed low down on the boilers, and are used to blow the salt water out of them. When the water in the boilers is too salt, which is ascertained by the salinometer, some water is blown out—and the blowing must be done when the fires are good and there is plenty of steam. The valves must not be kept too long open, to let the water too low in the boilers. The water will be seen by the glass gauge.

The valves should be opened and shut slowly, as a sudden jerk might break the pipe off.

Some boilers are furnished with small pipes and blow valves that are open, blowing all the time; but these boilers feed all salt water. The pipes are placed near the surface of the water in the boilers.

STEAM.

Steam is the elastic fluid generated by heating water to the boiling point. The force of steam consists in its elastic properties. Steam makes a continuous effort (so to speak) to enlarge its dimensions —to burst out of its confinement and fly into the open air.

A cubic inch of water, boiled off, makes a cubic foot of steam at the pressure of the atmosphere.

As the steam generates, it collects in the steam space above the water in the boilers, and from the steam drum it is led by pipes to the engine.

SUPERHEATED STEAM.

In order to give more elasticity to steam, it is charged with heat after it is generated. There are various methods of superheating the steam. Some ships have separate boilers, or superheaters; in other ships there is a steam jacket around the chimney; the heat of the chimney gives more heat to the steam.

THE SCREW PROPELLER.

Some propellers are constructed with two blades, some with three, and others have four blades. These blades are formed as parts of the threads of a screw, and as the engine turns, the screw or blades force their way into the water and push the ship along. The shaft passes through the stern of the ship, and the propeller wheel is keyed fast on the out-end of the shaft. There is a stuffing box, packed with hemp gasket, in the stern of the ship, where the shaft runs through. This packing keeps the water from entering into the ship at the hole where the shaft runs through.

The screw propeller sometimes works loose, and very often gets broken. It is necessary to haul the ship on a dry dock to get at the propeller, as it is all under water.

If an accident should happen to the screw, and the engineer wishes to repair it in a port where there is not a dry dock to haul the ship out, a box is made and placed under the propeller, around the stern of the ship. The ship is ballasted down forward, in order to raise the stern out of the water as much as convenient. This box is made of plank, and is fitted to the stern of the ship, as near as possible. There are blocks and falls to brace it up and keep it steady, and braces of wood from the top of the box up to and bearing against the stern of the ship, to prevent the box from rising up by the force of the water. The box is then pumped dry, and kept dry by the pump; the propeller can then be got at to repair it.

CLEANING BOILERS.

The boilers are cleaned before they are filled with water. There is a man head port above the tubes in the space, to get in to clean off the scale. Scrapers in the form of a half circle, with a handle attached, are used to scrape off the scale. The tubes are cleaned inside by pushing a circular brush through them, the brush being a tight fit for the tube. There is a spring scraper used sometimes to clean the insides of tubes; this scraper is made in two pieces that form a circle, but room is left between the pieces to allow them to spring. The pieces are welded to a rod that is long enough to reach through the length of the tubes. The edges of these circular scrapers are sharp, and as they are pushed through they spring out, and press the cutting edges against the insides of the tubes, and the scale is cleaned off. After the boilers are cleaned, and the scale and sediment washed out, the hand hole joints are made, and the boilers are filled with water; these being boilers for engines with surface condenser, are filled with *fresh* water at first.

FIRING FURNACES.

The water being high enough in the boilers—nearly up to the top gauge—which can be seen by the glass gauge, the man head joint is made, and the fires are lighted. Hook up the safety valve at first, to let out the air that is in the steam space. Shut the damper when lighting the fires. Put in a layer of coal on the grate bars first, then put in chips, oily waste, and wood to kindle with. Some fires may be lighted with charcoal and wood, put right on the grate bars, without a layer of coal first. If the furnaces are damp, and the smoke comes out at the fire doors, then a fire of shavings or paper may be kindled in the flues to start the draft. Put in coal on the top of the wood after it has burned bright, and open the damper some, to give draft, let the fires burn slowly, to heat gradually. After the fires are burned up bright, then regulate the coal in the furnaces, spread the coal over the grate bars regular, and about seven inches thick of coal will be a good fire if the draft is good; but the quality of the coal and the construction of the furnace have to be considered in firing furnaces.

Some boilers will steam with a fire six inches, while others require twelve inches thick. Take care that there are not any places on the grate bars which are not covered with coal; this will be found out by a drumming noise which will be heard proceeding from the chimney. When the steam begins to blow from the safety valve, shut it down, and put the weight out on the lever, to the notch that the boilers are calculated for. The furnace doors should not be left open but as little as possible. When the engine is stopped suddenly, and great fires in the furnaces, the fire doors must be opened, and the flue connections also, and the safety valve hooked up.

STARTING THE ENGINE.

When the steam is raising, the engine is being prepared for starting; all the glands having been packed, the cups are filled with oil; there are siphons put in the oil cups, to draw down the oil slowly on the journal, from the cup; these siphons are made with wire, twisted around woolen threads; the threads are thrust down the oil holes by the wires on to the journals, and the ends of the threads are coiled above in the oil cup. These engines are commonly furnished with slide valve, link motion, and a rack, pinion and hand wheel. There are two eccentrics, which are connected by rods one to each end of the link.

When the pinion is put down, by turning the hand wheel until the pinion is clear to the end of the rack, the engine will work full steam and not cut off any.

When the pinion is traversed to the other end of of the rack, the engine will run the other way; when the pinion is traversed to the centre of the rack, that will shut the slide valve, and the engine will stand still; when the pinion is traversed half the distance between the centre and the end of the rack, the engine will work by cutting off the steam at half stroke.

The rack is marked with letters, one end forward and the other end backward turn.

There is a handle that connects to a small valve on the side of the steam chest; this valve, when open, lets steam into the cylinder, to warm it, and to keep the piston up or down, so that the crank will not stop on the centre. this valve is used also for letting steam in to blow the air out of the passages and prepare the engine for starting. The handle is worked back and forth, until the engine is warmed up; then, when the engine is running, this small valve is not used, but kept shut. When the steam is strong enough, the engine is started to see if all is right.

The throttle valve is the valve that lets the steam from the steam pipe into the steam chest, where the slide valve works. The crank being well off the centre, to be sure to give the engine a good start, the hand wheel is traversed to the forward mark in the rack, the throttle is opened, the engine starts to run forward. After running forward slowly for a few minutes, the throttle is shut some and the hand-wheel traversed to the mark on the backward turn, the throttle is opened more, and the engine runs back slowly. The injection valve must be opened at the same time that the throttle is opened; then, when the engine has worked long enough to prove that all is right, the throttle is shut, the injection valve is shut, and the engine is standing still. The engineer is then waiting for the signal from the pilot-house. Care must be taken that the piston does not creep down or up, in the meantime, and get the crank stuck on the centre. The small valve must be used to prevent that, if the piston begins to move.

If the crank ever gets stuck on the centre, the way to get it off is by pinching around the balance wheel with a bar. The balance wheel is keyed on the propeller shaft, and is a wheel with recesses cast all around the outside of the rim of the wheel; the bar is put in those recesses, and a heel is provided for the bar. There are men stationed at this bar when the engine is starting.

THE SIGNAL BELLS.

There is a gong in the engine room, with wires that lead up on deck—one wire to the pilot house, and others, in some ships, to other positions on the upper deck, convenient for the captain. There is not a uniform system of signals, as some captains on the lakes adopt a different system to others. The steamers on the Mississippi river have a backing and a forward bell at each engine. (*Copied*): The navy regulation is: ahead, slow, 1 bell; fast, 4; slow again, 1; slower, 1; stop, 2; back, 3. The custom generally prevailing in the merchant marine is: ahead, slow, 1; fast 3; slow again, 1; stop, 1; back, 2.

The engine going full speed, the injection valve is opened full, the discharge valve tied up, the register set; the hand wheel is traversed some distance from the end of the rack, in order to work expansively, or to cut off, as it is termed.

CUTTING OFF STEAM.

This link motion is arranged so as to cut off the steam at any part of the stroke, or to work with full steam clear up to the end of the stroke. The cutting off is regulated according to convenience.

If there is plenty of steam and good speed wanted, then the engine may work full steam.

If the steam is scarce and cannot be kept up to a good pressure, then the steam may be cut off some. In rough weather, when the vessel is working irregular and unsteady, and the governor is being used, then the engine must work full steam. Cutting off steam will interfere with the action of the governor. The cutting off the steam is intended for the purpose of getting more power out of less fuel, and it is of no consequence what kind of a valve is used to cut off by, as long as it prevents the steam from entering the cylinder and acts quick. If an engine with boilers that keep up a pressure of twenty-five pounds on the square inch is worked expansively, as it is termed, or worked with the cut off, and the steam, after being let into the cylinder at full pressure, until the piston has traveled down or up as far only as the centre of the cylinder, then the valve is shut, the supply of steam cut off; the other half that the piston has to travel will be performed by the expansive power of the steam that is already in the cylinder—no more being admitted from the steam pipe, the valve being shut—cut off, when the piston has reached to the end of the stroke, the steam inside of the cylinder will be a great deal weaker than when it entered, as it will have expanded; but still the steam, when it passes out of the cylinder into the condenser, will be found to be strong enough for condensing purposes. If the steam had not been cut off, but allowed to follow the piston at the full pressure, clear up to the end of the stroke, after the piston had made a few strokes the condenser would get hot, and the vacuum be spoiled, because of so much strong steam passing into the condenser; but by cutting off at half stroke, the engine has got all the force of the steam at twenty-five pounds on the square inch for half the stroke, and the force only diminishes gradually from there and enters the condenser at as much pressure as the condenser is able to condense it at. If the steam was allowed to enter the cylinder at the same weak pressure as it leaves the cylinder at, then the piston would only have this weak pressure forcing it on, from the beginning to the end of the stroke, and the condenser would have the same quantity of steam to condense; but by the superior force of the steam at the beginning of the stroke, the engine gets more power, and the vacuum is as good as if the engine was using weak steam and not cutting off, but letting it follow the piston clear to the end of the cylinder.

A VACUUM DESTROYED.

If the condenser gets hot, and the vacuum is spoiled, which will be seen by the vacuum gauge, and also by the engine slowing down and stopping, open the bilge injection, and keep the sea injection valve open also; the steam that is in the condenser will then blow out into the bilge, and the condenser will get cool again; then shut the bilge injection. This method of cooling a *jet* condenser when the vacuum is destroyed, is a speedy remedy, as the contents of the condenser are discharged in the bilge, there being only one compartment.

CLEANING FIRES.

The watch is divided and changed every four hours. The engineers, and firemen and coal passers are on duty four hours, and off duty eight hours, night and day. The changes of the watch are at 12 o'clock, 4 o'clock, and 8 o'clock.

There are two firemen, one to each boiler, and one fire in each boiler is cleaned on every watch, and when the coal is bad the fires are cleaned oftener. When the firemen come on watch, they clean one fire each.

The fires are cleaned by raking all the ashes and clinkers clean out of the furnace, and spreading what fire there is left over the grate bars, and firing up with fresh coal.

The hose has to be used to play a stream of water on the ashes to cool them, before they are hoisted up and thrown overboard.

The coal is measured every watch, when the coal passers bring the coal from the coal bunkers, or the compartments where the coal is kept. There is an iron measure—it is an oval shaped large bucket, open at both ends; the measure is set upon the iron floor plates of the fire room, and the coal is filled into it; when the measure is full, it is lifted up, and, having no bottom, the coal is left on the floor plates, and the measure is put in another place and filled again. This is to ascertain the quantity of coal used on the watch.

The ashes are hoisted up and thrown overboard, and the number of measures of coal and ashes measured on the watch, is entered by the engineer on his log slate.

KEYING UP.

Melted tallow is put into the cylinder every hour, and lamp black if the piston growls. The journals and bearings are watched closely, to see if any of them get warm. The men on watch feel the working parts with their hands, to ascertain if they begin to heat. The heating may be caused by too tight keying, or too slack keying up, or by sand getting on the journals. All the principal bearings are furnished with water pipes, to let a stream of cold water run on them if they get hot. If a stream of water fails to cool a bearing, the hose can be used on it, and if that fails, then the engine must be stopped and the bearing slacked up.

It is best to stop to key up when the steam is low, as that will be a chance for the steam to make while the engine is not using it. There are copper hammers used to strike the keys—heavy hammers and light ones; the large keys require a heavy blow, and the key, after it is driven in, must have a blow on the point to ease it back. After the keys are all tightened up, and the bearings regulated so that the nuts will not slack up or the keys fly out by the working of the engine, then the engine is started up again.

BANKING FIRES.

When a steamship has to be detained for a few hours, the fires may be banked. This is done by cleaning the fires first in the usual way, then pushing them back so as to leave an open space on the grate bars at the furnace mouth for some distance back. The water is kept at the boiling point in that way, and the steam can be got up again in a short time, by spreading the fire over the grate bars and firing up again.

ENGINEER'S LOG.

There is a log book kept by the engineer, and in the engine room there is a slate with the proper heading for each entry; and each engineer on his watch fills out the result of his run:

The number of revolutions the engine makes per minute, the number per hour, and the whole number made on the watch, by the register. The pressure of steam, by the gauge; the pressure of vacuum, by the gauge; the density or saltness of the water in the boilers, by the salinometer.

The temperature of the injection or sea water; the temperature of the hot water for feed pumps; the temperature of the engine room and fire room—all by the thermometers as shown.

The number of measures of coal used on the watch; the number of measures of ashes hoisted up and thrown overboard.

The quantity of tallow and oil used on the watch, with remarks if anything has happened out of the regular routine, such as stopping to repair or key up, &c.

All this is transferred from the slate to the engineer's book, together with the result of the card from the indicator, when a diagram has been taken.

WORKING NON-CONDENSING.

Some of these engines are furnished with a valve on the eduction pipe, which, when opened, lets the steam, as it escapes from the cylinder, blow out into the open air. If an accident happens to the air pump or condenser, or foot or delivery valves, then the engine is changed into a non-condensing or high pressure engine, as it is termed. The air pump is disconnected, the injection valve and delivery valve are shut, and the condensing part of the engine being taken away, there is no vacuum, and the engine works as a high pressure engine. When an engine is not furnished with this valve to let the steam escape, there are other ways of working high pressure; one is by taking off the foot valve cover and fixing a wooden box to let the steam blow out, the air pump being disconnected, and the injection and discharge valves being shut.

FOAMING OF BOILERS.

Foaming of the water in boilers will be seen by the glass gauge tube. The water boils up and froths in the glass tube furiously. Foaming is caused sometimes by lifting the safety valve up suddenly; it is also caused by muddy water entering the boilers from the hot well, through the feed pump. Those engines which have a *jet* condenser, and use all kinds of water as it mixes with the steam, are liable to foam when entering into fresh water out of the salt water; but whatever causes foaming, it is a dangerous state for the water to be in, as the foam might get into the steam pipe and fill the cylinder with water, and break down the engine, or the water might be reduced so quickly in the boilers as to get below the flues, and let the fire burn the boilers. When the water is seen to foam, slow down the engine, by shutting the throttle valve and the injection valve some; open the fire doors and shut the damper some, to stop the furious boiling.

ARRIVING IN PORT.

When the ship arrives in port, the fires are hauled; the ashes are hoisted up and put on the dock pier; the hose is played on the engine to wash it down; the bilge water is pumped out by the donkey pump; the boilers are blown off; the sea valves, discharge valves, and other valves, are shut; the cylinder head is taken up to examine the piston; the oil is taken out of all the cups, with the siphons also, and the cups wiped clean; the engine is cleaned down, and the bright work polished; the man heads and hand hole doors of the boilers are taken off, ready for cleaning; all cocks and valves that leak are ground in; the glands are fresh packed; all bearings that have been heating are examined; new rubber joints are put in where the old ones have been leaking; and everything that has given any trouble on the voyage is attended to, if there is time to do it all.

SIDE WHEEL SHIPS WITH SIDE LEVER ENGINES.

Side lever engines, with jet condensers or marine engines, as they are termed, are the oldest plan of steamship engines in use; all the heavy works of the engines are placed below in the hold of the ship.

The bed plates are laid on the keelsons, the cylinders, condensers, air-pumps, and hot wells, are all in a line on the bed plates. Also, the columns (for the frame work to support the crank bearings, shafts, &c.,) are on the bed plates; the condensers are cast on the bed plates, and the main centers on which the side levers vibrate, run through tunnels cast in the condensers and keyed fast there; the side levers are put on the projecting ends of the main centers; the side rods are connected to the ends of the side levers, and lead up to and are connected on the crossheads above the cylinders; the piston rods are connected in the middle of the crossheads; the other ends of the side levers are connected by cross tails, through which the connecting rods are fixed in the middle, and lead up to and are connected on the cranks. The hot wells are on the top of the condensers; the valves are worked by motions arranged with eccentrics, keyed on the shafts; the cranks stand at right angles to each other: when one engine is on the centre the other engine is in full power at half stroke; the engines are connected by the intermediate shaft, which is placed above the engines, with a crank at each end, at right angles; the paddle wheel shafts are connected one at each end of the intermediate shaft, with cranks that couple to the others. The paddle wheels are keyed on the outer ends of the paddle shafts. The piston rods are guided true in their motions by what is termed

THE PARALLEL MOTION.

The parallel motion is constructed with a shaft that has its bearings on the frame work; on each end of this shaft there is a lever; these levers are connected by rods down to the side levers of the engines, which gives the cross shaft motion; there are parallel rods that connect on the levers at each end of the cross shaft; the other ends are formed with jaws that grasp the side rods—the side rods being connected to the cross heads, and the bars being connected on the levers of the cross shaft—the cross shaft getting its motion from the side levers; these parallel bars change their position as the piston rod ascends and descends, and, by this means, the piston rod is held in a parallel line as it works. Some beam engines are furnished with parallel motions instead of slides and cross heads to guide the piston.

JET CONDENSERS.

Those engines have jet condensers. Inside of the condenser there is a plate perforated with holes, to scatter the water as the injection valve lets it rush in from the sea. The exhaust steam, as it escapes from the cylinder, flies into the cold water in the condenser, and becomes condensed; the steam mingles with the sea water, and the air pumps draw the water out of the condensers and discharge it into the hot wells, and from there through two pipes, one on each side of the ship, back into the sea—all, with the exception of the water that is required to feed the boilers, which is taken from the hot wells by two pipes leading to the feed pumps. These condensers and air pumps are furnished with foot valves and delivery valves and air pump buckets, just like those described on page 45, for vacuum engine.

Those ships may have four or more boilers, and separate superheaters for steam, as the case may require. All the pipes may be traced from the boilers to the engines, and from the engines to the condensers, and discharge pipes from hot wells, and feed water pipes to the pumps, and from the pumps to the boilers, and the bilge pipes and pumps and donkey connections, and the hand gearing in the engine room traced to its connections. There is a little trouble at first, in a strange engine room; but the engineer soon becomes accustomed to it, when the connections are properly traced by him.

BEAM ENGINES.

Some steamships are furnished with beam engines; most of the river steamers on American waters are fitted out with beam engines. The beam is placed high up, which leaves plenty of room below to get around the works. The beam is built on the skeleton plan, and is light and strong, with long connections, which allows the journals to yield and work smooth. The bed plate is bolted down to the keelsons; the condenser is placed at one end, and the air pump is placed at the other end of the bed plate—the foot valve being placed in the passage below that leads from the condenser to the air pump. The cylinder is placed on the top of the condenser; the slides or guides for the cross head to work in are bolted on the top of the cylinder. The steam chest or casing is bolted on the front of the cylinder, at each end, and the two side pipes connect the casings together. One pipe is the steam pipe, the other is the eduction pipe; there are four double valves or eight valves coupled in pairs in the four chambers (puppet valves as they are termed); these valves are coupled, two on one valve stem; the steam acts on the top of the one valve and on the bottom of the other, in order to balance the pressure of steam; if the steam acted on one side of the valve only, it would be too heavy to lift. There are four rods in front of the steam chest — two that lead up to the top valves and two that lead down, and are connected with the lower valves. The rock shaft is placed in front of the side pipes, or it is two separate rock shafts in one line. There are cams fixed on the rock shafts that lift up the rods by coming in contact with toes that are keyed on the rods. The two cams on one of the rock shafts have a greater throw than the two on the other rock shaft. These with the greatest throw are arranged so that they lift up the rods and let them fall down quick. These valves are for the steam. On the other rock shaft the cams are so arranged as to lift up the rods and keep them up longer, and not allow them to drop until the piston has traveled clear to the end of the stroke. This holding up of the valves so long before they shut is done for the purpose of keeping the communication from the exhaust side of the piston open with the condenser, to get the benefit of the vacuum, while the valves that open to let steam to the other side of the piston are let drop and shut before the piston has traveled to the end; this is to cut off the steam. These rock shafts get their motions from eccentrics that are keyed on the paddle wheel shafts, and the eccentric rods lead down and are hooked into pins on the ends of the levers that are fixed on the rock shaft.

There is a small cross shaft below the rock shaft;

this small shaft has projections to lift the rods also. This is the shaft the starting bar fits into, and is used by the engineer to hand the engine when stopping or starting.

The gallows frame is carried from below, high up, and the beam centre pillow blocks are placed on the top of the frame; there are braces with turn buckles to hold down the gallows frame; there are two front links connected to the end centre of the beam, and to the cross head, by straps, bushes and keys. the cross head being keyed on the top of the piston rod, this gives motion to the beam; on the other end of the beam there is the connecting rod, which leads down and is connected to the crank pin; there are two cranks—one on each paddle wheel shaft, and one pin connects the two cranks together; the air pump is worked by two rods connected to a centre on the beam, and there are two injection valves—one to let water from the bottom of the ship, and one through the side of the ship; the low valve is used in deep water; the side valve is used in shoal water; these valves are opened by two wheels that are placed in the engine room.

In starting the engine, the engineer opens the throttle valve—opens the injection valve a little, and works the valves up and down, by the starting bar, always taking care to have the crank past the centre before the valve is open. When ordered to hook on, the eccentric hook is let drop on to the pin on the rock shaft lever. The injection valve is opened full; the throttle valve and damper are opened to suit; the starting bar is unshipped, and the engine goes along. When ordered to stop, the throttle and injection valves are partly shut, to slow down; then, at the next stroke of the gong, the eccentric hook is unshipped, the throttle and injection valves and damper are shut, the furnace doors are opened, and the safety valve hooked up. Care must be taken in handling a single engine, not to get the crank stuck on the centre, although a beam engine is not so liable to stop on the centre.

OSCILLATING ENGINES.

The oscillating engine cylinder is hung on trunnions, and there is not any connecting rods or guides or parallel motion needed; as the engine works, the cylinder rocks back and forth, and follows the crank around. The piston rod is connected on the crank pin with a strap and brasses, keyed on the end of the piston rod to a socket; the cylinder receives steam through the trunnion on one side and the exhaust steam escapes through the other trunnion on the opposite side—the trunnions being hollow. The air pump, condenser, and other details are similar to other marine engines.

DIRECT ACTING ENGINES.

The direct acting engine is one that has no beams or side levers, but the connecting rod from the cross head is led down direct to the crank pin.

The trunk engine has no piston rod; the connecting rod is coupled on the piston, and there is an open tunnel, inside of which the connecting rod vibrates.

The inclined engine has the cylinder laid at an angle. The horizontal engine has the cylinder laid level.

PART III.

LOCOMOTIVE ENGINES.

THE locomotive engine is a double cylinder high pressure engine, or rather two engines working together, on the same shaft, and both receiving their steam from one boiler.

The locomotive engine cannot be constructed on the condensing principle, as the condensing engine requires a great quantity of cold water to condense the steam, and it is not convenient to carry the water, nor even could it be discharged on the railroad if it were carried. Therefore, the locomotive engine is propelled by the force of the steam alone, as no arrangement can be made to have the vacuum also.

The space allowed for the boiler and wheels of a locomotive engine is very limited—it being confined to the distance between the rails on the track.

The body of the boiler is a cylinder with a square shaped fire box, with an arch top at one end, and a smoke box, with the chimney on top, at the other end. The body of the boiler contains a great number of tubes or flues; they are placed in rows, and as close together as convenient, and fastened at one end in the head plate of the fire box—at the other end, in the head plate of the smoke box. The smoke box, with the chimney on it, is the front or prow of the engine. The other end, where the fire box is situated, is the foot plate for the engineer to stand on. The fire box is a square or oblong box with grate bars in the bottom, and an arch top against which the fire strikes before it enters the tubes.

There are spaces between the fire box and the outside of the boiler; these spaces are filled with water, and strongly braced with stays, riveted through both plates.

The fire passes through the tubes into the smoke box and enters the chimney. The water fills the spaces around the fire box, and also all the spaces between the tubes (water spaces). These spaces between the tubes are left very small for the purpose of distributing the heat, and keeping all the water contained in the boiler heated to the boiling point. As the boiler is small in proportion to the steam and power required, every advantage is taken and no steam or water space left idle.

There is a steam space left above the tubes, and a pipe that is carried up and into the top inside of a dome. This pipe receives the steam as it is made, and there is a valve termed the regulator, which is placed in this pipe, which, when opened, lets the steam to the cylinder of the engine, which is similar to other cylinders of high pressure engines.

The engine has slide valves—one to each cylinder. They are worked by eccentric wheels keyed on the crank shaft that carries the driving wheels.

These cylinders are furnished with pistons, piston rods, cross heads—outside of the cylinder covers, working into slides to guide the piston and rods, just the same as other engines.

Some locomotive engines are constructed with the cylinders inside of the smoke box, and the connecting rods coupled on to the crank shaft. This shaft is forged with cranks, and arranged so that the one throw or crank stands at right angles with the other throw. The eccentrics are fixed on the shaft with screws. The driving wheels are keyed on the out ends of the crank shaft; the driving wheels are coupled outside of the other wheels by smaller connecting rods. The engines have all the weight of the whole machine, with boiler, water and all on the rails, which friction is intended to keep the wheels from slipping. The axles of these wheels are set on springs, in order to allow the wheels to correspond to the unevenness of the road. Locomotive engines are all furnished with cut off valves of same kind. A common plan for locomotives to work expansively is by the link motion.

The valve stems are connected to small rock shafts, one for each valve stem. There is a lever fixed on each rock shaft; on the end of the lever there is placed a pin, with a square or oblong box, that fits on it; this box or bush fits in the space that is in the link; the link forms part of a circle.

The eccentric rods are connected on this link, one at each end of the link; there is a lever connected with a cross shaft, that hangs the weight of the link. This cross shaft is worked by a lever on the foot *plate, where* the engineer stands.

The reversing lever works in a quadrant or circular guide; on the top of the circle there are notches cut at measured distances, so that the handle or lever can be rested on these notches. If the reversing lever is placed in the position in the centre notch, the square block on the end of the rock shaft lever will be in the middle of the space in the link; then the valve rod will have but little motion. If the reversing lever is pushed forward to the farthest notch, the engine will go forward and work full steam, and not cut off any; if the reversing lever is put in the middle notch, between the centre and the end notches, the steam will be cut off at about half stroke; and if the lever is put in the position to the notch at the extreme end in the opposite direction, the engine will run backwards. The quadrant is marked at each notch with figures indicating how many inches in the length of the stroke of the piston the steam is cut off at, and the engineer regulates that according as he thinks the speed of the train requires it. If the engine has a very heavy load to pull, it may require all the steam without cutting off. If it is a light train, and a good part of the road, the engine will have power enough by cutting off at some part of the stroke.

The links on both engines are operated by one reversing lever only. If the regulator valve is opened, that lets steam on to the engines; the reversing lever moved forward, the engine will start forward. If the reversing lever is moved back to the last notch in the quadrant, the engine will start and run backward. The engineer has full command of the engine by these two levers.

There are other plans of cutting off steam in locomotive engines. Some have two valves in the steam chest—the one is the cut off, the other is the regular slide valve. The principle of cutting off is the same. The end desired is to prevent the steam from getting into the cylinders.

When the steam is low, and the engineer wants to blow up his fires, he opens a cock that lets a jet of steam rush up the chimney from the boilers. This jet of steam, rushing up the chimney through a contracted pipe, causes a draft through the furnace, and blows up the fire and makes steam.

The engines also exhaust their steam in a pipe in the chimney (the blast pipe), and that keeps the fire good when the train is in motion. If the steam gets too strong when the engine is running, there is a handle that is connected to a rod which leads to the exhaust pipe, and by reversing this handle the exhaust steam is let out, and does not cause any draft. There is also a damper to shut or open in the chimney, or ash pan, to stop the draft. There are two pipes, with cocks to open from the boilers, for letting steam into the tank in the tender to heat the water. The tender is the carriage that holds the fuel and water, and is constantly hauled along with the engine, being coupled to it. There are handles, connected to rods, leading to the cylinder cocks. These cocks require to be opened at times when the engine is running, and they must be open when the engine is starting, for the purpose of letting out the water that has collected in the cylinders. There are other handles connected on rods that lead to small pet cocks in the pumps; these require to be opened at times to see if the pumps are throwing water. There are pipes connected to the water tank of the tender (suction pipes), leading to the pumps to feed the boilers.

There is a small dome on the centre of the top of the boiler; this dome contains sand, and there is a cock that the engineer can open, so that the sand will run down pipes that lead on to the rails in front of the driving wheels, to prevent the wheels from slipping. The sand is required at times when the rails are wet. There is also a sand box on the foot plate, close to where the engineer stands, to let sand down on the rails at the hind wheels.

The wheels are liable to slip when the engine is just starting, and before the train has got under way. Some locomotive engine furnaces are fired with wood, some with coal, and others with coke. The grate bars are fixed so that the fire can be dumped out easy.

The locomotive engine carries very high pressed steam—from one hundred to one hundred and fifty pounds on the square inch. Very high pressed steam is required, on account of having so much work to do for such a small machine.

There is a blow pipe, placed about the surface of the water line, in the boilers, that is for blowing out when the boiler gets too full, and when the water may be muddy.

The locomotive engine is furnished with steam gauge, safety valve, gauge cocks, &c., and all the arrangements necessary for high pressure engines. The firing up the furnaces must be learned by practice. The water in the boiler has to be watched closely, and the gauge cocks opened often, as the boiler carries but little water in proportion to the heating surface. The water gets boiled off quick, and the steam gets used up as quick, the engine running fast and the cylinders being large.

A knowledge of the road is required. The engineer must know all the stations, and use his skill about stopping his steam at the right time when approaching a station, so that the train will stand at the right place. The steam must be kept at a uniform pressure, and a good fire and plenty of steam when approaching a heavy grade. There are plugs carried along in the event of a tube flue bursting; the engineer must put one in each end, and drive them in, to prevent the steam and water from discharging all out.

THE INJECTOR.

There is a method of feeding boilers, without the use of the force pump. This is done by an instrument termed the injector. This apparatus is small, and can be placed in any position—vertical, horizontal, or otherwise. The injector is in the form of a tube, with several nozzles for the connections. It is connected to the boiler by two pipes—one leading from the steam space, and the other leading into the water space, as low down as it can be got. It works well at any pressure of steam, and can be applied to any kind of boilers, and will feed marine engine boilers from the water out of the hot well.

The steam pipe connection is placed highest up on the instrument; the water pipe or suction pipe connection is placed about the centre of the instrument, and there is a connection further down, termed the overflow; this pipe lets the water escape when there is too much in the instrument. The connection, where the water leaves the injector and passes into the boiler, is at the bottom of the instrument. There is a valve in this last connection (a check valve) to prevent the water from coming back from the boiler when the injector is not working. There is a cock placed in the pipe that gives the steam from the boiler to the injector; another cock in the feed pipe, where the water is forced into the boiler; and one in the suction pipe, where the water is supplied from.

There is a wheel on the top of the injector for regulating the water to it; there is a handle above the wheel for regulating the steam to it.

In setting the injector to work, the wheel is turned to let a little water on; then the cock in the steam pipe is opened, the handle on the top is next turned to let steam on the injector; the steam coming in contact with the water, a vacuum is formed in the chamber that opens to the suction pipe. The instrument must then be regulated by the wheel and handle, until the stream of water flowing into the boiler is as strong as is required; and the steam and water must be regulated so that there will not be any overflow, as all the water that runs out of the overflow or waste pipe is so much water lost. It is easily seen if the injector is acting, as there is a space left open in the passage way through which the water has to travel. This space shows the water flowing through and on its course to the boiler. The boiler can be fed with water when the engine is not working.

PART IV.

ERECTING ENGINES.

BUILDING A LOCOMOTIVE ENGINE.

SOME locomotive engines are constructed with the cylinders outside of the smoke box, and the crank pins are fixed on the driving wheels; while others are built with the cylinders inside the smoke box, and the connecting rods are led from the cross heads and connected to the cranks on the crank axle. In either of these plans the method of erecting the work is about the same—the machinery must be set square and level to the boilers.

A mechanic can use his own method.

In building a locomotive, the boiler is set upon blocks of square timber. If there is a crane, or some purchase to raise the boiler up at once, and place the blocks under, it is easily done; but if there is nothing of that kind, then screw jacks must be used: first raise one end of the boiler by the screws, and pack it up with blocks; then raise the other end and pack up, and keep on until the boiler is high enough up to get under to work; keep the blocks out of the way, so as to leave room to get inside the fire box, and also keep the blocks clear of the lines and the parts to be worked at; put some pieces of boiler plate above the blocks under the fire box, and some under the smoke box too; enter some iron wedges under each end of the boiler, above the blocks. The blocks are placed at each end of the boiler under the fire box, and under the smoke box; the shell or body of the boiler is all clear to get to work at.

In order to level the boiler, apply a parallel straight edge along the top of the shell or body of the boiler. Let the straight edge be made with a piece at each end, and one in the middle projecting about one inch, to rest on the boiler and to clear the rivet heads. Apply the spirit level on the top of the straight edge, and at the same time apply the spirit level or plumb rule on each side of the fire box; and if the fire box is not quite square, divide the difference and wedge up from the blocks with the iron wedges, until the boiler sits level along the shell and plumb on both sides of the fire box. Then hang two plumb lines, one on each side of the shell or body of the boiler, at the fire box end, and two more, one at each side of the shell at the smoke box end; take the centre between the two plumb lines with a rod across the boiler, and make a mark under the shell on the smoke box end; make a mark with a cold chisel and do the same at the fire box end; also measure from the outside of the fire box and the smoke box to the plumb lines on the shell to see if the sides of the fire box and the smoke box project equal on each side from the shell. If there is much difference, the centre mark will have to be altered some. But the boilers are generally well made, and little difference will be found. Having made these chisel marks, take a plumb rule and draw a line from the chisel mark plumb down to the bottom of the fire box, and another line from the chisel mark at the smoke box end plumb down to the bottom. Then find out where the centres of the cylinders should be, and put a straight edge across the smoke box, and level it with a spirit level, and when level draw a line with a scriber across the outside of the smoke box, under the shell of the boiler: that will be the level centre line for the cylinders.

If the cylinders are set on the level, then the line from that last mentioned cylinder centre line will be level, clear along to the fire box end, where another line will be drawn and marked along the outside of the firebox, under the shell; but if the cylinders lay at an angle, and are connected to small driving wheels, then the lines must be drawn to suit the angle that the cylinders are to be placed at. This may be done by making a straight edge to reach from the centre line of the cylinders to the fire box and nailing a piece of wood on the end of the straight edge at the fire box end, so that the mark can be put down as low as the angle requires; then the straight edge can be leveled with the spirit level, and the mark on the piece down on the end of the straight edge will be the centre mark, which must be leveled and drawn across the fire box. Having got all these lines drawn and marked slightly with a sharp cold chisel or centre punch, then find out how far apart the centres of the cylinders come from the centre mark on the smoke box; then divide them off with a trammel or pair of compasses, and describe the circles and cut the holes in the head plates for the cylinders to be bolted to. The cylinders will then be fitted to their places. Make two crosses to fit inside the cylinders, to hold the lines; the crosses may be made of pine board, three inches wide and three-quarters of an inch thick; bore a three-quarter inch hole in the centre of each cross and put a piece of sheet brass or tin over the hole; fasten the piece with small screws, then make a very small hole in the centre of the cross through this thin piece of brass or tin, and let that be the centre to put the line through. Put the crosses inside of the cylinders at the out end, and put the lines through the centre holes, and tie knots on the ends of the lines to prevent them from drawing through; then stretch the lines through the cylinders and fasten the ends of them at the centre mark that is made on the fire box; the lines can be fastened by bolting a straight edge across the fire box or fixing a piece of iron in some way to hold the lines to the centre mark. Then, when the lines are held tight in their places, take a piece of stout wire and make it the half the diameter of the cylinder; let the wire be pointed at each end; then move the cylinders with wedges until the lines come right in the centre of the cylinders by this wire measure; then, when the cylinders are set by the wedges true to the lines, take a pair of dividers and set them far enough apart to scribe the widest space between the cylinders and head plate; then scribe all around the edges of the flanges on the cylinders; then take them out and chip and file and fit them up to the head plate by the marks that are drawn by the dividers; then draw them up to their places with bolts; paint the head plates with red lead, and that will mark the spots which bear the hardest; then take them out and fit with chisels, files and scrapers, until the flanges have a solid bearing, and true to the lines. Then the motion bars or guides for the cross heads are fitted true to the lines also, and all the other works are fitted square and plumb to these lines. The frame work for holding the axle boxes for the crank axle is fitted and made square across the engine from the centre lines, and all the pieces of framing are made level across by the spirit level. When all the parts are fitted and the engine is ready to be set on the wheels, the chains are put around the body of the boiler to sling it and raise it up; the chains must be put around the boiler at each end inside between the smoke box and fire box, and blocks of wood or pieces of plank put between the chain slings and the boiler, to prevent the chain from slipping or injuring the plates of the boiler when the weight comes on. The whole affair is then raised up and the wheels are rolled under—each pair of wheels to their respective places. The axle boxes are kept straight and the boiler, with the works attached, is lowered down until the wheels take the weight—the axle boxes being supported by springs; then the engine is resting on its wheels. The blocks that the boiler were placed on while fitting on the works are removed out of the way. If there is not an arrangement for lifting the engine all at once with a crane or hydraulic machine, then the screw jacks must be used and one end at a time lifted, and, after rolling in the wheels, the weight must be lowered on to this pair of wheels, until the other end is raised up and the other wheels put under. It is a much better way to lift the whole weight at once, as the screw jack process requires great care.

After the wheels are put under, the eccentric rods and connecting rods are put on and the valves are set. There are four eccentrics for a locomotive engine of this kind—two to go ahead and two to back. In setting the valves of the locomotive engines, the driving wheels are raised up clear of the rails and the jack screws are kept under the axle boxes, or the axle boxes are propped up in some way, to let the driving wheels turn around.

The centres are taken on the driving wheels in the same way that the centres are found, and described in the article on setting the valves of a cane mill engine (see page 10.) The four centres are taken on a locomotive engine on the driving wheels, and the trammel is kept; the valves of a locomotive engine are set to give more lead than any other engine, as they travel so fast they require more lead. The eccentrics are liable to move around on the shaft, as they are commonly fixed on with set screws, and it is necessary to have a small trammel, similar to that kept for the centres, or the same one might answer. After the valve is set and when the engine is on the centre, and right by the trammel, make a small centre punch mark on the steam chest in front, and another on the valve stem to correspond with the trammel; then it can be seen at any time if the eccentric has moved, and the valve can be set again without taking off the steam chest cover. By blocking up the wheels and taking the centres, and applying the trammel to the valve stem, the valves may be set without blocking up the driving wheels, as the engine may be moved along the rails until the wheel rolls around to the right position to suit the centre punch marks to the trammel.

After an eccentric is set, it is well to make a mark on the eccentric wheel and shaft at the same time, by grinding a chisel to a point to fit in the corner between the shaft and eccentric wheel, and striking the chisel a blow, so that it will leave a mark on the shaft and eccentric wheel at once.

BUILDING A HORIZONTAL ENGINE.

The cylinder of an engine of this kind is placed upon the bed at one end, and rests in a horizontal position with the bed plate. The cylinder is fitted down level by the spirit level, and the bed is leveled both lengthwise and crosswise. The cylinder is lined off, with a cross in one end to hold the line, and the other end of the line is made fast at the end of the bed plate, with a piece of iron or wood cramped or wedged in between the sides of the bed.

The cylinder is fitted so that it will come in a line with the bed all along, and it must correspond with the pillow block at the crank. The guides for the cross head are leveled and in line with the cylinder; the shaft is set level with the bed by the spirit level, and square to the bed. When the shaft is put into its bearings, the crank is brought around until the centre of the bearing of the crank pin touches the line; the line will be in the middle of the pin journal; the crank is then reversed around to the other centre, and when it touches the line, and the line is in the centre of the journal, the shaft is then square to the cylinder, and the outside bearing of the shaft may be bolted down if the engine is in the place where it is intended to remain. All the other parts of the engine, such as valves, piston, packing, pumps, &c., are regulated as described in the cane mill engine (see page 9).

The horizontal engine is used for all kinds of work, and this kind of engine wears longer when it turns backwards—that is, if when the engineer stands at the cylinder and looks towards the crank, the piston, when travelling away from where he is standing, along towards the crank shaft, the crank will turn down below the top of the bed; and when the crank is at the end of the stroke, the piston is travelling again back towards the engineer. The crank will rise up above the bed; all the weight of the cross head and connecting rod is on the guides when an engine works horizontally; and if the engine turns backwards the steam, as it forces the piston out towards the crank shaft, the connecting rod being down at an angle from the guides, the resistance that the crank gives to the connecting rod tends to lift up the rod, and relieves the weight from the guides. And again, when the piston is returning, the force that is required to pull the crank along tends to keep back the connecting rod, and the rod laying at an angle above the guides, the weight of the rod and cross head is taken off the guides; but if the engine turns the other way, the guides get all the weight of the rod and cross head, and also all the extra weight exerted by the connecting rod, being pressed against the cross head at the angle. This should be considered when a horizontal engine is put down. If the position of the buildings and machinery will answer, it is best to run the engine backwards, which is done by setting the valves and eccentrics to suit.

BUILDING BEAM ENGINES.

The bed plate of a beam engine that is intended to work on land, or a stationary engine, as it is termed, is set down level. There is a line drawn along the bed plate in the centre, from one end to the other, the bed plate being wedged up solid so that it will not yield; there is a line drawn across the bed, right under the main centre, or where the main centres of the beam will come; this cross line is drawn at right angles to the line drawn along the plate (see erecting a perpendicular, page 131).

There are cross lines drawn, one on the plate at the centre of the cylinder, and one line across the plate at the centre of the crank shaft. The bearing for the cylinder to rest on is chipped level; the seats for the columns to rest on are chipped level, with a straight edge the level being applied along and across the plate, with the straight edge on the seats, until they are filed level and even with each other. All the lines that are drawn on the plate, and also the centre marks where the columns rest, are slightly cut in with a cold chisel, so that they can be seen. The cylinder is set down plumb inside, and the valve face square across the plate. There is a straight edge put across the top of the cylinder, and parallel with the face; but in the centre of the bore of the cylinder, from each end of this straight edge, a plummet is hung; the points of these plummets will be on the cross line of the bed plate. A straight edge is put on the top of the cylinder, and plummets hung, so that the points strike the line that is drawn along the bed plate; the cylinder is then plumb and square with the bed; it is then bolted down.

The columns are turned on the ends, all of equal length; they are bolted down to their seats, to the centre marks that have been made and measured off for them. The top frame that rests on the columns is faced off at the bearings of each column, the frame being put up and bolted on the columns; the main center journal bearings, or pillow blocks, are then set level on the top of the frame.

A straight edge is put in the bearings across, and a spirit level applied, and the straight edge is turned and a plummet hung from each end, and the pillow blocks are fitted until the points of the plummets touch the line on and across the bed plate, the straight edge being level when applied the other way.

The bearings are then ready to receive the beam, the middle between the pillow blocks being plumb by the plummet point to the centre on the bed plate, where the two lines cross each other, and square across by the line in the bed, and level across by the spirit level. There is a cross put in the bottom of the cylinder, and a line stretched up to the top frame; the line is set fair to the centre of the cylinder at the top, by the wire measure applied from four opposite points in the inside of the cylinder to the line; the cross at the bottom end keeps the line right there, the line being stretched tight and true to the inside of the cylinder. The guides for the cross head to work on are set straight with the line; a small straight edge is made and notched in at each end, until the notches measure the right distance that the guides must be set apart. The straight edge is notched into the half of the thickness of the working part of the guides, and a mark is made in the centre of the straight edge for the line; the guides are set and fitted until the centre mark in this straight edge touches the line at any part of the guides. The guides are then bolted fast, the beam is hoisted up into its place, and the connections are put on. If the engine is a condensing engine, the air pump and condenser are put on, by having their places measured and squared, and lined and marked off, the same way that the cylinder is marked off and fitted down. If it is a high pressure engine, then there is no condenser or air pump wanted. The other details of this engine, to finish the erecting of it, will be found in the article on the cane mill engine (page 9).

BUILDING A SKELETON BEAM.

There is some skill required in fitting up a skeleton walking beam for an engine. This kind of beam has a cast iron skeleton in the centre, with a strong wrought iron truss or frame fitted around the outside of the skeleton. The frame, or strap, as it is called, is dressed out clean at the places where the skeleton fits into it; the skeleton is put on the top of the strap, and marked with a scriber, then turned up and chipped, and fitted with a little taper, until it fits down into the strap; it is then fastened with keys and straps with gibs, and keys are fitted in to keep the skeleton and frame together.

The places to receive the centres are cleaned out and key beds are cut in them. The centres are made of wrought iron, and turned and planed on the key seats. The centres are planed parallel, and the taper for the key is allowed in the beam; $\frac{1}{8}$th inch part of taper to one foot in length, is a good proportion for taper for keys to drive and hold well. The main centre is put in first, and if there are to be eight keys put in, then sixteen stake wedges are used to hold the centre. The stake wedges, or temporary wedges, are driven into the space between the key beds, on each side of the beam; the centre is put in its place, as near in the middle as possible. In some places there is a pit with two pillow blocks for the journals of the main centre to rest in, and the beam is turned around on its centres, and trained and wedged until it comes true by measure from the side of the pit to all parts of the centre of the beam strap;

then the keys are fitted in and the wedges slacked out; but if there is no pit, then the beam must be placed on edge and propped up plumb, by the plumb rule, or spirit level and straight edge. Bring all the centres in a line, and level with the spirit level and straight edge, from one end of the beam to the other; then put in the main centre, and drive the wedges a little to steady it; then take a straight edge, with two legs of equal length; these legs rest on the journals of the main centre, and are made wide enough to fill the spaces between the collars of the journals at each end of the centre, and the legs are made long enough to bring the straight edge up above the beam strap. The wedges must be slacked in one side and tightened up in the other, until the straight edge is level on the top by the spirit level; then, to get the centre square the length way of the beam, a straight edge is used from the centre that reaches to the end of the beam. There is a piece put on the straight edge, and fastened and circled to fit on the end of the main centre; a wooden key is fitted on behind to fasten this straight edge, so that it will form a journal to vibrate on the main centre. Tighten up the wooden key, and move the straight edge, until the end comes opposite the end of the beam, and measure from the straight edge to the centre of the beam strap; then reverse around the end of the straight edge, and let it revolve on the main centre until the end comes opposite the other end of the beam, and measure to the centre of the beam strap, and drive and slack the wedges until the distance is the same from the straight edge at the one end of the beam as it is when the straight edge is reversed and revolved around the centre to the other end of the beam. The centre is then true, the stake wedges are driven in tight to hold the centre firm until the keys are fitted in. The keys are fitted in with files, until they bear hard and equal on the key beds and main centres; then the keys are all driven home regular—first one, then the one opposite, and so on until they are all home; a sledge hammer is used; but care must be taken not to drive one tighter than the other at first, but rather go around driving at three or four different times. When the keys are all home, slack out the stake wedges, and a moulding may be run around the heads and points of the keys.

A piece of wood is turned out inside, so as to form a moulding, and fitted in the beam centre, close up to the key heads, and wedged against the beam and jointed with clay; then the other side is done the same, and the mouldings are run full of molten lead; the lead runs around the keys, and makes a fine finish on both sides of the beam, around the main centre; the pieces of wood are taken off, and the lead moulding is filed clean all around on both sides.

The centres at each end of the beam are keyed in, either in the same manner as the main centre, or the strap is bored out to receive the centres, which fit in tight, and are fastened with one or two keys; the other centre for the air pump is keyed, and set like the main centre is set, by measuring and leveling.

ERECTING MACHINERY ON FOUNDATIONS.

When bolting down engines on foundations, the brick work is built around the holding down bolts. There is a frame of pine boards made, and the frame is put under the bed plate, and the holes for the holding down bolts are marked and bored through this pine board frame; the frame is put on the points of the bolts with a nut put on the screw to rest the frame on; this frame is put on to steady the bolts and keep them right for the holes in the bed while the foundation is building around them. There are plates and keys under the lower ends of the bolts to keep them from drawing out. The frame must be set square to the building, as the bolts cannot be moved when the brick is built around them. When the foundation is built up sufficiently high, the wooden frame is taken off from the points of the bolts, the nuts are taken off also, and a coating of cement or mortar is spread over the top of the brick work, and the bed plate is screwed down level on this bed of cement while it is soft; then it is left to dry and get hard. The other works of the engine are all put on to the marks and level as they have been fitted in the shop. Although most engines and machinery are built to a drawing or plan, still there are details left to the judgment of the engineer, who is sent out to erect this machinery—especially if the machinery is sent to a foreign country. In sugar growing countries, some of the sites selected for heavy machinery may be on swampy ground, and it may be necessary to drive spiles to get a good foundation. The timber that lasts long under water or in wet ground must be selected. These countries have their own kinds of timber. The engineer should be able to judge of the quality of the materials to be used—such as brick for foundations, fire brick for furnaces, timber, &c.

In erecting machinery, care should be taken to leave every part with an arrangement to get at it when it needs repair. Holding down bolts in the foundations that are built should have a space left in the foundation below at each bolt, so that the key can be got out, and the plate also, if required. The flues of boilers should have small arch top doors under the brick work to get in to repair the brick flues and also to clean them. All pipes that are carried under ground should be provided with means to get at them. Some foundations are built solid up, and no arrangement left to get at the works; whereas, if the foundation was arched, and chambers left to get handy under the floor to all the parts of the works, the foundation would be quite as strong.

If the foundation is on solid rock, then the holding down bolts may be fastened by drilling holes to receive the bolts; the holes may be made larger at the bottom and the ends of the bolts upset some, and molten lead poured in the hole around the bolt. There is a method of fastening bolts in rocks by drilling the rock the right size to receive a bolt, then making a drill that will recess the hole at the bottom. This is done by fixing two cutters on the end of an iron bar; the cutters are attached to the end of the bar by a pin through the bar and through the end of each cutter; the cutters vibrate on a pin the same as a pair of scissors; the points of the cutters hang loose when the bar is lowered down into the hole in the rock; but when the points of the cutters strike the bottom of the hole, the cutters spread out and cut all outside, and do not cut any deeper; the hole is made larger at the bottom in this way, by striking lightly on the top of the bar with a hammer, and turning the bar around as is usual in drilling rock. Having got the holes recessed, then prepare the bolts by splitting them at the ends and entering a wedge into each split. The wedge is made with a flat head. The bolts are lowered down into the holes; the heads of the wedges will land on the bottoms of the holes; then the point of the bolt above is struck with a sledge, which will drive the bolt down on to the wedge, and the wedge will spread out the end of the bolt and fill the recess at the bottom of the hole; the bolt will then be secure and cannot be drawn out. A hole can be drilled in a piece of rock and a bolt fixed into it in that way, in order to prove if the split in the point is long enough, and to show, also, if the drill will recess the hole right; the piece of rock may then be broken and the bolt and wedge taken out.

This is one method of fixing bars of iron in rocks under water.

When drilling holes in rock, the drill must be struck light blows with a hammer, and the drill turned around a little at every blow; if the blows are struck too hard, the hole will get spoiled by being three cornered, and it will not measure the size that is wanted: when a hole gets angled in that way, it is not easy to make it round again. Drills are made of octagon steel: they are made like a chisel, at the the cutting edge, and are left large enough to clear themselves when working.

ERECTING THE ENGINES IN A SIDE WHEEL SHIP.

When the engines of a steam ship are being set in their places, a spirit level or plumb rule cannot be used, as the vessel is afloat; therefore, fixed lines and straight edges and squares must be used.

There is a line drawn on deck, fore and aft the vessel, and as near the centre between the frame of the ship as possible; then a line is stretched across the ship, at right angles with the fore and aft line that is drawn along the deck; this cross line will be fixed at each end on the two beams that support the water wheels. From this cross line or straight edge square down with a long wooden square, from the centre mark on deck, where the cross line and fore and aft line cross each other, then mark at the point of the square on the keelson where the square touches; then from that mark draw a line fore and aft in the hold and let it be out of winding with the fore and aft line on deck; then draw a cross line in the hold, at right angles with the fore and aft line, and out of winding with the cross line on deck. Having got these lines drawn, then if there is only one engine in the ship, these fore and aft lines will be the centre lines of the engine; but if the ship has two engines this will be the centre line of the ship;

and the cylinders will stand at equal distances on each side of the lines.

A long straight edge can be placed perpendicularly, one at each end of the engine room.

The straight edge being placed right to the lines from the hold to the deck of the ship, the straight edge is nailed fast; then the plumb of the engine can be measured from these straight edges at any time. The keelsons are leveled and cut fair on the top sides by the carpenter's tools; the bed plates will be put down on the keelsons and bolted fast. The cylinders are bolted down to their places on the bed plates; they are wedged up plumb by centre lines stretched through the cylinders from crosses fixed in the bottoms of the cylinders, and the lines are set out of winding with the perpendicular straight edges. Having set the cylinders true, they are jointed down to the bed plates, and the centres between the ends of each pair of side levers will be the centre of the crank shaft—that is, after allowance has been made for the overhang of the side levers or beams.

What is meant by overhang of side levers or beams, is the distance that the beam projects at each end over the centre of the cylinder or the centre of the crank. Each end of a beam as it moves up and down, or vibrates on its centres, describes part of a circle, and if the distance between the two end centres of the beam was the same as the distance between the centre of the cylinder and crank, the beam would be too short.

The walking beam or side levers of an engine are kept as much longer as the half of the distance between the straight line and the circle that the beam describes on the length of the stroke of the engine; that is, each end of the beam, when level, overhangs the centre, between the cylinder and crank, the half of the difference between a straight line and the circle which the beam describes in travelling the length of the stroke.

ERECTING A BEAM ENGINE IN A SHIP.

In erecting a beam engine, the centre lines of the ship must be squared in the usual manner, and the centre of the space between the pillow blocks on the gallows frame for the beam to rest on is in the centre of the engine.

The bed is bolted down level, and the cylinder is placed so that the line, when stretched from the cross in the bottom, is in the centre of the cylinder at the top end; the line is carried up to the beam and fixed on the end centre of the beam strap by a yoke; this yoke is a straight edge with two legs; the legs are of equal lengths, and are the right breadth to fit between the collars of the end centre; there are pieces that fit on the end of the legs to form joints, with keys to tighten them up on the end centre, like the fork end of a connecting rod; the line is fixed on the centre of this straight edge, and the yoke can move or vibrate around the end centre, so as to bring the line in the centre of the cylinder, fore and aft, to allow for the overhang of the beam. There is another line from the other end of the beam, attached to a yoke;

this line is carried down to the keelson, and is out of winding with the perpendicular straight edges that are fixed up at each end of the engine room in the hold.

The air pump is also set plumb on the bed plate, and a line from the beam centres, from where it receives its motion, is stretched down to a cross in the bottom of the air pump, with allowance for the overhang. There is a line stretched fore and aft, made fast to the parallel straight edges at each end. This line is stretched for the purpose of bringing the shafts square to the line of the engine; the bed plate being set level, the frame being level and square to the lines and straight edges that have been erected at first, the cylinder being plumb, the beam having been set true, until the lines from the yokes at each end correspond with the centre marks on the keelson and bed plate.

The shafts are put in their places, the wheels are turned around until the crank pin at the top centre touches the perpendicular line; the crank pin should be in the centre of the line.

The crank is turned back until the pin touches the line on the low centre; and, if the pin is in the centre of the line, the shafts are level with the engine. Then slack this perpendicular line away from the yoke, and stretch the fore and aft line tight; then turn the crank up to the half stroke—the pin will be in the centre of the line; then turn the crank until the pin touches the line on the other half stroke, and if the pin is in the centre of the line, the shaft is square across the ship to the line of the engine; the marks on the keelsons and the bed plates are left so that they can be seen if the engine needs repair or gets out of line; the lines can be stretched to the yokes and through the cylinders, and fore and aft, and the pillow blocks on the top of the gallows frame can be wedged and the shafts raised or moved at the outer ends until the centre of the crank pin touches the lines equally between the collars of the pin, at all four centres —that is, top centre, bottom centre, half centre forward, and half centre back. The engine will then be in line.

ERECTING ENGINES IN PROPELLER SHIPS.

The engines in propeller ships are below, and the propeller shaft runs foré and aft the ship, and is in a line with the hull, keelsons, &c.

The cylinders must be set square with the line of the shaft, so that the guides and cross head may work square to the shaft. The cylinders are set either perpendicular to, or at an angle with, the line of the shaft. The lines and cross lines, and perpendicular lines or straight edges to fix the lines on, are all erected in the same way that the lines are erected on the hull of a side wheel ship.

MISCELLANEOUS.

LEATHER AND RUBBER BELTS.

Some machinery is driven with rubber and some with leather belts. New leather belting should be stretched before it is used; the belting is suspended from a beam high up, and weights are made fast to the lower end of it, and it is allowed to hang for a day or two. Small belts can be sewed with a lace and awl, but most belts have holes punched for the laces with a cutter. The holes should not be too close together, or too near the end, but space large enough should be left, so that the laces cannot tear out the pieces. The two ends are cut square and butt together; some allowance is made for stretching. The lace should be sewed straight on the side that goes next the pulley, and crossed on the back or outside of the belt; the ends should be put through under the sewed part, so that it will jam them and keep the ends from getting loose.

In putting on a belt, the engine must be slowed down if the speed is quick, and the belt is first put on the pulley that is not in motion. If the belt is a heavy one, a piece of rope may be passed around the rim of the pulley and around the belt, and the pulley turned slowly; the rope will keep the belt from slipping off the pulley; then, when the belt is entered on the edge of the pulley, the rope is slackened off.

Large belts that are put on tight must be put on with screw cramps; two pieces of iron are fastened with bolts on one end of the belt, and two pieces on the other end; they are kept far enough back from the ends to leave room to lace them; there are screws (with nuts) put through the holes in each end of the cramps, and the nuts are tightened up until the two ends of the belt come together; the ends are then sewed with strong laces, and fastened with double rows of holes; the cramps are then taken off.

Iron hooks are sometimes used instead of laces for belts. The hooks are made of half round iron wire. They are turned or hooked at each end, and a space left in the centre at one side; the hooks are passed, one through each opposite hole, in the ends of the belt; then the ends are closed in by pressing or hammering.

FIXING TOOLS.

TO SHARPEN COLD CHISELS OR DRILLS.

Heat the chisel or drill a little brighter than blood red; hammer it regular, striking it sharp blows at first, and lighter blows as it gets colder; hammer it until the color is gone; but it must not be hammered cold, as that will make it brittle. The tool must be dressed as quick as possible, with few heats; it must be hammered lightly on the edge, and not at all on the edge when cool. Having got the chisel or drill, or whatever it may be, made into the right shape, then it is tempered. That is done by heating it again to the same color; then dip the point in water a few moments; then take it out and polish it a little on sand or sandstone, to see the color; the heat will come down to the point slowly and change colors; first, from gray to bright straw color, then dark straw to purple, then blue. For cold chisels or drills, plunge them in water when the color comes to purple; other tools, such as punches or dies, will stand at dark straw color when cooled off.

Scrapers are made as hard as possible by water. The scraper is heated to a cherry red, and plunged in water. The best refined steel is used to make scrapers for scraping surfaces. A scraper less than one inch wide, and the one-sixteenth part of an inch thick at the point, hammered well and heated to a cherry red, and plunged in water, then ground straight and square at the point, and set up on an oil stone, will work well, it being thin at the point. It is easily set up when blunt.

WORKING STEEL.

Steel must not be heated any higher than a bright cherry red. When steel is overheated, it is rendered useless. If a tool should get overheated at the point, cut the piece off and form a new point.

TO SOFTEN STEEL.

Heat the piece, and cover it over with hot coal, and let it cool gradually, fire and all.

TO WELD TWO PIECES OF STEEL TOGETHER.

Dip the ends (that are to be welded) in borax, well crushed; then heat the pieces in a clean fire, put plenty of borax on the ends as they heat, and when the borax melts and forms in white spots all over the steel, take out the pieces and hammer them together on the anvil. Thin delicate pieces of iron are welded in this way by a borax heat.

WELDING IRON.

To weld two pieces of iron together: first heat and upset the ends to be welded to make them larger; to allow for waste and hammering, the ends are beveled as short as convenient, so as to make the weld short; a long scarf will not make a good weld; clean the fire free of clinkers and ashes; heat the two ends to a welding heat; the iron will first appear to sweat, then it will change to a melting white heat; if any part of the iron begins to melt before the other part is ready, which will be seen by the sparks flying from that part that is burning, throw a little sand on the place where the sparks come from; then, when the ends are hot enough, that is, to a regular white heat, lift the two pieces out of the fire; lift them straight up, and do not draw them through the ashes; strike the ends a blow on the anvil, to free the scarf from dirt and ashes; then one part is held steady on the middle of the anvil, with the bevel side of the scarf up; the other part is put carefully on the top, and as quick as possible; then the joint is hammered with sledge hammers, hard, quick blows, until the weld is perfect. Iron is softened by heating it and covering it up with ashes to cool slowly.

CASE HARDENING.

To case harden, or to make iron as hard as tempered steel, put the pieces into an iron box; put in some pieces of leather, bone dust, hoofs and horns; fasten the lid of the box with pins, or tie it with wire; put clay all around the joints, to make them air tight; put the box in a fire or furnace, and heat the box to a bright red, and keep it at that heat for an hour; then plunge the contents of the box in cold water.

Another plan of case hardening is to heat the iron to a cherry red color; then rub it in prussiate of potash; put the iron in the fire again, and keep it in for some minutes; then plunge it in cold water.

TO SOFTEN COPPER OR BRASS.

Heat the pieces to a dull red, and plunge them in cold water. Copper and brass get hard when hammered much, and may be softened in that way.

SOLDERING.

To hard solder iron or copper, first clean the joint or the place where the solder is wanted; file the joint bright; then tie the pieces together with wire or a rivet, at several places; then put on borax and spelter, and hold the joint over a charcoal fire until the heat melts the spelter; turn the joint around until the spelter has run into the seams, and united the pieces solid.

SOFT SOLDERING.

This is done with a copper bolt or soldering iron. It is heated so that no color will be seen, and filed clean at the point; then dipped in rosin, and put into the solder, until the solder melts and adheres to the bolt; the bolt is then applied to the part to be soldered. In soldering two pieces of iron, the places are cleaned with the file, and some muriatic acid put on; there must be some pieces of zinc put in the dish with the acid; the zinc is put in until the acid will not melt any more of it; it is then used.

MAKING JOINTS.

There are various kinds of steam and water tight joints; first, the surface joint. The surface joint is made steam, water or air tight, by making the two faces fit together, so that they will be tight without any substance between them. If the faces are rough castings to begin with, they must be planed or chipped and filed first; then they are filed smooth and out of winding, which is proved by applying a facing board or face plate. This face plate is got up, a perfect face scraped, and two handles are screwed into the back of the plate to hold it by; if a face plate cannot be got, then a piece of two-inch thick pine plank faced up true, with two bars across the back to keep it from warping. This face board is painted over with red lead, and rubbed lightly over the face. The high spots will be shown by the red lead; the high places are scraped off; then the two surfaces are applied, one on the other, and a little red lead put on each face; the high spots will always show by rubbing the one piece over the other. After the joint gets to have a pretty good bearing, which will be seen by the hard black spots getting close together, then the scraping must be more fine and close. A little oil and ground glass may be put on the joints, and rub them together—this will show the hard spots; then the scraping must continue until the surfaces bear all over, when the joint will be tight. The scrapers must be kept sharp, and held low down, and care must be taken not to scrape the surface into small ridges. This is done by holding the scraper handle too high up, and not keeping the scraper sharp. If the surface should get into ridges, then the scraping must be done across the ridges until the surface is smooth. This kind of joint is good for steam, water or air. Slide valves are made tight in that way.

RUST JOINTS.

The rust joint is made with cast iron turnings, sifted and damped with urine, or water and sal ammoniac—a very small portion of sal ammoniac must be used. The rust is driven into the space, all around the bolts, tight, with caulking irons nearly the thickness of the space. There is a margin left inside of the joint to prevent the rust from driving through; sometimes a ring of iron, about one-eighth of an inch thick, and wrapped around with hemp and white and red lead; then this ring is put between the joint inside, and the bolts screwed hard down until the joint is less than three-eighths of an inch thick; the joint is then driven, full of rust, hard all around the bolts, and butt up against the ring inside. When this joint has stood two or three days to dry, then it is ready for steam; and if it is well made, steam may be turned on to it at once. If this kind of joint is right made, hard and regularly driven, it will last and keep steam tight as long as the iron flanges between which it is driven.

RUBBER JOINTS.

These joints are easily made. The rubber is cut to the size of the flange, with holes for the bolts, and the bolts squeeze it up steam or water tight.

In making rubber joints, if the flanges are large or rough surfaces, it is best to cut the rubber the size of the space inside of the bolts; that will be a rubber ring inside of the bolts, instead of a piece the whole size of the flange. This ring will be made tight with less pressure from the bolts than a whole flange would require.

LEAD JOINTS.

Cold water or air joints may be made by pouring molten lead into the space. These joints answer very well for water. The pipes are cast with a socket at one end, and the small end of the other pipe is put into the socket end of the first pipe; a piece of hemp packing is driven into the space first; this hemp is covered over with red and white lead to keep it from burning; there is clay put around the outside of the socket, to keep the lead in; if the space is damp, some whale oil may be poured in first; the lead is poured in until the space is full; then the lead is caulked around with a caulking iron; the joint will then be tight.

GASKET JOINTS.

These joints are made with plaited spun yarn. They are used for boiler man heads or hand holes. They are plaited three strand flat, and sewed together at the two ends; white and red lead is used with them when they are screwed up. For a man head joint of this kind, it is best to cast a lead ring. Some sand is laid down level and smooth, and a wooden pattern is pressed into the sand, or the shape of the ring is cut out of the sand, as near as possible, and the lead is poured in. The ring is then taken out of the sand and filed up, or planed with a carpenter's plane. After the ring is got up in good shape, and about three-eighths of an inch thick, or less, it is wrapped around with hemp packing yarn, and white and red lead covered over it, when it is screwed up.

ERECTING A PERPENDICULAR.

To erect a perpendicular, or to draw a line at right angles with another line:

On each side of the point from which the line is to be drawn, take equal distances, and from these distances, as centres, describe lines that will cross each other at any convenient distance from the given line.

The point where the lines cross each other will be at right angles, or square, or perpendicular with the first drawn or given line.

AREA.

Area means the superficial contents of any figure. To find the area of a square plate, say ten inches each way: multiply the length by the breadth; the length and breadth being equal, ten multipled by ten gives one hundred square inches of area. Make this square plate circular, by describing a circle around the four sides, and cutting off the corners. The plate will then have neither length nor breadth—it being round—but it will have diameter and circumference.

Circumference means the outside of the circle or the line that bounds the circle, or the periphery.

Diameter means a right line through the centre of a circle, dividing it into two equal parts.

To find the area of a circle, multiply the diameter by the diameter. This plate being ten inches in diameter, ten by ten gives one hundred; but, the corners being cut off, the area is one hundred circular inches. This must be brought to square inches by multiplying by the decimal of .7854, which will give 78.5400 square inches. The area is found in this way, whatever size the circle may be.

TO CALCULATE THE POWER OF A STEAM ENGINE.

A horse power is equal to 33,000 pounds weight raised one foot high in one minute. Therefore, multiply the area of the piston in square inches by the pressure of the steam and vacuum in pounds (as shown by the indicator), and by the number of feet the piston travels per minute, and divide by 33,000; the quotient is the actual horse power of the engine, after deducting one-tenth for friction, or power used in working the engine.

THE DYNAMOMETER.

This is an instrument used for the purpose of ascertaining the pressure given out by the shaft of a screw propeller. It is also used to ascertain the tractive force of side wheel steamers, and the traction on railroads. It is constructed with levers and a spring balance weighing machine. A pencil and a piece of paper is so arranged that the variation of pressure is marked by the pencil on the paper as the shaft revolves. This instrument is not used by engineers—only by some constructors of engines, or in dock yards.

THE BOILING POINT.

In the open air, fresh water boils at 212° of heat, by the thermometer; salt sea water, at 213°; sugar, at 236°. Fresh water will boil in a good vacuum, at about 90°. Sugar boils in the vacuum pan, at from 150° to 160°.

CONCLUSION.

In order to give satisfaction to his employer, an engineer must be industrious and careful.

All the tools should be kept in their places and in order. Wrenches should be made the right size of the nuts, so that the corners will not be injured. Packing yarn and tallow should be kept in clean places; lamps ready trimmed; portable forge and blacksmith tools kept in readiness, with plenty pieces of iron handy for different jobs; blocks, tackle, and slings kept in a dry place, and coiled up; and all parts of machinery kept clean.

The engineer should be able to rig up a purchase, or sling a heavy piece of work, in order to get it out quick.

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