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A Motor Boat Model

"In the making of little models of this kind, you will encounter many things that will tax your skill and ingenuity, as amateur workmen."

The Library of Work and Play

MECHANICS, INDOORS AND OUT

BY FRED T. HODGSON

GARDEN CITY NEW YORK
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1911

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PART I

I

A PATHWAY OF CEMENT

"I DO wish papa would buy the land from Mr. Breigel. The weather will soon be fine enough to play out of doors!"

So said Jessie Gregg, a rosy-cheeked girl of twelve, to her eldest brother, Fred, one evening in March, as they stood in the porchway of their home, situated near the bank of the Passaic River, a few miles from the city in which Mr. Gregg had his business offices.

"Why, Jessie," said Fred, "papa told me this morning, at breakfast, he expected to close the deal, that is, get the deed of the property, this afternoon. I am just as anxious as you are to have the matter settled, for if he gets the land, I will have a lot of work to do, and I want to commence it right away. The land must be ours, for papa is later than usual this evening. Oh! there's the train just coming in; he will be here in a few minutes, and then we'll know."

"Oh, Fred! he and George are coming now. I see them at the turn of the road. I'll run to meet them." Away she scampered, and almost upset her father by jumping into his arms, as she was quite a plump, husky girl and evidently a pet, for her father kissed her fervently as she slid from his arms to the ground. Then the three trudged homeward.

"Jessie," said George, a younger brother, "I have a secret for you if you won't tell Fred, until papa has told him.

"What is it?"

"Papa has bought the land, and has got it in his pocket."

"Oh! I am so glad," said Jessie, "but how can he have it in his pocket."

"George means that I have there the papers, deeds, conveyances, and receipts, giving me the sole ownership of the land, and all that is on it, including the trees, old barn, and other structures; so, girlie, you can get down to the river now without having to climb a fence."

Fred met his father on his arrival at the house, but was too well behaved to ask him about the land, though he was as anxious to know as he could be. His father saw the boy's anxiety and after tea asked him to go with him into his den, a little room nicely fixed up some time previous, containing many articles of wood, brass, and plaster of Paris, Fred and George had made during the past winter. Jessie, also, had contributed many little things toward the decoration of "the lion's den," as she called the room into which her father retired to have his evening smoke, to take a friend, or to do a little private business.

When seated, Mr. Gregg called Fred to his desk, and talked over some home affairs before he said: "Now, my boy, since I have secured the property behind us, as you children desired, I shall expect you and George to help by your labour, and by the knowledge you obtained at the training school, in making the improvements on the land and the water front we have talked of so often. I am sure, with my advice and assistance, you will be able to do most of the work, or at least to superintend it in such a way that the labour and expenditure will not be wasted. You know, Fred, I am not a rich man, so cannot afford to waste money on experiments."

"Indeed, father," said Fred, "I will do all I can. You may count on my giving my best attention to whatever work and improvements you entrust me with."

"That is well said, my boy, and what I expected from you. We will begin operations by putting down a cement pathway from the walk now leading to the house from the street, and continue it to the river, where you must build a small boat house and workshop, as I intend either to purchase a small gasoline launch for our own use, or have you build one, if you feel equal to that."

"Oh! father, you are so good," said Fred. "There is nothing I'd like better than to do this work, and particularly to build a boat. I'm sure I can do that with your help and advice. As to putting down the pathway, that I can do very well, after my good training in cement works."

"All right, my son. We'll see in the morning what old material we have on the two places which can be used. There must be quite a quantity of lumber, timber, bricks, hard mortar, and plaster in and about the old barn and the smaller buildings."

The next morning George evidently had something on his mind, and seemed to be on the point of explosion. Mrs. Gregg noticed this and said to him, "Why are you so restless this morning? Why don't you finish your breakfast?"

"Oh! mother," he exclaimed, "I am too glad. I am so full of the good things Fred told me last night and this morning I haven't any room for breakfast."

"What did Fred say to you?" asked the mother.

"Oh! he told me he was going to build a cement walk right from the door here to the river, and do lots of other things; and best of all, mother, he is going to build a boat, a real boat, that will be driven by a gasoline engine, just like Walter Scott's. That will be glorious! I can take you and Jessie up the river to Belville to see aunty, whenever you want to go."

"Very well, George; we will see about that after the boat is ready to take on passengers."

Breakfast over, the whole family walked out to see the newly acquired property. They had all seen and walked over the grounds often, but never before with that feeling of pride in ownership which possession creates.

As there could be no objection to the removal of the line fence between the newly acquired property and the homestead, Fred got a handsaw, and cut down a part of it, making an opening some nine or ten feet wide, so that all could pass into the new place without climbing or stumbling.

The old barn was the first thing examined, and it was found to be in a state of good preservation, and quite large. It had been built — perhaps in Colonial times — of heavy timber, oak, chestnut, and pine, and it contained enough timber and lumber to build two or three small cottages. There was a big pile of broken bricks and mortar lying against one side of the barn; and another large pile of bowlders, or field stones, near the fence. "These," Fred said, "will be fine to build a little landing place or pier for the boat. The broken bricks and hard mortar will make grand stuff for the foundation of the cement pathway."

There were also two or three small buildings on the place. One had been used for a poultry house, another for a tool house, and a third seemed to have been a sort of cattle shed. Mr. Gregg suggested their removal, of which all approved.

There were quite a number of good-sized trees on the grounds, and these rendered it a little difficult to set out a straight line to the river for the cement walk, without cutting down several, which could not be considered. There was one direction, however, that would admit of a walk, about four feet wide, but there were some big rocks or bowlders in the way, that would have to be removed before a straight path could be made. Still it was decided to put it there.

"The rocks," said the father, "can be removed by blasting, by lifting them out of their beds and rolling them aside, or moving them down to the river, where they will form a good protection against both current and ice."

"I think they can be moved," said Fred, "if I can get levers and rollers; and they will make fine breakwater stones."

Jessie found two suitable trees, upon which Fred promised to put up a strong rope swing, as soon as the place could be cleaned up and made tidy.

"Now, Fred," said the father, "this cement walk should be commenced at once, so that it will be dry and hard before you go on with other work. I will employ a labouring man to help you, one who will do the heavy work, as I do not want you to over-exert yourself. You have a number of tools now in the shed, and, when I come home from the office this evening, we will make out a list of the other tools and materials you will require to finish the intended work. In the meantime you and George can be making a number of wooden stakes, about eighteen inches long and two inches square. Point them sharply at one end so that they may be driven into the ground their whole length. You will require thirty or forty of these. After getting them, take a clothes line, old halyard, or any rope or heavy string your mother can find for you, and stretch it from the house down to the river, at the point we decided upon. Drive in a stake near the river, tie one end of the rope to it, pull tightly, and stretch the rope from the river to the house. It will then show you where one edge of the walk is to be. After that is done, get another rope or string and, starting from the house end of the walk, measure off four feet for the proposed width. Drive in a stake at that point, and tie one end of the second rope to it; then go toward the river with the other end, making the rope extend the whole length of the path and drive in another stake which must be four feet from the first rope. To this stake tie the end of the rope and make it tight. Be sure to have the two ropes exactly four feet apart at each end, as well as along the whole length. You will find it to your advantage to get a straight strip of wood, say, one or two inches thick both ways, and cut it exactly four feet long. It can then be used as a measuring stick or gauge, for the distance between the ropes, which is to be the width of the walk, and by using it you will have a parallel and uniform path from start to finish."

Mr. Gregg had passed an examination in the

Massachusetts School of Technology, and had won a position as civil engineer in New York which later he abandoned for the profession of law; hence his knowledge of practical mechanics and engineering.

After Jessie and George had gone to school, Fred started on his new undertaking with enthusiasm. He found quite a number of pieces of wood, out of which he made over forty stakes, and pointed them nicely with the large hatchet he always kept sharp and in good order. By tying several pieces together, it did not take him long to find cord enough to set out the whole walk. An old halyard that had been taken from the flag pole and replaced by a new one answered the purpose admirably. Driving a stake into the ground, near the house, he tied one end of his cord to that, and stretched it down to the river bank to the point chosen for the end of the walk, where another stake was driven in and the cord tied to it. The long stretch between the two stakes would not allow the cord to be tight enough to make a straight line between the two points, but Fred left it as it was, to be adjusted when his father came. With his rod he measured off four feet from the first stake, across the intended path, and drove in another stake to which he attached another cord. Then going down to the river he measured off the width of the walk from the long cord, and drove in another stake. He was now ready to have his father examine the work he had done, and to make suggestions or changes if such were deemed necessary.

Jessie and George arrived home from school, having run most the the way, "to help Fred make the walk," and were quite disappointed to be told there was nothing they could do until the work was further advanced.

"We might, perhaps, commence taking down the old buildings," said Fred, "and pile the lumber where it will be snug and dry."

"All right," said George; so the three of them went over to the poultry house and Fred began by taking out the two or three small windows, and removing the doors by unscrewing the hinges. George's desire to pull, tear, and smash the old material was held in check by Fred, who advised him to be careful, and not break or destroy anything that could be used. After the doors had been taken off and laid nicely away —"to be used on the boat house"— and the windows and frames placed in a dry spot, Fred began to remove the old siding, or clapboards. He found this a rather difficult job, as they were nailed on with old-fashioned wrought-iron nails which could not readily be drawn, and, in trying to get the boards loose, the ends kept breaking and splitting; so he stopped, went inside the building, and took off the lining there; this also was a little difficult to do, but, as the boards were an inch thick, he did not split many of them.

He then sawed off the boards alongside the studs, on the corners, and at the doorways to relieve the siding at the ends, and give him a good chance to wedge off the boards wherever they were nailed. With the help of George, he succeeded in getting most of them loose without serious damage. Of course, he had to begin tearing the boards off at the top of the wall, as they lapped over each other like the scales of a fish.

Mr. Gregg arrived, went over the ground, and was well pleased with the results of Fred's day's work. He assisted in straightening the long cords, and made a number of suggestions for the boys to follow. He had a strong-looking man with him, who he told Fred was to help him. He was an Italian, named Nicolo, called "Nick" for short, a kindly fellow, who could speak English fairly, for he had been employed in Newark, as a handy labouring man for years. He, Fred, and George soon became good companions, and even Jessie, though a little shy at first, soon became quite friendly toward him. When it was explained what was wanted of him, he was quite satisfied, and agreed to begin work in the morning.

Next day Fred and George were at work before their father was out, and soon Nick arrived, bringing a spade, a crowbar, and a pick. He was immediately set to work by Fred, digging a shallow trench for the pathway, a little over four feet wide and about eight inches deep. The stretched cord and the four-foot rod were the guides.

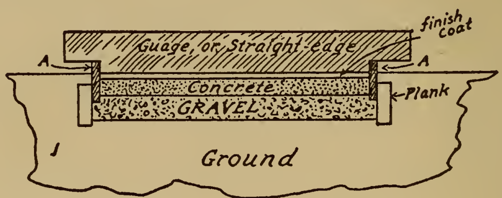


Fig. 1. Section of sidewalk

There were a number of rocks to be removed from the trench, one of them near the river bank weighing over a ton. These were left to be removed later. Their father, on coming out, was glad to see them all at work; he showed Fred and Nick how to prepare the edges of the trench by putting planks along them, as shown in Fig. 1. The boards, about twelve inches wide, and from twelve to sixteen feet long, had been taken from the old barn.

After breakfast Fred worked along with his man, and got the trench well cleaned out, except for a few of the larger rocks. The smaller bowlders were wheeled down to the river and rolled over the bank to the water's edge. Near one side of the walk grew a large tree, whose main root ran under the proposed path. Mr. Gregg had noticed this in the morning and had told Fred to see that the root was cut off close to the line on both sides and pulled out altogether. "If it isn't cut off, it will grow larger, lift up the cement flags, and perhaps break them." Fred saw the force of this, so had the root cut off and taken out. The operation would not kill the tree, though it might do it some injury.

Now came the process of taking out the big stones, and a lever, ten or twelve feet long, was brought from the barn, in the shape of a red cedar pole, five or six inches in diameter at the larger end. Nick took an axe and chopped the big end a little flat on two sides, so that it could be shoved under the stone. A flat plank was next laid behind the stone on the ground, on which a fulcrum was to be placed, in order to get what is termed by workmen a "purchase." On the side of the stone next to the river, three planks taken from the floor of the barn were laid down flat at the bottom of the trench. Three other planks were laid on the top of the first layer, thus making a bed in the trench, two planks in thickness, on which the big stone was to be rolled. A fulcrum, consisting of an old fence post, was laid upon the plank, and forced up as close to the stone as possible. Everything was now ready for lifting the bowlder out of the bed, where it had lain perhaps for thousands of years.

As had been arranged, the work at this stage was suspended, and other work gone on with, until Mr. Gregg made his appearance. Upon his arrival all hands went to the stone, Jessie included. Having approved what had been done, the father suggested that rollers be placed between the two thicknesses of plank to increase the ease of moving the stone to the river when it was started. Fred and Nick went to the barn, and among a big pile of old planks, boards, and timber found eight or ten old fence posts, six or eight inches in diameter, and long enough to make two rollers, each three feet long, when cut in two. These were quickly stripped of bark by George and Jessie, while Nick and Fred, with axe and hatchet, soon had a number of them round enough to serve as rollers. The father then directed that the ends nearest the river, of the top layer of planks, be raised up, and one of the rollers placed between the two layers of plank near the stone, while the ends of planks nearest the stone should be left resting on the bottom ones. Another roller was placed nearer the river end of the planks, and all was made, as shown at Fig. 2 — where fulcrum, lever, stone, planks, and rollers may be seen.

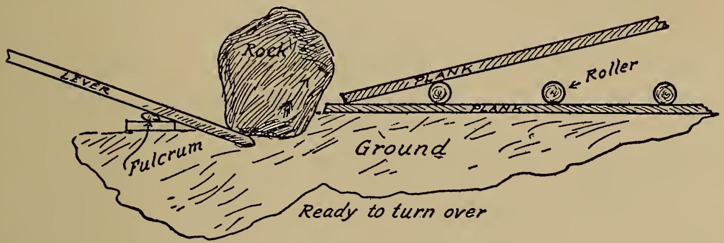


Fig. 2. Raising rock with lever

All was now ready; the lever was adjusted in place under the stone and on the fulcrum. Mr. Gregg, Nick, and the children were gathered about the lever, each one pushing down, and the stone began to move, as the top end of the lever came down, much to the delight of Jessie and George, who kept shouting, "There she goes! Up she goes!" Finally the great stone turned over on the plank, and was moved to near the centre. Now came the labour of getting the monster down to the bank. This was made easier by raising the ends of the upper planks under the stone and inserting another roller, five or six feet from the end. The planks holding the stone were now resting on rollers, as seen in Fig. 3, and it was found easy to move, but in order to get it to the bank of the river the "runway," or lower planks, had to be laid down that distance; this would take too many planks, so it was decided to lay only a second length

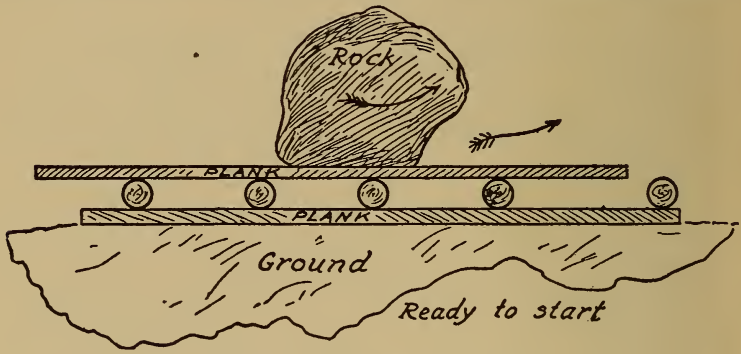


Fig. 3. Moving rock on rollers

on the ground, and then when the load had travelled to this length, the plank behind the stone should be carried forward and laid down again. This was continued until the load was slid into the water. Mr. Gregg called the children and told them to push against the stone, and they all were filled with wonder to see this great stone move along so easily on the rollers.

Fred and Nick got more rollers to put between the planks as the stone was pushed forward, for, of course, these were continually coming out at the rear end of the loaded planks. The rollers had also to be watched and kept square across the plank or they would slide, making it hard to move the load.

When the river bank was reached, Fred and Nick made a rough slide of old timber down to its side from the trench. Getting the lever properly adjusted under the planks and stone, the latter was turned over on the slide, when it plunged into the river with a great splash, causing the water to fly and sprinkle each one of the workers, much to the delight of George, who thought it fine fun to see his father, Fred, and Nick get a wetting.

It was decided that the stone as it lay in the water should form the end of the pier for the boat, as it was nicely situated and the proper distance out, being about a foot out of the water at high tide. The other stones were easily removed from the trench by Fred and his man, and were either rolled or wheeled down to the river, where Nick built them as well as he could on both sides of the big rock, leaving a hollow space between the walls, to be filled in afterward with small stones, mortar, and broken bricks, for the making of a good, strong boat pier.

Mr. Gregg then took out his note-book and pencil, and figured out the quantity of cement, sand, and gravel required to complete the cement work. He found there was good sand, clean and sharp, on one corner of the new lot. A big pile of gravel and broken stones out on the street had been left over from the building of a two-story concrete house nearby, so he concluded to buy it, if not too dear.

Measuring the trench, he found it to be 300 feet long, by 4 feet wide, making a surface of 1,200 feet to be laid with cement, concrete, and gravel, or broken stones. He calculated that every 100 superficial feet of the concrete walk would require about a barrel and a third of Portland cement; and that the top dressing of cement and sand, or fine crushed stone, required another third of a barrel; which totaled up to 20 barrels, all told. The concrete to be used was to be proportioned as follows: One part of cement, two parts of good, clean sand, and five parts of gravel, or broken stones, which should be small enough to pass through a ring having a diameter of not more than two inches. This mass should be well mixed, dry, on a wooden floor or movable platform, and then wetted just enough to have stones, sand, and cement, well moistened. All should be again mixed before being placed in the trench, and it should not be thrown in place, but shovelled in gently.

Mr. Gregg ordered the cement by telephone, to be delivered at once, either in barrels or bags; and he got into communication with the owner of the gravel, and bought the whole pile. He then engaged a team of horses, wagon, and driver, to commence work the next day. By this time Nick had gone home, and the children came rushing into the house, anxious to tell their mother all the work they had done that day.

The keen appetites of the younger folks gave positive proof of their having earned their supper, by actual work, and, when the meal was over, the father invited Jessie and the boys into his little room. George was asked to take with him his portable blackboard, some chalk, and a ruler, and all marched into their father's den.

"Now," said Mr. Gregg, "I have often told you I would explain to you some things about the mechanical powers, and this seems to be the most appropriate time to begin, as you have fresh in your minds the application of the lever as we used it to-day in raising and moving the big rock. I am glad to see that Fred grasped the idea so readily, for that encourages me to let him use his own judgment while doing this job.

"The lever is known to accomplished mechanics, as 'the first mechanical power', and Archimedes said of it, if he only had one long and strong enough, together with a suitable fulcrum, he could, alone, lift the earth from its place.

"This Archimedes was a celebrated Greek philosopher and mathematician, who lived from about 287 to 212 B. C. The discovery of the law of specific gravity, which I will some day tell you about, is attributed to him. I think George can tell you something about this great man, as I saw him and Jessie the other day reading Plutarch's 'Lives,' in which he is mentioned.

"A lever may be formed of any strong, stiff material, wood, iron, steel, or similar stuff, and it may be of any length, or dimensions, according to the purpose for which it is to be used. In theory, it is supposed to have no weight, and is simply figured as a straight line having neither breadth nor thickness. In practice, however, a lever may be a handspike, a pry, a crowbar, a fire poker, a windlass bar, or any other appliance or instrument that can be used for prying. While we may not know the proper name of the little steel tool the dentist employs when preparing one's teeth to receive the filling, by cleaning out the cavities, we are safe in calling it a small lever. When your mother stirs the fire in the grate, she makes a lever of the poker, and bars of the fireplace become fulcrums. The fulcrum is the fixed point on which the lever rests when in use. The force applied is called the power and the object to be acted upon is called the weight. The spaces from the power and the weight, respectively, to the fulcrum, are called the arms of the lever. There are three different ways of using the lever, according to the relative positions of power, weight, and fulcrum. This rough sketch I am drawing on the blackboard (Fig. 4) shows the lever being used to raise

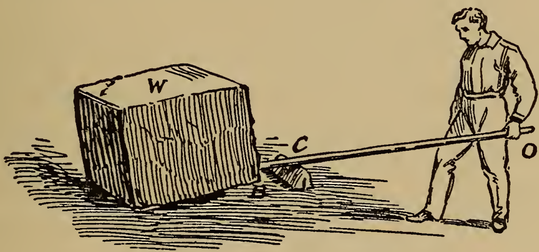


Fig. 4. Principle of lever and fulcrum

one end of a heavy stone. Suppose W is a big rock, C will be the fulcrum, B the end of the lever under the stone, and O the power. The weight thrown on the lever by the man at O, raises the stone so that it can be blocked up, the lever and fulcrum arranged for another lift, and the process repeated. This can be continued until the stone is raised to the height required, or until it is turned over. This method applies to the raising of any sort of weight, engine, boiler, heater, etc.

"In this sketch the distance from B to C shows the short arm of the lever, and the distance from C to O shows the length of the long arm.

"A lever, used in this way, is called a lever of the first kind, because of its simplicity and easy adaptation to many purposes. I saw George digging in the garden the other day, making a flower bed for his mother. The spade he used formed an excellent lever. He forced it into the ground to its full depth, pried the handle toward him, and broke loose the soil, after which he turned over the earth in the bed. Now, in this case, the top of the blade or foot-plate of the spade, rested on the hard ground, which was the fulcrum; the soil dug up was the weight, and George's hand at the top of the spade handle, furnished the power. I am sure you all understand the working of a lever of this kind, but I will give you another illustration.

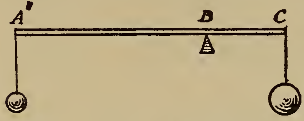


Fig. 5. Lever as a mechanical power

"Here's another sketch (Fig. 5), in which A,B,C, together show the lever, also the power A, the fulcrum B, and the weight C. If I should place the fulcrum B so that it would be in the middle between the ends A C, there would be what is termed an equilibrium between the weight and the power, and if they are equal there will be a perfect balance maintained. It is on this principle that scales for druggists are made, the lever being suspended in the centre of its length, as I show in the sketch (Fig. 6). These scales are very nicely adjusted, and the chains and receivers are made as nearly alike in weight as possible. The arms of the lever being of equal length from the centre, or pivot, permit the lever to stand in a perfectly horizontal position, unless disturbed by having a weight placed in either one or other of the receivers. In this case, the pivoted point P is the fulcrum, and the two points O and X may be taken as the power and the weight. If one pound is placed in the receiver at O, it will tip the scale down, and that will become the weight, while any commodity placed in the receiver at X, until the lever is again brought

Fig. 6. Double lever as scales

level, or horizontal, may be called the power. As another illustration I'll tell you of something that took place the other day. In the vacant lot are several piles of bricks, stones, and planks. George, seeing this, took one of the planks and threw it across several others, making a 'Teeter Tauter,' or, as some children call it, a 'Seesaw.' He balanced the plank nicely, and then invited Jessie and her cousin to sit on it, one at each end. The two girls were about the same weight, and George held the plank until both were seated. It remained level and balanced, until George got on the top of it, and stood on the centre of its length, placing his feet so that one was on one side of the centre, or fulcrum, and the other on the other. By causing his weight to rest on his right foot, the right end of the plank would dip downward; then by throwing his weight on his left foot, the movement of the plank would be reversed, and the motion continued until George ceased to exert any extra pressure on either of his feet. What do you call the boy or girl who stands on the plank?"

"Sometimes," said Jessie "we call him a 'candle-stick' and sometimes 'the balancer'."

"This teeter tauter and the explanation of the druggist scales," said the father, "show you that many of our conveniences are due to the lever in one way or another. These are but a few of the thousands of instances I could name. Take a nut-cracker, for instance. There we have a sort of double lever, the joint being the fulcrum, the nut the weight, and the two handles the combined power or lever. By pressing the handles or levers, we crack the nut or overcome the weight, by crushing it. We owe many of our amusements to the lever in one form or another. Even our pianos would be impossible were it not for the combination of levers in the adjustment of the keys. Machinery and all kinds of moving instruments, including watches, clocks, and other fine mechanism, could not be perfected without the lever. The common every-day wheelbarrow is a good illustration of the use of the lever combined with the wheel. George fills up his barrow with stones or other materials that weigh two or three times the amount he could lift easily. Yet he gets away with the load, apparently with very little trouble. The handles form the lever or power, the wheel the fulcrum, and the stones the weight. George raises the handles, and throws the greater part of the weight on the fulcrum, which is the wheel, and this latter, acting as a roller, is easily moved around its own axle, thus enabling George to move his threefold load with ease.

"This example shows you how, by a simple combination of mechanical devices, labour may be reduced. The roller is related to the wheel and axle class — another of the mechanical powers.

"In your bicycles you have a fine illustration of the application of the roller principle, in the ball-bearings. The little round balls, over which the axle of the wheel runs, are simply rollers rounded in every direction, and placed there to destroy friction, which they do almost entirely.

"Another excellent illustration of the use of the roller is seen in the hanging of the grindstone we have in our back shed. The axle passing through the stone rests on two pairs of wheels or rollers, one pair at each side of the stone. If you turn the stone on its axis, you will notice the wheels turn also, and the effort required to turn the stone is hardly noticeable. If the grindstone were well balanced and true, and the little wheels the same, so that they could be run without friction on their bearings, the stone, by giving it one good turn with the hand, would keep revolving a very long time. So you see how much we are indebted to the mechanical powers for our present state of civilization."

Next morning being Saturday, George was up early, put on a pair of overalls his mother had bought, and, when breakfast was over, all but the mother went out to the new property. They found Nick helping a teamster to unload gravel, also a load of cement, which was placed in a dry and convenient place, for once damp or wet in the least it becomes of little use, unless worked up immediately. George was full of glee. He got his wheelbarrow and wanted to commence work without delay. The father took Fred and Nick to the trench and explained what was to be done and the way to do it. "The trench is now eight inches deep," he said, "and you must wheel gravel, broken bricks, hard mortar, or cinders into it so that there will be about five inches of it in the trench from one end to the other. Put all the larger stones at the bottom, but before throwing in any, tamp or pound the ground at the bottom of the trench until it is solid and hard, making a good bottom for the stones to rest on, and ensuring the walk from settling or sinking in spots. Where the big root and rocks are taken out, the holes must be filled up level, and tamped solid. Rake off the largest of the gravel, and let George wheel as much of it as he can, and dump it in the trench, while Nick or you wheel in the balance. Finish the top of the gravel off with smaller sized stones, and after you have filled in about five inches, throw water on the whole with the garden hose until quite wet, and then pound the gravel down until it is compact and firm. This bed forms a good foundation for the concrete which must be laid on it about four inches thick, and well tamped.

"After you have raked off the larger gravel, take a wire sieve, with meshes not larger than four to the inch, and sift the finer gravel out, to save for the top finish. Before filling in the concrete, strips of wood having straight edges on top must be nailed to the stakes on both sides of the walk, as I showed you on the blackboard in Fig. 1, marked A A. These strips must be placed at proper grade in their length, and level across from one to the other. A straight edge made of wood, and long enough to reach over the walk, and the strips as well, must be provided, and it may be notched out as I show at X, in Fig. 1. This straight edge is to be used in levelling off the top or finishing coat, by keeping both ends on the strips A A, and moving it along lengthwise of the walk. If the top of the walk is to be below the edges of the strips, you may notch the ends, as shown, to suit whatever depth may be required."

Fred told his father he thoroughly understood the process as far as explained, and the latter then left. By this time Nick and George — and, we might add, Jessie — had wheeled into the trench quite a lot of gravel, but for the want of a proper "tamper" they had to stop. So Fred cut two pieces off a fence post, each about a foot long, and with an auger or boring tool, made a hole in the centre of the end of each, about eight inches deep, into which he inserted a round wooden handle, about three feet long. These made excellent "tampers," not too heavy for George to use. Jessie, persuaded Fred to make her "just a little one," but he told her not to use it much or her hands would get sore and too stiff to practise her music.

The strips for the stakes were prepared, nailed on, and properly adjusted, and then it was time to commence the real work. Nick had nailed some boards on three pieces of scantling about six feet long, which made a good mixing table for the concrete. This was carried up near the top end of the walk, and placed where it would be handy. A pailful of cement was put on the board, next two pailfuls of nice clean sand, and then five pails of gravel that had no stones in it larger than would pass through a ring having a clear diameter of two inches. All this gravel, sand, and cement being in one heap on the board, Fred and Nick worked at it steadily for more than ten minutes, mixing it up until the sand and cement were thoroughly and evenly blended with the gravel. Fred then sprinkled the mixture with clean water from the hose, while Nick kept shovelling it over and over until the whole was damp, but not so much so that the cement and sand were washed from the gravel. The whole mass looked like a pile of dirty stones that had just been under a light shower.

"This," said Fred to Nick, "is a very important process, for if we make the stuff too wet, it will starve the concrete by washing away the cement, and if we leave it too dry the work will be rotten and crumble away."

Fred might also have added that the proper proportioning of the materials was as essential as the proper mixing, and in this case, where we are making it one of cement, two of sand, and five of gravel — all by measurement — we must adhere closely to the rule or the walk will be uneven in texture and colour.

The concrete being properly mixed, Fred and Nick began to shovel it into the trench, spread it to about four inches in thickness, and tamped it down until the top mass looked sloppy and muddy. While in this condition, a new lot of cement mixture was made, consisting of one part of cement and two parts of sand and the fine of the gravel that had been sifted. All were mixed thoroughly while dry, and afterward wet to the consistency of thick mortar. This was spread over the concrete to about one inch in thickness and levelled down by the notched straight edge until the proper thickness and level were obtained. The surface was then ready to smooth, or "float," as the workman calls it, which always gives to the top of the work a nice, even, level appearance, and makes it solid and firm. The "floating" is done with a tool made of wood, as shown in Fig. 7, and may be finished off with a plasterer's steel float, merely to give the surface a better finish.

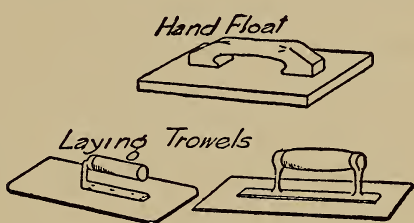


Fig. 7. Floats and trowels

The floating operation is laborious, for it must be done at once, while the operator is on his knees. Fred and Nick, however, worked away at it until they made a good job of the portion that they were putting down. All of the walk they could finish at one time was about sixteen or eighteen feet, so that the whole job required a number of days to complete.

The first instalment being done, so far as the floating was concerned, it was now in order to make joints in the walk across the face, firstly for the purpose of marking it off into flag sizes, four feet square; secondly to prevent expansion. If there were no joints made in the walk, it would "lift" up, crack, break, and ultimately be destroyed. Fred, who knew that the walk would contract in cold and expand in warm weather, explained this peculiarity to George and Nick, and having a "jointer" along with the floats which the father had sent, he, with Nick's help, ran some joints, at four-foot intervals, across the walk, while Nick pushed his spade through the joints to the ground, actually cutting cement and concrete into sections of four feet each. This would allow for expansion or contraction, and even admit the raising of some of the sections above the others, without cracks or breaks occurring.

The first instalment of the walk being made, it was left to George to wheel damp sand and scatter it over the face of the walk about an inch thick, to keep the sun and rain from injuring it.

Then he received instructions to wet the surface every morning for a week. At the end of two or three days the cement was hard, or "set" enough to bear walking on, and in a week it was cleaned off for use. One peculiarity about concrete or cement work is, that it improves and gets stronger with age.

The walk was complete in due time, in sections of about sixteen feet long, and proved quite satisfactory. Mr. Gregg was pleased with it, and he explained to Fred, George, and Jessie that it might have been made more ornamental, as there were many tools for rounding off the edges, indenting the surface, to make it less slippery, or for laying the flags off in panels; but in this case all were pleased with the way the boys had finished it.

II

BUILDING OF A BOAT HOUSE

THE cement walk being finished to the satisfaction of all concerned, and the admiration of the neighbours, Fred turned his thoughts to the building of a boat house and workshop. It was decided to make it 16 feet wide and 22 feet long, as these dimensions would suit the timbers in the old barn, and be ample for stowing away the boat and allowing space for a work bench.

Lines for a foundation were set out, and stakes driven in the ground at the corners, alongside the cement walk and pier. A trench about two feet deep was dug on the two sides and ends; and in this were laid large rocks and stones, in a single course all round. Nick, who was quite handy at this kind of work, built up a wall of smaller stones laid in cement mortar. This mortar was composed of one part of cement to five of sand, and made quite thin and easy to spread. When the wall was high enough, about level with the highest part of the ground, it was levelled off by using smaller stones and plenty of cement mortar. The level was obtained by laying a straight plank flat on the top of the cement finishing, and then applying an ordinary spirit-level. Any errors in the level of the wall showed at once, and were made right by adding more mortar, or by taking some off the top of the wall.

Timbers from the old barn were next pressed into service, chestnut wood that had served as girths and beams. Two pieces were cut, 22 feet

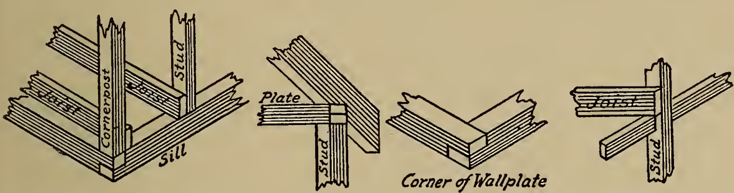


Fig. 8. Framing studding

long, and two of 16 feet. The ends were then halved, as shown in Fig. 8 — the simplest method of framing a corner — and the timbers were spiked and so squared as to make right angles at the corners.

Fred then took the old window and door frames, and measured off on the foundation timbers the outside distance where each one was to be placed. He put the double doors in the end of his boat house, next to the river front. The other door and windows were set in the best places to provide an entrance opening on the cement walk, light above the work bench, and views over the river and grounds. Fred decided to build his house ten feet high; so a quantity of studding, 2 x 4 inches in section, was taken out from the walls of the barn, and cut exactly ten feet long. These were to form the side walls between the corners,

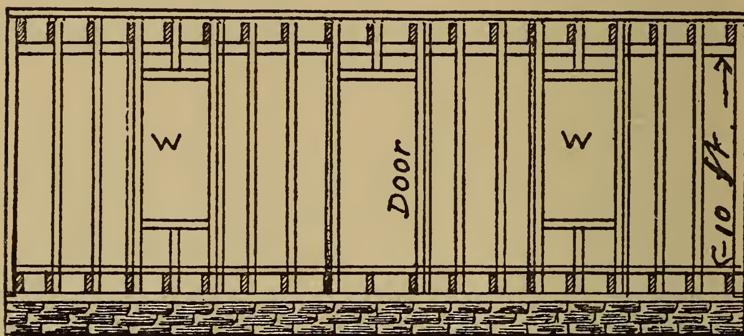


Fig. 9. Side of boat house frame

doors, and windows. Heavier studs were found in the barn, and Fred wisely used them next the windows and doors.

These heavy studs were set up in the places marked on the timber sills, also at the four corners, and were toe-nailed at the bottom to hold them in place. They were then made vertical or plumb, by aid of a spirit-level, and the corners were braced temporarily to hold them in that position. The picture (Fig. 9) shows how the side of the building next to the cement work looked when the studding was all in place. The dark ends shown are the joists on which the floor is laid. The lower joists were made from timbers taken from the barn floor, 2 x 8 inches wide and long enough to reach across the building. The joists on top were 2 x 6 inches, by 16 feet long. These latter floor beams were set about 15 inches apart, ready to receive the flooring plank, which was nailed solid to them. You will notice that cross pieces of studding are nailed between the studs at the window openings. These form the tops and bottoms of the window frames. The spaces above and below are also filled in with short pieces of studding, to nail the clapboards to, as shown. The ends of the

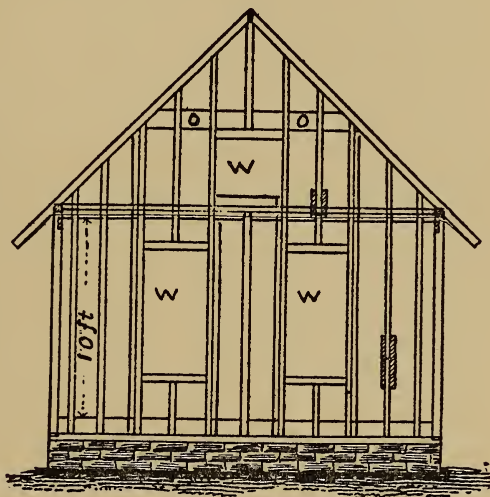


Fig. 10. End of boat house frame

building were finished as shown in Fig. 10, a small window being left in each to admit light and air, also lumber, poles, or other stuff that could be put into the loft through these openings. Inside the building a trapdoor was to be left, so that Fred or George could get up to take in or hand out the stuff.

The end (Fig. 10) shows how Fred and Nick, with George's help, built that portion, the collar beam, O O, and the rafter being seen, while the details in Fig. 8 give larger sketches of the manner of doing the work. The stone-work, as built by Nick, for foundation walls, is shown in both Figs. 9 and 10.

All the clapboards having been taken off the barn and old sheds, the better portions were selected for covering the outside of the new frame, and a lot of old boards were used for lining the inside of the walls and nailing on to the rafters. The next thing was to lay on the shingles. These had been provided some days before by Mr. Gregg, who had figured out the number required. He found the roof would measure 24 feet in length, including the projections over the ends of gables, and that the length of the rafters was 17 feet each, including the overhanging eaves or cornice. This made the whole stretch of length on both sides of the roof

34 feet. Multiplied by 24 feet, the length of the roof, this was 816 feet. To cover an area of 816 feet about 8,000 shingles would be required, as 100 surface feet require nearly 1,000 shingles, laid 4 inches to the weather, according to the usual custom. Mr. Gregg explained to Fred what is meant by the term "weathering," applied to shingles, clapboards, slates, or anything similar. The "weathering" part of a shingle is that portion of it exposed to the weather, when in place on the roof. It makes no difference how wide or how narrow a shingle may be, it is that portion showing from the lower end of one shingle to the lower end of the next one above it, that is the "weathering." This is generally four inches wide and it runs from end to end of the roof. Another thing Mr. Gregg explained — the term, "a square of shingling." "In this case, as in flooring, clapboarding or similar work, a square is an area 10 x 10 feet; or 100 superficial feet. In nailing down shingles," went on Mr. Gregg, "the nails should be driven so that the next course or layer will cover up the nail heads, thus protecting them from rain and damp, and preventing them from rusting. When laying the shingles, after the first courses are on, which should be laid double at the eaves, a string or chalk line must be stretched

from one end of the roof to the other, four inches up from the ends of the first courses. This string or chalk line may first be rubbed over with chalk or soft charcoal, and when drawn tight from each end, it may be 'struck' or 'snapped' by raising it up in the middle and letting it strike the roof suddenly so that a mark will be left on the shingles from end to end. This will be the guide for the thick ends of the shingles to be laid against when nailing on the next course, and the process must be continued until the ridge, or top of the roof, is reached. When you paint your boat house, don't forget the roof, for a good coat of paint on the shingles will lengthen the life of the roof fully five years."

Fred, to whom these instructions were more particularly given, told his father he understood the whole matter, and he was directed to go on with the work. In the meantime the father ordered the shingle-nails required; five pounds for each thousand shingles, or forty pounds altogether.

The building being small, the whole work was soon completed, windows put in, doors hung, and floors laid; and Mr. Gregg was greatly pleased with the manner in which Fred had managed the job.

The next thing was to take down the heavy

Photograph by Frank H. Taylor

BOAT HOUSE AND WORK-SHOP

"A Good Coat of Paint on the Shingles Will Lengthen the Life of the Roof Fully Five Years."

timbers of the barn, still standing. Fred saw at once that they were too heavy to be removed without mechanical aid or more human help, so he brought from his father's stable a rope and set of pulley-blocks like the ones shown in Fig. 11. Nick, who had seen some service at sea, hooked the block into a loop formed by a short piece of rope tied over a limb projecting from one of the trees. The question of lifting the timber now was an easy one, as another short rope was tied to the heavy post W, in this case the weight P being the power. Each of the blocks shown contains pulleys which make the relation of the weight to the power as one to four. The weight being sustained by six cords, each bears a sixth and a weight of six pounds will be kept in equilibrium by a power of one pound. The blocks used in a system of this character are called single if there is one pulley in each, double if there are two, treble if there are three, and quadruple if there are four.

Fred, George, Nick, and Jessie who liked to help whenever she could, counted for four times their number when they all pulled together on the rope P. It was astonishing to the youngsters how easily the heavy timbers were taken down and piled in a nice heap.

Two timbers, each about twenty-five feet long, were chosen and marked, to be used for slides or ways, on which the proposed boat could be hauled in and out of the boat house. It was quite a distance from the timber to the river end of the boat house, and, the former being heavy, Fred decided to make an inclined plane of planks — of which there was an abundance — so that the timbers could be slid or rolled down to the river. It took but a few minutes to lay the planks, and as the incline was gentle, rollers were used and the timbers went down as easily as the big rock had done. This pleased the younger children very much.

"When papa comes home," said Jessie, "I'm going to get him to tell me about the 'inclined plane' as well as the ropes and pulleys."

The two timbers were rolled into the river and floated to the boat house, where one end of each was raised to the floor level at the doorway and made fast; the other end sank to the bottom, where Nick dug down and made a bed for it to rest in. These beds were made deep enough to bury the ends, and large stones were then thrown in to keep them from moving, but these were not allowed to reach within 18 inches of the surface of the water, which was then at its lowest mark. The timbers were kept about three feet apart, ample space to admit of any ordinary launch or row boat being taken into the boat house.

"Oh, Fred," said Jessie, "do you think those two sticks will be strong enough to hold the boat while you are pulling it up?" "Why, yes; strong enough to hold a dozen boats no larger than the one we intend having made. I don't know how much weight these timbers will support, nor how heavy our boat will be with the engine in it, but I'm sure the timbers are strong enough."

Jessie's question, however, caused Fred to think over the matter, and he set to work to find out how to tell the strength of timber beams. He discovered that to be able to determine the strength of beams and wooden pillars under all sorts of conditions required considerable training in mechanics and mathematics, but that the case before him was comparatively easy. A general rule for finding the safe carrying capacity of wooden beams of any dimensions, for uniformly distributed loads, is to multiply the area of section in square inches, by the depth in inches, and divide their product by the length of the beam in feet. If the beam is of hemlock, this result is to be multiplied by seventy, ninety for spruce and white pine, one hundred and twenty for oak, and one hundred and forty for yellow pine. The product will be the number of pounds each beam will support. For short-span beams, the load may be increased considerably. Fred, who had some knowledge on the subject, acquired at the training school, determined to pursue his studies in this direction.

In talking over the matter of nails with his father, their holding power was mentioned, and Mr. Gregg told Fred of a test that had been made some time ago by the U. S. Ordnance Department, where cut and wire nails had been tested respectively, showing a decided superiority for the former, both in spruce, pine, and hemlock. Thus in spruce stock nine series of tests were made, comprising nine sizes of common nails, longest 6 inches, shortest 1⅜ inches; the cut nails showed an average superiority of 47.51 per cent.; in the same wood six series of tests, comprising six sizes of light common nails, the longest 6 inches and the shortest 1⅛ inches, showed an average superiority for cut nails of 47.40 per cent.; in 15 series of tests, comprising 15 sizes of finishing nails, longest 4 inches and shortest 1⅛ inches, a superiority of 72.22 per cent. average was exhibited by the cut nails; in another six series of tests, comprising six sizes of box nails, longest 4 inches and shortest 1¼ inches, the cut nails showed an average superiority of 50.88 per cent.; in four series of tests, comprising four sizes of floor nails, longest 4 inches and shortest 2, an average superiority of 80.03 per cent. was shown by the cut nails. In the 40 series of tests, comprising 40 sizes of nails, longest 6 inches and shortest 1⅛ inches the cut nails showed an average superiority of 60.50.

Speaking of the ropes used in blocks, while taking down the old barn timbers, Mr. Gregg suggested that it would not be a bad idea if the boys were taught a few general items concerning hempen ropes; so he asked them to memorize the following: A rope ¼ inch in diameter will carry 450 pounds, and 50 feet of it will weigh one pound. If ⅝ inch in diameter, it will carry 3,000 pounds and 7 feet will weigh one pound. When a rope is ¾ inch in diameter, it will carry 3,900 pounds, and 6 feet will weigh 1 pound. A rope one inch in diameter, the same as we have in our blocks, will carry 7,000 pounds, and 3 feet 6 inches will weigh one pound. "It is not likely that sizes greater than these will ever be used by you. If they are, you can obtain a fair knowledge of their strength by finding their areas, and comparing them with the areas of the ropes given, taking the rope having one inch in diameter, as a constant example."

Wire ropes are much stronger than hempen ones, whether made of steel, brass, or bronze. The care and preservation of ropes is deserving of consideration, particularly in localities where the atmosphere is destructive to hemp fibre. Such ropes should be dipped when dry into a bath containing 20 grains of sulphate of copper per gallon of water, and kept soaking in this solution some four days, before they are dried. The ropes will thus have absorbed a certain quantity of sulphate of copper, which will preserve them for some time, both from the attacks of animal parasites and from rot. The copper salt may be fixed in the fibres by a coating of tar or by soapy water. In order to do this the rope is passed through a hot bath of boiled tar, drawn through a ring to press back the excess of tar, and suspended afterwards on a staging to dry and harden.

The figures given are intended for new manila ropes, and do not hold good for ropes made of inferior hemp. It is always safer never to load a rope to more than 60 per cent. of its capacity, and not even this much when it is old and weathered.

Jessie reminded her father of his promise to give them some information regarding the power of blocks and tackle and the qualities of the inclined plane. Accordingly, Fred, George, and Jessie joined their father in his den after supper, and George placed his blackboard in a convenient place with chalk, rule, and other requisites.

When all were seated, the father said: "Some time ago I tried to explain to you the uses of the lever in quite a number of different situations; to-night I'm going to show you how the various ropes and pulley blocks are made to do service for mankind. These devices are used very generally, especially in building operations, where heavy beams, girders, or blocks of stone have to be raised. On board ship, it is the favourite mechanical power by which rigging is raised, cords and ropes tightened, and goods lifted from or lowered into the hold.

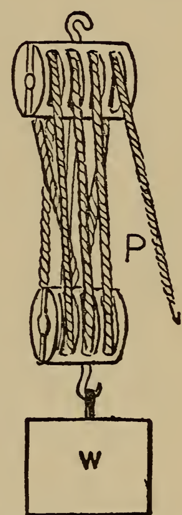


Fig. 11. Blocks and tackle

"The pulley, the main feature of the third mechanical power, may be explained almost on the same principle as the lever, as you will see upon examining the sketch (Fig. 11) I now make on the blackboard.

"The pulleys seen in the blocks around which the rope runs may be considered so many levers whose arms are equal, and whose centres are fulcrums.

"In describing this power, it will perhaps be better to begin with the first and simplest form of the combination. The pulley, weight, and rope I show now (Fig. 12) is the simplest form of making use of this power. It is called a snatch-block and often employed for drawing water from wells, or for hoisting light weights. It is very handy, but we do not get any additional power from it, though we get a change of direction and quick movement. From its portable form, its low cost, and the handiness with which it can be applied, this arrangement is one of the most useful of our mechanical contrivances.

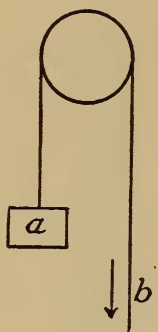


Fig. 12. Theory of block and tackle

"When pulleys are adjusted, as I show you in this sketch (Fig. 13), the block which carries the weight is called a movable pulley, and the whole, as shown, a system of pulleys.

"In this illustration, suppose the weight is 20 pounds. It is supported by two cords, A and B; that is, the two sections of the cord support 10 pounds each. Now, the cord being continuous, the power must be 10 pounds.

"We leave out of consideration the weight of pulley and the friction of the various parts.

"We have seen that the weight is sustained by two cords; if, therefore, it has been raised two feet, each cord must be shortened two feet. To do this, the power P must run down four feet. To get the full value of this machine the cords must be parallel.

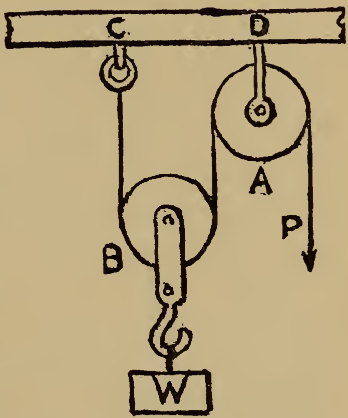


Fig. 13. Double block and tackle

"If we increase the number of movable pulleys, as sketched at Fig. 14, to three, the relation of P to W will be as 1 to 8 and the distance through which P will travel will be eight times that through which W is raised.

"If we apply this principle to the sketch (Fig. 11), which illustrates the blocks you used to-day in lifting the large timbers, and which is the usual form of pulley employed to lift heavy weights, you will notice that there is a four-sheave block at the top, and a three-sheave block at the bottom, with the end of the rope fixed from the top block. The three-sheave block is movable. A power of 10 pounds will, with this form of pulley, balance a weight of 60 pounds.

"Suppose a block of stone weighing 8,000 lbs. is to be raised to the top of a wall and we use a system of pulleys where each of the two blocks has four pulleys; we shall find that it will require a power of 1,000 pounds to raise it.

"Now, as to the inclined plane: this is called the fourth mechanical power, and it is not in any way related to the lever, but is a distinct principle. Some writers on the subject reduce the number of mechanical powers to two, namely, the lever and the inclined plane. The advantages gained by this are many for just so much as the length of the plane exceeds its perpendicular height is an advantage gained. Suppose A B C (Fig. 15), I make in the sketch, is a plane standing on the table. If length A B is three times greater than the perpendicular

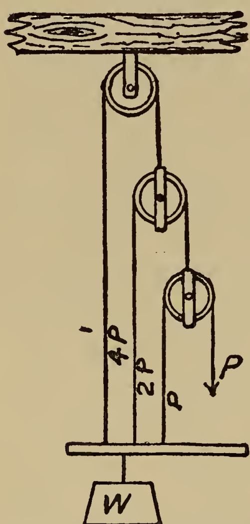


Fig. 14. Multiple blocks and tackle

height C B then a cylinder at R P may be supported upon the plane A B by a power equal to a third of its own weight. That is, a block of that weight would prevent the roller or cylinder from going farther. From this we gather that one third of the force required to lift any given weight in a perpendicular direction will be quite sufficient to raise it the same height on the plane; allowance, of course, must be made for overcoming the friction, but then, you see, you will have three times the space to pass over, so that what you gain in power, you will lose in time. We see the use of the inclined plane every day we pass a building under construction, where the workmen wheel bricks, mortar, and other materials from the street to the floors above, using long planks for the plane or tramway. Merchants, too, often make use of an inclined plane when rolling heavy boxes and packages from the street to the floors of their warehouses.

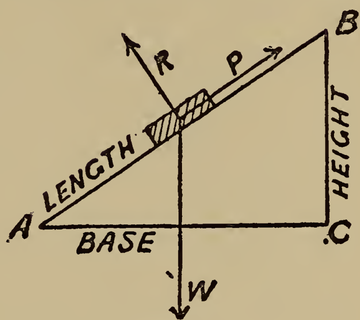


Fig. 15

"An excellent, practical illustration was given you to-day when Nick and Fred built the ways on which the proposed boat is to be slid into the new house. It would require five or six strong persons to lift the boat bodily into the new house; but I expect two or three will easily slide it up into the building on the ways; and by arranging a winch — another mechanical contrivance — at one end of the boat house, Fred, or George, for that matter, will be able to haul the boat up. The winch for this purpose will be a very simple affair, merely a ready adaptation of the wheel and axle, as I will show you later. Now, however, we are talking about inclined planes, and to illustrate its early application to the building arts, it is only necessary to tell a few things we know regarding the moving and raising of the great stones used in building the Pyramids. For centuries it was a mystery how the heavy stones in these structures had been placed in their present positions. Recent investigations have led many scientific men to believe the stones were taken up inclined planes, on rollers, and then put in place by the workmen, who moved them to the different sides of the building on strong timber platforms, where rollers, or rolling trucks, carried the load. According to one authority, there are the remains of the approach to an inclined plane near the Great Pyramid, which, if continued at the angle, as now seen, would rise to the apex. According to this writer, the foot of the plane was more than a mile from the building, fifty or sixty feet wide, and had been one huge embankment, formed of earth, sand, and the clippings and waste of stone made by the workmen. This, of course, would be an expensive and a tedious method, but in those days time and labour went for little. Every time a course of stones was laid and completed, the plane was raised another step, to the height of the next tier of stones. The same angle of incline was probably maintained during the whole period of erection, and this angle, you may rest assured, was made as low and easy as possible; for the Egyptian engineers were not slow in adapting the easiest and quickest methods available.

"This method of conveying the heavy stones to their places in the Pyramids was simple and effective, with no engineering difficulties that could not be readily overcome. Moreover, it was really the very best method considering the narrow limits of their appliances.

"You may ask, 'How were these big stones carried to the foot of the inclined plane?' The quarries, in some cases, were five hundred miles distant, and most of the stones had to be brought across the Nile to the works. We know from the monuments, and from the papyrii that have come down to us from remote periods, that many of the stones were brought down the river on large rafts or floats, and on barge-like vessels; and we also know that many of the larger ones were hauled or dragged down from the quarries at Assowan to Memphis, alongside the river, a distance of 580 miles. This is particularly true of the obelisks, for all along an old travelled road evidences have lately been found that these stones had been taken that way, and that resting places for the labourers had been provided at stations about twelve miles apart, along the whole distance. It has been estimated that a gang of men — say forty — well provided with rollers, timbers, ropes, and necessary tools, could easily roll an obelisk like that in Central Park, New York, twelve miles in twelve hours; and doubtless this was the system employed in conveying those immense stones that great distance.

"A large number of obelisks were erected near Memphis, though there are none there now, for the Greek and Roman engineers, at the command of the rulers, took a number down and carried them to the city of Alexandria; but we have less knowledge of how these later engineers transferred the stones to the newer city, than we have of the methods of the older. The beautiful column known as Pompey's Pillar was once an obelisk, and was transformed into a pillar, by either Greek or Roman artisans, it is not clear which. The work of putting those huge stones in place was not easy, as Commander Gorringe discovered when he stood the New York obelisk in the place it now occupies.

"But let us get back to our inclined plane.

"I have shown you how a weight or roller acts on the incline, but I did not explain it clearly, nor in a scientific way, as I do not want to puzzle or confuse you with terms and problems you cannot understand. I will, however, give you another illustration or two on the subject, in which another factor plays a part, namely — gravitation. Let us suppose you have two golf balls laid on a table that is perfectly horizontal or level in every direction; they will remain at rest wherever placed, but if we elevate the table so that the raised end is half the length of the top higher than the lower end, the balls will require a force half their weight to sustain them in any position on the table. But suppose they are on a plane perpendicular to the table top, the balls would descend with their whole weight, for the plane would not contribute in any respect to support them; consequently they would require a power equal to their whole weight to hold them back. It is by the velocity with which a body falls that we can estimate the force acted upon it, for the effect is estimated by the cause. Suppose an inclined plane is thirty-two feet long, and its perpendicular height sixteen feet, what time should a ball take to roll down the plane, and also to fall from the top to the ground by the force of gravity alone? We know that by the force of attraction or gravitation, a body will be one second in falling sixteen feet perpendicularly, and as our plane in length is double its height at the upper end, it will require two seconds for the ball to roll down from top to bottom. Suppose a plane sixty-four feet in perpendicular height, and three times sixty-four feet, or one hundred and ninety-two feet long; the time it will require a ball to fall to the earth by the attraction of gravitation will be two seconds. The first it falls sixteen feet, and the next forty-eight feet will be travelled in the same time, for the velocity of falling bodies increases as they descend. It has been found by accurate experiments that a body descending from a considerable height by the force of gravitation, falls sixteen feet in the first second, three times sixteen feet in the next; five times sixteen feet in the third; seven times sixteen feet in the fourth second of time; and so on, continually increasing according to the odd numbers, 1, 3, 5, 7, 9, 11, etc. Usually, the increase of velocity is somewhat greater than this, as it varies a trifle in different latitudes. In the example before us we find that the plane is three times as long as it is high on a perpendicular line; so that it will take the ball to roll down that distance (192 ft.) three times as many seconds as it took to descend freely by the force of gravity, that is to say, six seconds.

"The principle of the inclined plane is made use of in the manufacture of tools of many kinds, as in the bevelled sides of hatchets, axes, chisels and other similar tools, the examples of which are in a great measure related to this power, though many of them partake largely of the wedge, of which we shall now have something to say.

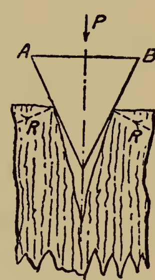


Fig. 16. Action of the wedge

"The wedge may be a block of wood, iron, or other material, tapered to a thin edge, forming a sort of double inclined plane, A P B, (Fig. 16) where their bases are joined, making A B the whole thickness of the wedge at the top. In splitting wood as is shown in the illustration, R R being the wood, the wedge must be driven in with a large hammer or heavy mallet which impels it down and forces the fibres of the wood to separate and open up. The wedge is of great importance in a vast variety of cases where the other mechanical powers are of no avail, and this arises from the momentum of the blow given it; which is greater beyond comparison than the application of any dead weight or pressure employed by the other mechanical powers. Hence, it is used in splitting wood, rocks, and many other things. Even the largest ships may be raised somewhat by driving wedges below them. Often, in launching a vessel, wedges are used to start it on its way. And they are also used for raising beams or floors of houses where they have given way by reason of having too much weight laid upon them. In quarrying large stones, it is customary to wedge or break off the rock by first drilling a number of holes on the line of cleavage. Wooden wedges are then driven tightly into these and left there until they get wet, when they expand and split off the rock as required. This method of quarrying large stones was well known to the old Egyptians, and employed by them in quarrying their famous obelisks.

"Owing to the fact that the power applied to force a wedge is not continuous, but a series of impulses, the theory of the wedge is less exact than that of the other mechanical powers. Considering the power and the resistance on each side, however, as three forces in equilibrium, it may be demonstrated that the

$$\text{Resistance (R) equals } P \times \frac{\text{Length of equal side}}{\text{Back of wedge}}$$

Then the mechanical advantage will be —

$$\frac{R}{P} \text{ equals } \frac{\text{Length of equal side}}{\text{Back of wedge}}$$

So that by diminishing the size of the back and increasing the length of the side — that is, diminishing the angle of penetration — the mechanical power of the wedge is increased. While I did not intend to inflict you with arithmetical or algebraical formulæ, I have been compelled to give you that simple example which I know you can all work out, as it is concise, and the same would be long and tedious if rendered in text."

Next morning, as Fred and his father were out on the new place early, looking over the boat house, the slide for the boat, and some other matters, Mr. Gregg suggested that a winch be placed at the upper end of the house, to haul the boat out of the water. He also suggested that Fred prepare for work on the boat at once, and provide himself with all the tools and materials necessary. He promised to call on a friend of his in the city, who is a noted boat builder, and ask him the best method to adopt in building the craft.

"Perhaps," said the father, "it might be a good plan to buy a full set of shapes or patterns from some one of the professional boat builders who advertise such. They are sold at a very low rate — being made of paper — and many firms sell all the material that is required to build a boat complete; with the sweeps, ribs, and curved stuff cut out to the required shape and numbered all ready to set up.

"What we want, Fred," continued the father, "is a boat sixteen or eighteen feet long, just the size of the one belonging to your friend, Walter Scott; that is plenty large enough for all our purposes. His boat can stand as a kind of a model for you to work after in case you do not thoroughly understand the patterns you are to get, or the manner of arrangement. The gasolene motor we'll order from some manufacturer, with whom we'll arrange to install it, with a suitable propeller and necessary attachments."

Fred was quite satisfied with all his father had said and started to get ready. Jessie began to question him about several things she did not fully understand in her father's talk the night previous. Fred explained matters, made them quite clear to her, and then asked her to get her memorandum book and write down the following, which he said, she would often find useful: "There are six mechanical powers, two of which father has not told us about, but will no doubt do so, before long. These are called, the Lever, Pulley, Wheel and Axle, Inclined Plane, Wedge, and Screw. The Screw and the Wheel and Axle, you have yet to hear about. Now, study carefully the following rules:

"*The Lever.*—Rule: The power required is to the weight as the distance of the weight from the fulcrum is to the distance of the power from the fulcrum.

"*The Pulley.* — A fixed pulley gives no increase of power. With a single movable pulley the power required will equal half the weight, and will move through twice the distance. Increasing the number of pulleys, diminishes the power required. Rule: The power is equal to the weight, divided by the number of folds of rope passing between the pulleys.

"*The Wheel and Axle.* — Rule: The power is to the weight as the radius of the axle is to the length of the crank or radius of the wheel.

"*The Inclined Plane.* — Rule: The power is to the weight as the height of the plane is to the length.

"*Wedge.* — Rule: Half the thickness of the head of the wedge is to the length of one of its sides as the power which acts against its head is to the effect produced on its side.

"*The Screw.* — Rule: As the distance between the threads is to the circumference of the circle described by the power, so is the power required to the weight."

Fred told George also to copy the foregoing in his memorandum book, so that he would be able to work out any problems for himself.

III

BRIDGE AND BOAT WORK

THE next day Fred and his father talked over the proposed boat, the result being that Walter Scott was asked over the telephone if he would come down in his launch to the Gregg property in the evening, as Mr. Gregg and Fred would like to see the craft, hear all about it, and find out if it had any defects that might be avoided in the building of another one. Walter said he'd be glad to sail down, and would take his sister to see Jessie. In the meantime some addresses of boat builders were handed to Fred, with instructions to write and ask for catalogues, prices of materials, and the other information usually sent out to prospective customers. Fred immediately wrote to a number of firms, including several who manufactured motors and other requisites for small launches.

A little after the city clock struck four, Jessie, who was home from school, saw *The Mocking-Bird* sailing down the river at good speed, with

Walter, his sister Grace, and their mother on board. Fred went down to the water's edge, and helped Walter haul the boat to the unfinished landing place, where Mrs. Scott and Grace were safely landed.

Fred and Walter soon became deep in "boat talk," and kept it up until the arrival of Mr. Gregg, who began to make inquiries regarding the speed, capacity, and safety of *The Mocking-Bird.* All his questions were intelligently and favourably answered by Walter, a bright and earnest little fellow. He was some months the senior of Fred, but was not so strong or robust looking.

"She's just 18 feet long over all," said he, "with a 5-foot beam, a draft aft of about 18 inches, and a forward draft of 1 foot. She is fitted with a 6-horse-power gasolene engine, and her speed is from 8 to 9 miles an hour."

An illustration of her, as she appeared when partly built, is shown in Fig. 17, where a plan and a section of her length may be seen. The manner of her construction is also shown, also the lines of ribs, portion of inside lining, position of motor, rudder, and propeller.

Mr. Gregg also ascertained from Walter that his father had sent to a firm who made a business of preparing the complete woodwork for many kinds

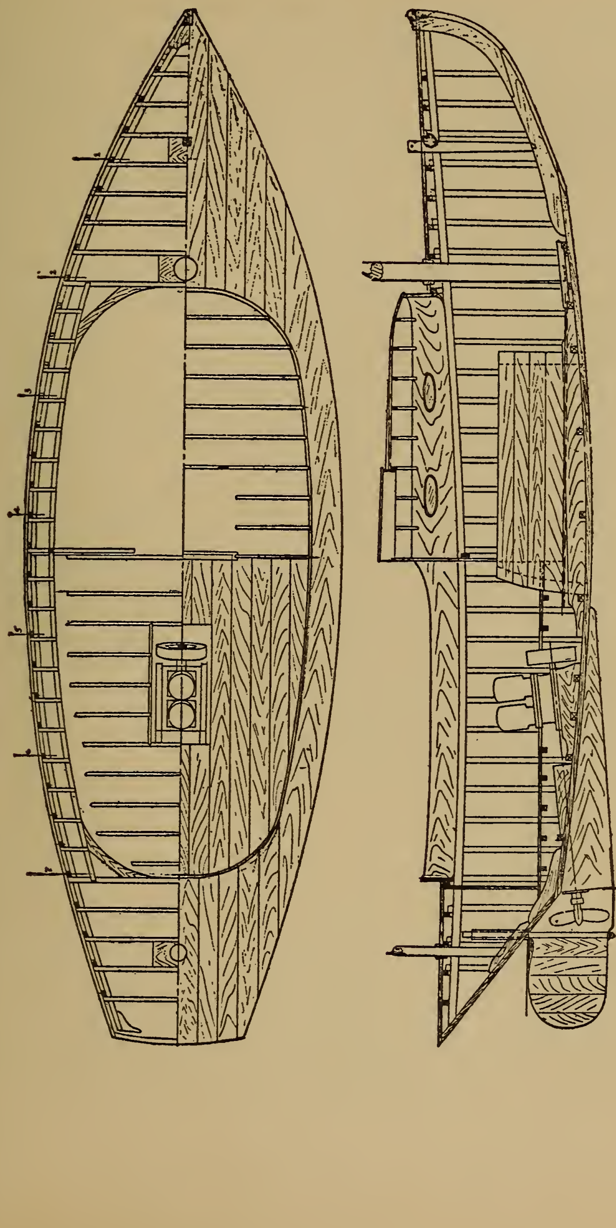


Fig. 17. Plan and section of *The Mocking-Bird*

of boats on the "knockdown" system, selling the whole material ready to set up without the aid of an expert. Printed instructions came along with each boat, so that the buyer would have but little difficulty in setting up the wood-work and making it ready for use. An expert workman had been engaged by Walter's father to install the engine, line up the propeller shaft, and connect the wheel and shaft to the engine. On the arrival of the materials — within a week after the order was sent — Walter had gone to work; and inside of fourteen days, *The Mocking-Bird* took to the water.

So fully and so satisfactorily did Walter explain to Mr. Gregg all that he asked about, that Fred was able at once to order the material for a similar launch, to be sent on immediately. In order to hurry matters, a cheque was inclosed with the order, and Fred, Walter, and George walked over to the post-office with the letter, so that it went by the night mail.

On returning, it was suggested that the boys, Grace, and Jessie go for a sail on the river, and all were soon at the landing. Walter adjusted his engine and made all ready as George and the girls got on board, while Fred cast off the rope which held the boat to the dock, then stepped after them.

The engine was started, Fred took the tiller, and they were soon afloat, sailing with the tide in their favour at a rapid speed, and returning to the landing place inside of an hour, well pleased with their little outing. Fred showed Walter his new boat-house and workshop, explained to him how Nick and he, with the help of George and the advice of his father, had completed the work and the building. He also pointed out other work he was going to do as soon as his boat was finished.

Though not yet dark, it was getting rather late, and Walter's mother advised that they start for home as soon as he was ready. So wishing Fred every success in the building of his boat, Mrs. Scott, her daughter, and Walter left for home.

"Well, Fred," said Mr. Gregg, when his family were all seated in the living room, "you are now in for quite a job, one that will test your working qualities; but I am sure you will come out with flying colours. You will meet difficulties, but you must overcome them, and when the boat is finished, painted, and ready to name, you can have some of your friends up for the launching. Mother will have a special tea for you all, and we'll christen the new craft. Meantime we must think over the matter of a name, and decide upon one we shall all like."

Next morning, Fred and his father went down to the river's edge to examine the little ravine that had been cut out by the spring and fall freshets. It was a small affair, only about six feet deep and ten or twelve feet wide. At present, the opposite side was reached by crossing a couple of planks, safe enough while the land had been in a measure unoccupied. To leave it so now would be a different matter, as Jessie or her mother, attempting to cross, might easily fall over; so it was decided to have a foot-bridge built over the creek, which was nearly dry the greater part of the year. There was plenty of material on the ground for the purpose, and Fred was asked by his father to get Nick to help, so that the bridge might be ready as soon as possible.

Fred felt he was getting to be quite an important person when his father trusted him with work which must necessarily entail considerable expense, but he accepted the responsibility with pleasure, and promised to commence at once, so as to have it finished by the time the material for the boat arrived. So, when Nick arrived, operations began immediately.

Taking a tape line, Fred sent the Italian to the other end of it, and they picked out a favourable

The Creek

location to measure across, making it over 11 feet at the narrowest spot from one edge to the other. Allowance was then made for bearings five feet on either side of the span, so that timbers 21 feet long would be required to cross the chasm. This width would require three string-pieces, or chords, to run across, one on each side, and one in the centre. These, covered with three-inch plank from end to end, would make a good, solid deck sufficient for all purposes. The planks were cut off seven feet long, to have the deck of the bridge, over all, exactly seven feet wide.

Among the timbers taken from the old barn were nine pieces, measuring 22 feet in length, 8 x 10 inches in section, so Fred decided to make use of three of these just as they were, without cutting, and to place them on their edges to get the most strength out of them. He then had six posts cut off the old cedar fence posts, about two feet long, which were sunk into the ground their whole length, as shown in Fig. 18, three on each side of the creek, and the tops made level, so that a flat timber or plank would rest on them, touching each one. This plank was made nine feet long, so as to project over the posts about a foot at each end. This was, of course, the same at each end of the bridge.

After the flat timbers had been laid on the ends of the posts and fastened with spikes, there were laid the three long timbers spanning the gully. The spaces between were equally divided, and then covered with three-inch planks taken from the floor of the old barn. The boards were cut off to the

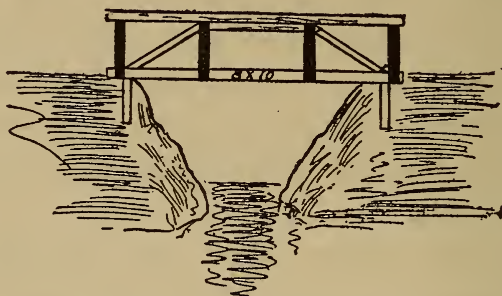


Fig. 18. Frame of foot-bridge

proper length and fastened down on the three timbers with spikes five inches long, the planks not laid close together, but kept about three-eighths of an inch apart, in order to let the water run off after a rain, as well as to allow air to circulate underneath and between the joints to prevent the planks from decay.

In order to make the bridge safe, it was necessary to build a rail on each side. Two pieces of timber about 20 feet long and 6 x 6 inches square were used for the rails, while posts and braces were made of timber of about the same dimensions. The bottoms of the posts were halved, so that they could be spiked or nailed to the long outside string-pieces, as shown in the illustration. Tenons were made on the top of these posts, and these fitted into mortises made in the top rails, and all were then put together and fastened with wooden pins.

Nick dug away the surplus earth from the approaches to the bridge, and made an easy grade to its deck. This completed the work all but the painting, which was left to be done some other day.

Mr. Gregg inspected the bridge, pronounced it all right, and congratulated Fred on his workmanship, at the same time saying a good word to Nick and George, both of whom had helped very much to make the effort a success.

In the evening Mr. Gregg told Fred and George that a friend of his had given him a copy of the rules to be observed when running a launch, so he asked the boys to get their note-books, and take these down as he read them out. Even Jessie, too, he thought, ought to be acquainted with the rules, as she might be called upon some time to make use of them, so three pencils were soon at work, as the father read out the following:

"1. When at the wheel, remember as a first consideration, that you cannot entertain the boat's occupants as well as steer.

"2. Keep your course, and know what that course is.

"3. Regulate your speed to the company you are in. Marine motors are, as a rule, very flexible.

"4. Do not cut corners.

"5. When approaching a landing, learn to judge exactly the distance your boat will travel after your propeller has stopped, so as to run alongside without using your reverse gear. This requires some practice, but is amply rewarded by time saved, in the long run, and decrease of wear and tear on engine, gear, and propeller. Any one can get to a landing in time by alternately running full speed ahead and then astern.

"6. When aboard your boat, and facing the bow your right hand is starboard, your left, port. Keep to the right. Should you be overtaking any one, it is your duty to pass clear on their left. The above applies only to narrow waters.

"7. When going up or down stream, should you wish to cross over to the other side and return, and another boat is overtaking you on your left, don't attempt to cross its bow; slow down until it has passed.

"8. Keep clear of non-engined crafts. You have greater freedom of action than they; it costs you nothing, and their occupants appreciate your courtesy.

"9. Do not tow canoes or skiffs alongside. If towed at all, they should be right aft with as short a towline as possible.

"10. Finally; remember the rules of the road —

"'Green to green or red to red
Perfect safety — go ahead
If to starboard red appear
'Tis your duty to keep clear.
When upon your port is seen
A steamer's starboard light of green,
There's not so much for you to do
As green to port keeps clear of you.'"

The children all promised to memorize these rules.

As the stuff for the boat was not expected for some days, Fred and Nick kept at work about the new boat house, and building up the landing dock. The former fitted up a work bench, and put his little shop in readiness for actual use. Fred also hunted for a nice stick of timber among the old barn ruins, on which to set up the boat. A good piece found, he cut it to a length of 20 feet, and then he and Nick got it into the boat house, where Fred planed it off a little with a rough jack plane, keeping a sharp lookout for nails, sand, or gravel. Nothing destroys the cutting edges of tools more than nails, bits of iron, glass, sand, or small pebbles, which sometimes escape the vigilance of the workman. Especially is this true of saws, which Fred knew quite well since he had once run a good sharp saw against a nail, while cutting a piece of timber in two. This taught him a lesson he never forgot, and whenever he had to cut up old material, he was always careful to examine it all round, and to scrape or brush off all the dirt and sand from the parts through which the saw teeth had to travel. In planing, or "dressing" the stick of timber, the same precautions were taken, and the surface of the wood was made as clean and free from dirt and sand as it possibly could be. Notwithstanding all this, Fred found it almost impossible to keep the cutting iron of his jack plane sharp enough to take off shavings. He had to sharpen it every few minutes. This is nearly always the case when working up wood which has previously been used. However, he managed to "dress" his stick very nicely, and after finishing it, laid it down along the middle of the floor of the shop, putting blocks of wood under it here and there to raise it up from the floor five or six inches. It was then made level on top and fastened down so that it would not move or get out of line. This was about all they could do on the boat until the materials arrived. Nick had managed to fill in the space between the two walls of the little pier with heavy bowlders, and had strengthened the whole with coarse rubble-stone work in such a manner that there was little danger of injury from floating ice or flood tides; and he had covered the whole over with small stones, gravel, and a good thick layer of cement concrete, which made it correspond with the cement walk.

The question of a winch was then taken up with Mr. Gregg and it was decided to construct a simple affair at the end of the boathouse opposite the large doors, where the boat would have to enter.

Mr. Gregg suggested, in order to make the end of the building strong enough, that two upright posts be set up, well braced by being fastened to both floor and ceiling, and that the winch be attached to them in a way that would be easy to work, as shown in Fig. 19, room enough being left between the posts and the wall for the crank to turn without the hand of the operator striking the boards. The cylinder around which the rope should wind ought to be about six inches in dia-

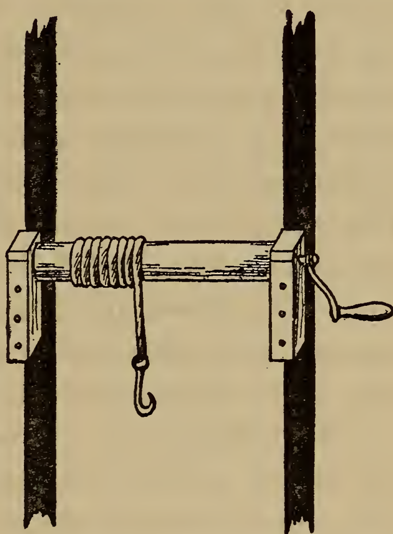


Fig. 19. Winch and crank

meter, and the crank or handle on the end, not less than fifteen or sixteen inches long. The longer the crank, the less force it would require to haul in the boat. If desired, a crank could be fitted to the other end of the cylinder so that two persons could work at one time, pulling in the weight.

In the evening Mr. Gregg asked the boys and Jessie to visit his room, and he would try to explain the principle and advantages of the wheel and axle, as the winch they were to make was in a measure related to that principle. Mr. Gregg began by saying: "The wheel and axle is merely a modification of the lever and consists of a couple of cylinders turning on a common axis, the larger cylinder is usually called the wheel, the lesser one the axle. This arrangement, which I draw on the blackboard herewith, forms a kind of lever of the first or second class. Considered as a lever, the fulcrum is at the common axis, while the arms of the lever are the radii of the wheel and of the axle.

"The fulcrum is at C, the centre. The arm of the weight is W W, and the arm of the power is A C. In Fig. 20 the arm of the power is the spoke of the wheel, while the arm of the weight is the radius of the axle. Fig. 19 shows the ordinary winch, often used in well-digging for hauling up dirt and rock, and also for raising planks, shingles, rafters, and other light stuff, to the roofs and upper floors of buildings. Often it is made more powerful by adding spur or geared wheels to the end of the shaft, consisting of a pinion and a larger spurred wheel. The crank or handle is attached to the pinion,

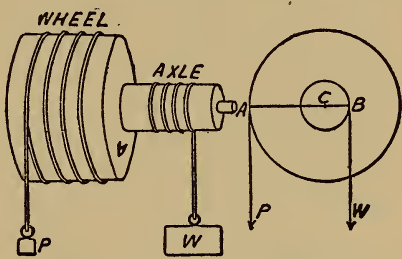


Fig. 20. Wheel and axle

and the power is increased according to the difference in diameters of the spur wheels. The machine is then called a 'crab' and it is often used for lifting safes and other heavy weights to elevated situations. In Fig. 20 the length of the crank (in a straight line) is the arm of the power.

"The mechanical advantage of the wheel and axle equals the ratio between the diameter of the wheel and of the axle.

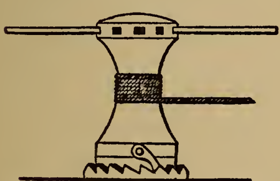


Fig. 21. Capstan and hand bars

"It is not necessary that an entire wheel be present. In the case of the windlass and the capstan (Fig. 21), the power may be applied to a single arm or to a number of arms placed in the holes shown. The cable or rope on the barrel of the capstan is hauled in by turning the capstan on its axis, with handspikes or bars. The capstan is prevented from turning back by a pawl attached to its lower part, working in a circular ratchet on the base.

"As an illustration of the lever action, and of work put into and got out of a machine, there is no better illustration than the ingenious contrivance termed the fusee (Fig. 22). In good watches and clocks, where the elastic force of a coiled spring is used to drive the works, the fusee compensates the gradually diminishing pull of the uncoiling spring. The driving of the works at a constant rate is the object for which a watch or clock is designed. This usually entails a constant resistance to be overcome, but since one of the most compact and convenient forms of mechanism into which mechanical force can be stored is that of the coiled spring, and since the very nature of the spring is such that its force decreases as it uncoils, we must employ some

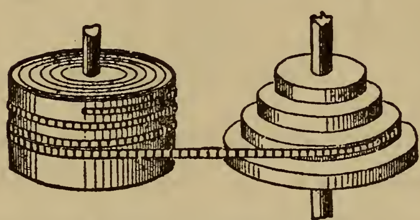


Fig. 22. Compensating fusee

compensating device between this variable driving force and the constant resistance. The fusee does this in a most accurate and complete manner. As the fusee to the right is to compensate for the loss of force of the spring as it uncoils itself, the chain is on the small diameter of the fusee when the watch is wound up, as the spring has then the greatest force.

"In the differential, or Chinese windlass (Fig. 23), different parts of the cylinder have different diameters, the rope winding upon the larger and unwinding from the smaller. By one revolution the load is lifted a distance equal to the difference between the circumference of the two parts.

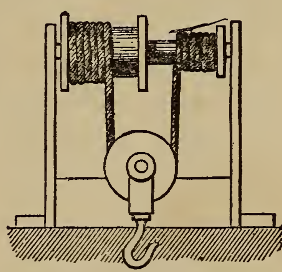


Fig. 23. Chinese winch and pulley

"There are many other contrivances and appliances of the wheel and axle for performing various services, but I think the examples I have shown you will be sufficient to enable you to make use of the device to perform any duty you may be called upon to attempt in ordinary life, but, should you enter professional life as civil, mechanical, naval, or mining engineer or architect, you will be obliged to pursue the study of these subjects further.

"Before closing I may add a few problems for you to solve at your leisure by the application of the rules I have given you when describing the other mechanical powers.

"The pilot wheel of a boat is 3 feet in diameter; the axle is 6 inches; the resistance of the rudder is 240 pounds. What power applied to the wheel will move the rudder? Here the difference between the axle and wheel is 18 inches.

"Four men are hoisting an anchor of 3,000 pounds' weight; the barrel of the capstan is 8 inches in diameter; the circle described by the handspikes is 7 feet 6 inches in diameter. How great a pressure must each of the men exert?

"With a capstan four men are raising a 1000-pound anchor; the barrel of the capstan is a foot in diameter; the handspikes used are 5 feet long; friction equals 10 per cent. of the weight. How much force must each man exert to raise the anchor?

"The circumference of a wheel is 8 feet; that of its axle is 16 inches; the weight, including friction, is 85 pounds. How great a power will be required to raise it?

"A power of 70 pounds on a wheel whose diameter is 10 feet balances 300 pounds on the axle. Give the diameter of the axle.

"An axle 10 inches in diameter fitted with a winch 18 inches long is used to draw water from a well. How great a power will it require to raise a cubic foot of water, which weighs 62½ pounds?"

The first mail in the morning brought word that the whole of the partly prepared stuff for the boat had been shipped by "fast freight," and that it would reach its destination in the course of a few days. The paper patterns, directions, and all necessary instructions for building would be mailed at once.

IV

MAKING A GASOLENE LAUNCH

TWO or three days after Mr. Gregg had talked over the principles of the wheel and axle, with the children, Fred received notice that a consignment of wood-work was at the station awaiting his orders. Mr. Gregg made immediate arrangements with the railway people, and by the time he got home from his office, the stuff was being unloaded by the boys, who carried it piece by piece into the workshop, each section being laid by itself in the order in which it was to be put in place in the boat. Printed instructions were in the equipment for laying the keel, setting up the frames, and even for taking the stuff out of the packages and putting it in heaps, so that it could be readily picked out when wanted for use.

Each rib was numbered, and marked or stamped "right" or "left," and all the pieces were cut off to the right length and to the right bevel or angle to suit the positions they were to occupy, as specified in the printed instructions. This made the setting up an easy matter, requiring only care, patience, and a fair knowledge of the use of wood-working tools. That Fred possessed these qualities, was partly due to the training he had received in the technical school, and partly to his natural aptitude for picking up methods, ideas, and new applications.

Fred, George, and Mr. Gregg himself, were much interested in the selection of the various materials, and when the plank that was to form the keel had been unpacked, George was anxious that it should be laid down on the bed that had been prepared for its reception. He was quite disappointed when he found it considerably shorter than he had expected the boat to be. It was explained to him, however, that the overhanging of the stern, and therefore shortening of the forefoot, or stem, necessitated the keel being shorter than the boat would be when measured over all on top. The keel was found to be a fine piece of tough oak, nicely dressed, made the proper shape at each end, bored and gained to receive the stern post, the stern ribs, and side stanchions. Everything was marked, and each timber was sized so that it would fit in place snugly without using a tool on it, except a hammer or mallet.

At tea time George felt it difficult to keep reasonably quiet, he was so enthusiastic about the boat—much to the amusement of his father, who knew exactly how the boy felt.

After tea, all walked to the boat house, and the father assisted Fred to set up the keel, which was in two pieces, halved together midway and well fastened with screws. The joint was painted with

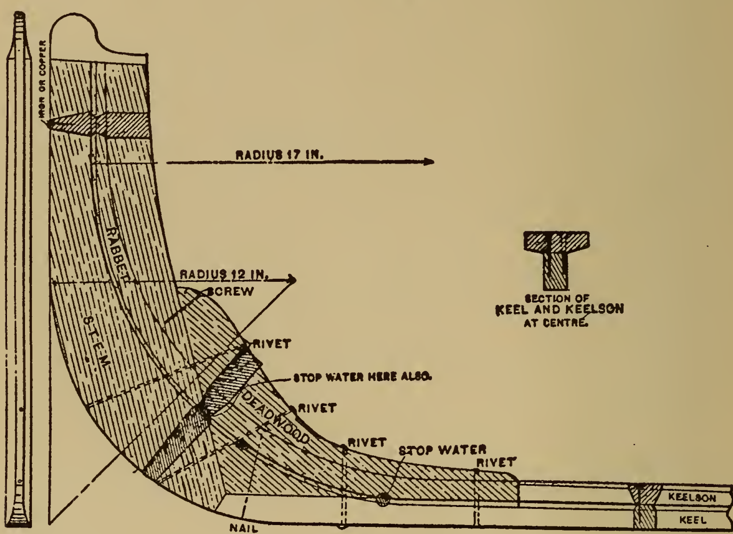


Fig. 24. Stem of launch

a heavy coat of white lead and linseed oil paint, before being put together and screwed up. The keel is the lowest timber in a boat or ship, and it runs nearly the length of the craft. Sometimes there is a keelson placed on the top of the keel, and the ribs of the boat, or stanchions, are made fast to that timber, as shown in the illustration, (Fig. 24,) in which the gains for the ribs or moulds are made. This portion of the boat was put together temporarily, so Fred had no difficulty in assembling the various pieces. The stem, keel, keelson, and deadwood were all made of oak, and looked strong. The keel and keelson were properly laid and adjusted, and after some explanations by Mr. Gregg the manner of setting up the ribs was thoroughly understood. Fred decided to telephone Walter Scott to come down next day, as it was Saturday, and help him to set up the skeleton.

As the weather was getting warm, the whole family spent the evening on the veranda and George introduced the question of naming the boat. He suggested *Red Bird*, but this did not seem to take well, and several others were proposed but none seemed to suit everybody. Jessie sat quietly on the steps till asked by Fred what her choice would be.

"I would like it called after mamma, *Caroline*."

"That's a good idea, Jessie," said her father, "and if the boys or your mother don't object, I think we'll settle on *Caroline*."

Early next morning the boys were out watching for *The Mocking-Bird*, which very soon made its appearance. Fred and Walter tied the boat up to the new dock and went into the boat house, where the latter began to examine the boat stuff, and to explain the manner of setting it up and fastening it in place.

Nick, who was on hand to help, did the heavy work, and helped to put up the stanchions. Walter seemed quite familiar with the work, and he and Fred soon had the boat so well in hand that it seemed to grow under their fingers. The ribs were easily selected, as they were tied together in pairs and numbered. They were then set in their places according to their numbers and were fastened to the keelson with the strong copper nails. All the nails required for the boat were of copper, because that metal is less likely to corrode than iron or steel.

It was found necessary to brace the ribs in order to keep them in line. Thin pieces of lath were tacked on the tops to hold the ribs the proper distance apart, and longer and stronger strips of wood were used for bracing the boat sideways. These were nailed to the joints in the ceiling or high up on the walls of the boat house.

At noon the boys had the skeleton of the boat well advanced, and to one standing in front of the bow,

MAKING A MOTOR LAUNCH

"All the Nails Required for the Boat Were of Copper, Because That Metal is Less Likely to Corrode Than Iron or Steel"

it presented an appearance like the sketch shown at Fig. 25.

The launch might be called "carvel ribbon built," or nearly so, and it would have a displacement of 14 or 15 hundred-weight when fairly loaded. This weight would bring her down to the third W. L., as shown in the end sketch. To load her to the fourth W. L., would give her a load far beyond these figures. The sections had to be closely spaced, and

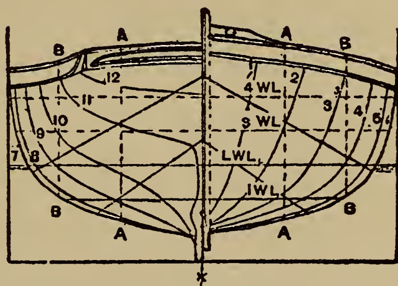


Fig. 25. Section of launch — abeam

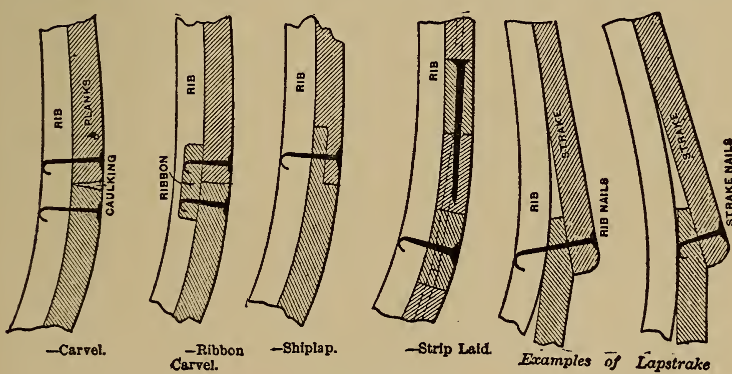


Fig. 26. Methods of sheathing

the ribbons or slats let into the temporary section moulds before the outside boarding could be put on, the edges of the boarding being clinch fastened, as shown in the ribbon carvel, Fig. 26. Other styles of sheathing boats, as shown, are often used, but the *Caroline* was "ribbon carvel."

It is usual to lay off the sheer profile on a suitable floor, and line in the rebate line, scarf of stem, deadwoods, fork timbers, etc., making thin moulds of each member to be lined off, sawn, and bolted together. The section moulds, from which the boat derives its shape, are also laid off, and the planking, 3/8-in. thick, deducted when making them.

The stem, of crooked oak, was 2 1/4 in. thick by about 3 in., shaped as shown in Fig. 24. The fore deadwood was 2 1/2 in. thick, moulded about 3 in., and through-bolted to the stem and keel with 3/8-in. copper bolts; and the stern-post, 3 1/2 in. thick, was wrought to shape, as shown. The centre line of the shaft, as shown, is subject to alteration, since different makes of motors have different sizes of propellers and flywheels. The fork timbers were let into the stern-post, and carried the transom, wrought out of a flitch of elm 3 1/2 in. thick. The planking, of 3/8-in. cedar, was closely jointed and varnished, and secured to the ribbons. The timbers were of rock elm, 7/8 in. by 1/2 in., steamed and bent or sawn to shape, and through-fastened at the top and bottom edges of the planking. These were spaced on 7½-in. centres, with two clinch nails into the ribbons between them. Three or four solid floorings should be worked into the motor space; fitting of the motor bed thwartships gives great support to the boat.

The thwarts were of oak, 8 in. wide and 1 in. thick, with the side seats, ⅞ in. thick, supported by turned legs of oak. The decks at each end should be of ½-in. oak or cherry reeded into 3 in. widths, and filled with marine glue. The covering board, 2½ in. wide, with a nosing worked on the edges, and ½ in. thick, was carried by a clamp or binding stake, 2½ in. by ⅝ in., through-fastened at every timber. The knees were of oak, 1 in. thick, about 10 in. on the foot by about 3 in. at the head, and through-fastened. A breast hook 2 in. thick should be fitted. The floor boards may be of ¾-in. spruce, elm, or ash grating, as preferred. The centre of the motor was at No. 6 section, as indicated, the gasolene being stored in a strong tank under the forward deck, just high enough to feed by gravitation. After being cleaned off and sand-papered, a coat of good shellac varnish, may be followed, if desired, by three coats of best yacht varnish. The spacing of the sections was: No. 1, from face to stem, 1 foot 2 in.; No. 2, from No. 1, is 1 ft. 2 in., the other sections to No. 11 each 1 ft. 6 in.; No. 12 was 1 ft. 1 in. from No. 11 (see Fig. 25). The water-lines were 5 in. apart, and the buttock-lines, A and B, 1 ft. and 1 ft. 9 in. respectively from the middle line.

The boys followed these directions, and with the help of the following table, managed to get the boat ready to varnish and finish up. The following table, which refers more particularly to the section shown in Fig. 25, shows the sheer lines, counting from

TABLE OF OFFSETS

	Stem	*Section Numbers*												*End of Transome*
		1	2	3	4	5	6	7	8	9	10	11	12	
	ft. in.	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*
Sheer heights above L.W.L.	1 7	1 6	1 5	1 4⅛	1 3¼	1 2¾	1 2¼	1 2⅛	1 2⅛	1 2½	1 3	1 3⅝	1 4¼	1 6
L.W.L. to rebate line		7	8¾	9	9¼	9½	9⅞	10	10½	10¾	11			
Half-breadths at gunwale		8¼	1 3⅛	1 9½	2 1⅛	2 3½	2 4½	2 4⅜	2 3⅝	2 2⅛	2 0	1 9½	1 6¾	
Half-breadths at 4 W.L.		6⅞	1 1½	1 8	2 0½	2 2⅞	2 4	2 3⅞	2 3¼	2 1¾	1 11⅜	1 7¼		
Half-breadths at 3 W.L.		5⅞	11⅝	1 6⅜	1 11	2 2	2 3¼	2 3¼	2 2½	2 0¾	1 9¼	8½		
Half-breadths at L.W.L.		4⅜	9⅜	1 3⅝	1 8¾	2 0	2 1½	2 1½	2 0⅝	1 9½	1 2⅛			
Half-breadths at 1 W.L.		2½	5¾	10½	1 3	1 6¾	1 8½	1 8½	1 6½	1 0⅞	5¾			
Buttock A from L.W.L.			5½	4⅛	6⅜	7⅝	8	8	7½	5¼	1	6	11¾	
Buttock B from L.W.L.					⅜	3⅜	4¾	4¾	3½	⅜				

L W L (low water line). While all the work and calculations regarding the plan had been already done, Mr. Gregg, who had watched the work's progress for a week, thought they should know the principles on which the craft was being built, and therefore advised them to examine the illustration and table, so that they would have some knowledge of the science required to build a boat intelligently. Fred and George did this, and were helped along by Walter, who seemed to have mastered the subject pretty thoroughly.

It was necessary, before installing the motor, that a foundation should be laid for it, so varnishing and the final finish were left over until the engine and propeller should be put in and tried.

The engine was brought to the boat house from Newark, and the expert, engaged by Mr. Gregg some time previous, came along with it, bringing such tools as he might want. He examined the bed for the engine, and saw that all was properly fastened and in good condition to place the engine and the propeller shaft. Mr. Watts (the machinist) laid off a line for the propeller shaft and with a long auger bored a hole from the engine bed through to the stern-post, large enough to permit the shaft of the propeller to revolve in it easily. A bearing, or "box," was adjusted to the stern-post in which the shaft ran, and the "box" was made water-tight to prevent any inflow. The propeller was made of bronze, had been nicely fitted to the shaft before it came, and had a set screw in its hub to hold it firmly on the shaft. The diameter of the propeller wheel measured 15 inches and it had two blades. The shaft and wheel being properly adjusted, the next thing was to place the engine, which weighed about 200 lbs. The blocks and tackle used in taking down the old barn were rigged up to the ceiling by cutting a hole through

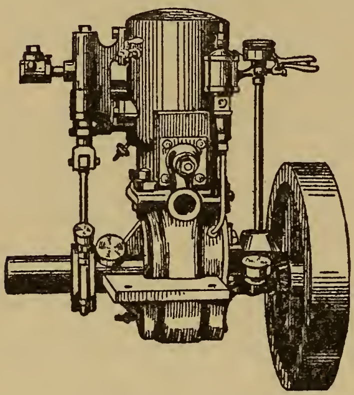


Fig. 27. Starboard side of motor

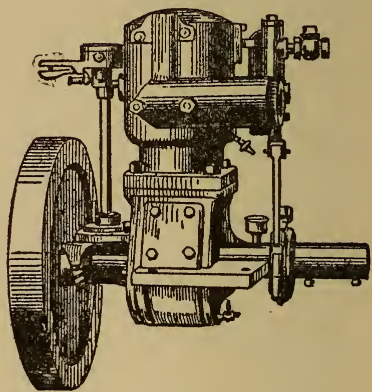


Fig. 28. Port side of motor

the floor, laying a short timber across the joists, hitching a rope around the timber, and letting a loop hang down through the hole made in the floor. The hook of the upper block was attached to the loop, a sling was fastened to the engine, the whole was hoisted by Nick with the greatest ease, and the machine dropped on its bed. As it did not lie quite level, it was raised again and held suspended until the bed was trued up, when it was permanently lowered into place and fastened down. Two views of the engine are shown in Figs. 27 and 28.

In "shop talk," the engine may be described as follows — Bore of cylinder $4\frac{1}{2}$ in. Stroke $4\frac{1}{2}$ in. Crank shaft $1\frac{3}{8}$ in. Revolutions per minute from 60 to 750. Propeller shaft one inch. About 15 or 16 horsepower. A float-feed carburetor, Fig. 29, was installed at the same time. This carburetor is an excellent one. It insures a regular supply of gasolene and air, in proper proportion, and prevents trouble when the motor is in use. The float guarantees an even level of gasolene in the float chamber at all times. The proper balance of the cork float closes the supply of gasolene automatically when it reaches the proper level. This prevents waste of fuel, every drop being thoroughly vaporized and mixed with the proper amount of air. The

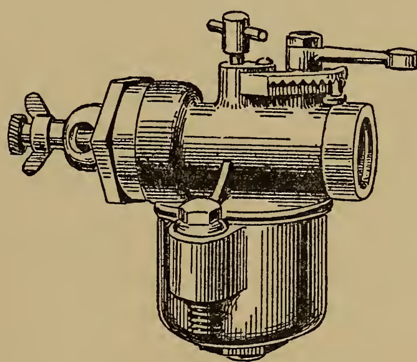


Fig. 29. Carburetor

spraying nozzle is higher than the gasolene in the float chamber, and prevents the gasolene from getting into the engine, unless it is running. The throttle valve on the carburetor gives the operator the power to change instantly the speed, without changing the timer, and affords him absolute control of the engine.

When all the machinery was in place, and the propeller attached, Mr. Watts told the boys that he would finish up the work of installing the next day, and would then run the engine "dry" for an hour or two, to get everything working nicely before declaring the *Caroline* ready for sea.

It was just two weeks from the day the stuff arrived when the engine was finally installed.

"That's pretty quick work," declared Walter, "and if the boat were varnished, we could have her in the water in a couple of days."

In the evening, as all the Greggs were seated on the veranda, Fred tried to explain to his father the installation of the engine, but he failed to make himself quite clear.

Mr. Gregg said to him: "You seem to have grasped the theory of the matter, but I see you don't understand some important points, so I think a few suggestions may be of use to you. I will not confine myself to marine motors altogether, as gasolene engines are used for many purposes, more and more every day. With regard to installing an engine in a boat, the first question is the bed, as you have seen in your own case, where your foundation is made good and solid.

"Small engines may be supported upon a single cross piece at each end of the bed, but this method should be employed only for the smallest sizes.

"The heaviest, and in most cases the hardest, pipe to fit up is the exhaust. It runs from the exhaust nozzle on the engine to the muffler and thence outboard.

"The muffler is commonly placed in the stern with the outlet directly outboard. It may, however, be in any convenient position, like under the seats in the standing room, and the piping led outboard. In any case, the piping for the exhaust should be as direct and as free from sharp bends as possible.

"When the motor is near the middle of the boat, a good practice is to lead the exhaust pipe out through the bottom, and along it to a point near the stern, where it again enters the boat and connects with the muffler. The outlet from the muffler then leads directly outboard as before. This method, especially on a large cabin boat, avoids much loss of space and the disagreeable heat of the exhaust pipe. The surrounding water quickly cools the exhaust, reduces the pressure and makes the exhaust almost noiseless.

"The particular function of the muffler is to afford a comparatively large space into which the exhaust may pass and expand, greatly reducing the pressure. The gas, under the reduced pressure, then passes out with little disturbance. The muffler need be of no particular shape, as long as the volume is sufficient. It is usually made of cast iron in the smaller sizes and of sheet iron in the larger. In many cases a long piece of rather large pipe will answer the same purpose.

"The muffler may be dispensed with and much space saved by carrying the exhaust directly through the bottom of the boat and exhausting under water. Although this is a very convenient and many times satisfactory way, great care must be used or poor results will be obtained. When the exhaust leads directly out, a certain amount of pressure is used in displacing the water. This pressure is, of course, supplied by the piston and is a 'back pressure,' retarding the piston and decreasing its power.

"A small expansion chamber or muffler should be provided between the engine and the outlet, in order to break up the violent pulsations and make the flow fairly constant. Some form of shield should be fitted over the outer end of the exhaust pipe to guide the stream of the exhaust aft and prevent the water being forced into it by the movement of the boat. Several forms of these are on the market in the shape of brass castings which bolt on to the outside of the hull and have a thread on the inside to take the exhaust pipe.

"When the under water exhaust is fitted, a pet cock should be put in the exhaust pipe near the engine. This is opened when the engine is stopped, thus preventing the water from being drawn up into the cylinders by the vacuum caused by the cooling of the gases in the pipe and cylinders.

"The under water exhaust is a very neat and simple method, when correctly installed, as all noise and heat from the exhaust pipe are avoided. The exhaust may be considerably cooled and the noise reduced by dispersion.

"With regard to stationary engines, used for domestic or other purposes, any old place is considered good enough to put them in. Now, this is one of the biggest and most expensive mistakes one can make, for as soon as some small screw gets loose in the far corner, the engine, salesman and manufacturer are unjustly blamed, simply because the present owner has not left enough room to make the small adjustments necessary in every engine and piece of machinery. Therefore, it pays always to install the engine in a light, dry place, easy of access and with sufficient space all round to enable all parts to be reached and to give plenty of room for turning the fly wheels in starting. Whenever possible, place the engine on the ground floor. On an upper floor, the necessary provision should be made to avoid vibration; if installed in the basement, place it in the best light.

"Without a good foundation, an engine may be expected to give more or less trouble from vibration, since it is subjected to forces, suddenly and repeatedly exerted, which produce violent reactions. Care should be taken to excavate down to good soil and to line the bottom with a substantial thickness of concrete in order to form a single mass of artificial stone. The foundations may then be built up of either concrete, brick, or stone. Anchor plates should be extended to the bottom of the masonry and fastened so as to prevent turning while the nuts are being screwed up. Place gas pipes or tubes with an inside diameter twice the diameter of the bolts around them, while the foundation is being built; this allows the bolts to be adjusted, and any variations between the tubes may be filled with thin cement after the engine is set.

"The top of the foundation should be finished perfectly flat and level with a dressing of cement, and after this is thoroughly dry the engine may be placed in position. When bolting down the engine, it is better to draw each bolt down a little at a time until all are tight and thus avoid straining the engine crank. After the nuts are drawn tight, if the crank turns unreasonably hard without loosening the main bearing caps, it may indicate an uneven foundation, which is a strain in the engine bed casting.

"When setting up large engines, for farm or other purposes, especial care must be taken to avoid straining the bed castings. Foundations hung from an upper floor, or built upon it, should be placed as close to the wall as possible. For the smaller sizes of engines it is a good plan to lay wooden beams on top of the foundations and then to place the engine on top of them so that when the frame is bolted down it beds itself into the timber. The timber cap often saves an annoying vibration when it can be overcome in no other way.

"All the connections should be as short and as free from turns as possible, and no mistake can be made by having plenty of unions, so as to disconnect with ease. The gasolene tank should be set as near the engine as is convenient, with the top of the tank, preferably, not more than a foot or two below the base of the engine. In cases where the gasolene tank must be set from forty to fifty feet away, it is necessary to place a check valve in the suction pipe near the tank. Both suction and overflow pipes must have a gradual rise all the way from the tank to the pump and should be as straight as possible to avoid the air traps, which prevent a steady flow of gasolene. It is most essential to clean thoroughly all pipes and fittings before they are put together, by hammering lightly to loosen any scale and washing out with gasolene, as solid matter of this nature may be responsible for some of the simple, but hard-to-get-at troubles common to gasolene engines.

"Shellac is best for joints in gasolene piping, but when this cannot be obtained common laundry soap will answer the purpose just about as well. Remember, also, that gasolene is a rubber solvent, and should never be applied to joints where rubber is used. In some cases it will be found advisable to use gravity feed instead of a pump, except in the case of the tank, which must be so arranged that its lowest point is slightly above the generator valve.

"The exhaust pipe must be of full size, free from turns and short as possible, since the shorter it is the more economically the engine will run. It will be found advisable to place the muffler and exhaust piping away from combustible material, and never to turn the exhaust into any chimney or flue.

"There are two general methods of supplying the water, the first being that of the cooling tank commonly used with small engines. For convenience in piping, the tank should be slightly elevated, and both pipes, having as few bends as possible, should slope from the tank to the engine, a valve being placed in the bottom pipe near the tank. By using a circulating pump, fitted to the engine or shaft, water may be used from an underground cistern or tank.

"The other method is to use a continuous cooling stream from water-works' or other source. When city water is used, it is a good plan to have a break and funnel inserted in the drain pipe so that the current of water flowing through the cylinder jacket may be seen. For making joints in water pipes, either thick lead or graphite may be used with almost equal success. It may be well to place particular emphasis on the fact that it will pay to get into the habit of always shutting off the water at the tank and draining the cylinder every time the engine is stopped — not necessary in summer, but absolutely essential in winter — as a fair percentage of gasolene users know to their cost.

"The greatest care must be employed in using and handling gasolene, as it is dangerous and highly explosive. It has been known to explode when 20 or 30 feet from light, the vapours having reached the fire in the way of a gas, igniting and firing the liquid. And, now, right here, let me impress on you this warning; never handle gasolene near a fire or light under any circumstances, and be very careful with it under all conditions.

"Fortunately, there are few accidents resulting from gasolene, when we consider the large amount used since it has become almost a universal fuel for engines, and it is also used largely for domestic heating and lighting.

"It is a product of petroleum, of which in its crude form about 76 per cent. is turned into kerosene, 11 per cent. into gasolene, 3 per cent. into lubricating oils, and the balance into vaselines, paraffine, coke and so forth.

"Different petroleums produce different proportions of the various products, some of them being considerably richer in gasolene than 11 per cent.

"Gasolene is usually designated according to its specific gravity by an arbitrary measure, known as Baume's hydrometer scale. This designation is in degrees, the most common gasolene ranging between 65 degrees and 85 degrees, and the average being 70 degrees, the usual density used in engines.

"You will find it somewhat difficult at first to start up your engine when you wish to, so I will give you a few hints to show how this difficulty may often be overcome.

"There is always a reason why a gas engine refuses to obey the behest of its driver.

"In the first place, see that the compression is right and the admission valve so tight that it will admit only enough of the mixture (gasolene and air) to make a charge that will take fire from the sparker and move the piston forward. Next see that the sparker is clean, that it will make a bright spark at white heat when the contact is broken, and at the right time. 'In time' means to go if everything else is right, and 'out of time' means not to go even when everything else is right.

"The valve of the engine must be kept well ground down with emery and oil so as to preclude the possibility of a leak, as one would very seriously weaken the power of the engine even after it had started. The spark must be made when the connecting rod of the engine is on the 'up stroke,' with the crank shaft about three inches below the horizontal line of the centre of the index, and herein lies the whole secret of the greatest efficiency from the least amount of gasolene. As there is an interval of time after the spark is made until it ignites the charge, it is very evident that the movement of the machinery continues and the moment of ignition should take place when the compression is greatest. This will be when the piston is on its farthest 'in stroke,' *i. e.*, in perfect line with the centre of the cylinder. But if the charge be ignited at this point the engine will not develop the greatest power, as the interval spoken of will elapse and the piston will have started on its 'out stroke', thereby not getting its full force of the expansive gases liberated by combustion of the air and gasolene.

"So you will readily see that you must allow for the interval spoken of, if you would get full returns for the energy used in propelling the motor. I have tried to make this plain, and I hope my efforts will help you out with your engine, either in starting or developing the power at which it is rated."

It was not yet late, so the boys took down from the book shelf a code of yacht flag signals, and found the following:

"There are no hard and fast rules regarding shapes and colours of yacht bunting, but the following are generally accepted by the prominent clubs in the United States and in foreign countries.

1. The "pennant" (a triangular shaped flag) is used for the club burgee.

2. The "shallow tail" is adopted for the private signal.

3. The rectangular flag is chiefly used for a flag officer's signal.

4. The shape, consequently, at once denotes whether a flag is that of a club, a flag officer, or a member.

5. The majority of flag officers' signals are coloured: Blue for commodore, red for vice-commodore, and white for rear-commodore.

6. The international code of signals enables yachts to communicate with each other, and is also used for dressing ship.

The ensign should be flown from the peak of the main-sail on a sailing yacht, when under way, and from a stern flag pole when moored.

On a yawl, it should be hoisted at the mizzen truck.

On a steamer, launch, or dinghy, it should be flown from a stern flag pole, when under way or at anchor.

Club Burgee.— The burgee should measure in length about one-half inch for each foot of height of truck from the water; width to be two-thirds of the length. Private signals may be smaller.

The burgee should be flown from the mast-head or truck of a cutter, sloop, or cat-rigged yacht, the main truck of a yawl, the fore truck of a schooner and steamer, and from the bow pole of a launch or dinghy.

Flag officers' and private signals should be flown from the truck of a cutter, sloop, or cat-rigged yacht, the main truck of a schooner, yawl, or steamer, and from the bow pole of a launch or dinghy.

The following flags are not considered as colours:

Night Pennant (blue).— Is hoisted at the main truck from sundown to 8 A. M.; also occasionally used as a tell-tale when racing or sailing.

Owner's Absent Flag (blue rectangular).— Is flown from the main starboard spreader when yacht is at anchor only. It denotes owner is not on board, but should never be flown when under way.

Owner's Meal Flag (*white rectangular*).— Is flown from the main starboard spreader, and denotes the owner is at meals — boarding a yacht when this flag is flying is considered bad form.

Crew Meal Flag (*red triangular*).— Is flown from the foreport spreader on schooners and mainport spreader on single-masted yachts. This denotes that the crew is at meals.

The Ensign.— Displayed on a vessel indicates distress and want of assistance.

Flag "*B*," of the International Code of Signals, is used for a protest flag, and is conspicuously displayed in the rigging of a yacht protesting during a race.

A yacht, on withdrawing from any race, should at once lower its racing colours, and allow yachts still competing the right of way.

This code was studied by the boys until both of them thoroughly understood its full meaning, and George became so enthusiastic over it that he exclaimed: "Fred, I am going to be an admiral of the navy!"

V

A TALK ABOUT ENGINES

MR. WATTS was early at the Gregg residence next day, and busied himself preparing the engine to start up. A big tub was taken to the boat house filled with water by a hose attached to the suction pipe, and dropped into the water. This was a mystery to George, who inquired about the use of the water and the other attachments. It was explained to him, that outside the cylinder there was a hollow space, called the "water jacket," extending over the top of the cylinder, and this had to be kept full of cold water by continual circulation. It was pumped in by the engine and forced out by the same means, a simple contrivance being arranged for the purpose. This circulation of water is necessary to keep the inside of the cylinder cool, otherwise the walls would soon become red hot, on account of the rapid explosions of gas and air employed in the cylinder to keep the piston moving to and fro.

George seemed to grasp the idea thoroughly.

Mr. Watts also explained the use of the carburetor, the spark coil, the battery, and the method of contact to produce a spark at the proper moment. After some screwing of bolts, adjusting the piston, and trying the valves, the tank in the carburetor was supplied with gasolene and Mr. Watts tried the engine for a few revolutions, as gently as it could be done. It was a little stiff at first, some of the connections fitting too tight, and the piston, being new and harsh, did not work smoothly. By the judicious use of good lubricating oil and a few turns of some of the nuts on the bolts, a little more freedom was given to the machine and the starting was easy and smooth. George and Jessie were delighted with the rapid movement of the machine, the buzz of the propeller, and particularly interested in the movement of the water in the tub.

Mr. Watts allowed the engine to run quite a little while, and arranged the exhaust so as to beat regularly and to "pop! pop!" as little as possible. He then called Fred into the boat and taught him how to run the machine, arrange the contact breaker, and regulate the feeding of fuel. The engine was stopped to cool and to be examined again by Mr. Watts, who pronounced it all right. Mr. Gregg, who had arrived just before the engine was stopped, examined all its parts and watched it work for a minute or so.

Fred arranged his pots and brushes, and he and George went to work varnishing, so that before sunset the *Caroline* looked quite smart and trim. The boys were very careful in applying the varnish to put it on light and thin so as not to let the coats lap over one another as they went along. They finished each "streak" from end to end, before starting on the next, and following this method they obtained a nice, even surface. The varnish did not look "blotchy" or patched, as it would have done had the ends of the varnish lapped. To avoid "lapping" is one of the most essential operations in varnishing, when a nice piece of work is desired.

It was decided to give the little craft two more coats of shellac varnish before launching her, and the following spring to give her a good coat of marine varnish. Mr. Gregg thought that in another week, say the following Wednesday, the *Caroline* might be launched with safety, as the varnish would get dry and hard, and the inside paint would also be hard enough. Jessie and the boys were given permission to invite a few friends each to the boat launching, and were promised suitable refreshments to be served on the new grounds, if the weather was

FINISHING THE MOTOR LAUNCH

"To Avoid 'Lapping' is One of the Most Essential Operations in Varnishing"

favourable. Fred asked his father if he could not build up some temporary picnic tables and seats for the occasion, as there was plenty of material still left unused from the old barn stuff. Permission was granted, and after counting up the number that would probably be present, it was found that three tables, each about fifteen feet long, with necessary seats, would give ample room for the accommodation of the proposed guests, with a good allowance for overflow.

Just then the whistle of a small steam tug, that often plied on the river, gave warning of her approach; and all went down to the river edge to watch her pass and to see what effect her "wash" would have on the new pier and the boat house "skid" or slides. She came up stream rapidly against the tide — which was on the ebb — and there was a considerable "wash" from her wheel, but it struck the bank, the pier, and the "skids" without doing the least harm or giving any evidence that trouble would result from any reasonable wash. The little steamer's exhaust, as she passed, made quite a noise and Jessie was somewhat puzzled at this, as the exhaust from the gas engine of the *Caroline* only made a plaintive puff in comparison. Her father promised to explain the reason after tea.

Returning to the boat house, George suggested that the name of the boat be painted on both sides of the bow, in large letters, but Mr. Gregg and Fred, thought it better to have "Caroline" placed on the second streaks of sheathing, in gold, the letters to be not more than two inches over all. This was agreed upon, and a young artist, who was a near neighbour, was suggested as the person to do the work.

After tea, Jessie and the boys followed their father into the den, where Mr. Gregg gave the children a brief history of the steam engine, as far back as known, commencing with the Colipyle, the invention of Hero of Alexandria about 130 B.C. An illustration of this is shown in Fig. 30. It was simply a pot or boiler, partly filled with water, the lid or cover being fastened down tightly. On the top of this was attached a hollow bent tube having a tap fitted to it, which supported and communicated with a hollow metal ball hung on another tube or bearing on the other side in such a manner that the ball could revolve easily. Attached to this hollow ball or sphere were four other hollow tubes, so fastened as to project from the surface two

Fig. 30. Hero's steam engine

or three inches, and these were bent at their outer end, as shown in the illustration. These tubes were of course attached and bent in a direction at right angles to the axis of rotation. The tap leading to the hollow ball, when turned open, allowed the steam from the boiler to rush into the ball and fill it up. If it was closed entirely, the ball would remain still, but the steam exerting an equal pressure on all points of the inner surface, and finding the openings, escaped through with a rush and noise as it condensed in the air, which it pressed against, causing the ball to revolve in an opposite direction to the outflow of steam. This Hero engine or Colipyle, was doubtless the beginning of steam motors, but during the 2,000 or more years since Hero's toy engine was invented, great strides have been made toward bringing the steam engine to its present efficiency.

"But I do not intend," said Mr. Gregg, "to give a history of the growth and development of the machine, at this time. There are numerous works on the subject, obtainable in any fairly-equipped library."

Steam, as everybody knows, is generated by heat being applied to a closed metal kettle or boiler containing water. This boiler must be strong and properly arranged so as to admit more water —

which is usually injected with a force pump — and it must have an outlet for the release of the steam to the cylinder of the engine. Generally, there is a small dome on the top of the boiler, called the "steam dome," and to this the steam outflow pipe is attached. The actual use of this dome is to hold a volume of steam that will remain unmixed with water, as it is placed considerably above water level. On the top of the dome there is an automatic arrangement called a "safety valve," so that when there is too much pressure of steam in the boiler, it will open and allow the over-pressure to escape, and thus prevent the boiler from exploding or being over strained. This valve is controlled by a simple device, somewhat similar to a steelyard. A movable weight is arranged to slide on a long arm which is loosely fixed to the valve flange by a bolt and nut, and extends some distance past the seat of the valve. The arm or lever has an iron pin attached to it directly over the valve seat, which holds down the valve and keeps the steam from escaping. The movable weight on the arm is adjusted so as to regulate the pressure on the valve. When there is too great a pressure, the valve forces up the lever, and at the same time opens a passage for the extra pressure of steam to escape. There are several other contrivances for relieving the boiler of over stress, but the one described, or rather the principle on which it is built, is most in use on this country. There are many kinds of boilers, or steam generators, but the best, and very likely the strongest, are those employed on our first-class railway locomotives. These are frequently under a pressure of 200 or more pounds to the square inch, which seems an enormous load for a hollow shell to carry, yet, so near perfection are they, we rarely hear of a locomotive boiler explosion. As there are many kinds of boilers, so also are there many kinds of steam engines, but all of these latter, with very few exceptions, have a cylinder and piston for converting the force of the steam into useful and effective motion. The manner of using this force and keeping it under proper control is somewhat complex and difficult to describe briefly, without elaborate diagrams, but Mr. Gregg explained, in his own way, how the

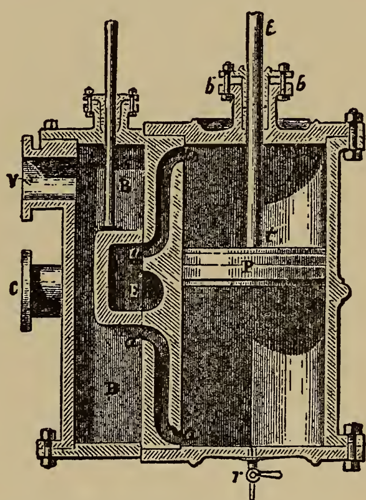


Fig. 31. Steam cylinder and piston

great force was converted into motion. On the blackboard he drew a rough diagram of a cylinder and valve or steam-chest, with piston and slide-valve, about as shown in Fig. 31, which gives a longitudinal section of the whole arrangement. Here we see near each end, the opening of a double conduit aa, made in the thickness of the side; these are the openings by which the steam comes alternately to work on one end, then on the other, of the piston. These are called the steam-ports. These two open outward on a well-polished surface, and between the two a third opening, E, is seen, which serves to let the steam escape when it has done its work, and is called for that reason the exhaust port. C is the pipe by which the steam gains access to the open air or to the condenser, where it parts with its elastic force.

Here is shown by what contrivance the distribution is effected, consisting, as it does, of two partial operations; the admission of the steam and its escape, which must be repeated twice to obtain a complete phase of the to-and-fro movement of the slide-valve. There are various methods employed according to different engines — but the first described is the one represented by the illustration.

In the valve chest, BB, is seen a prismatic box, open on one side, called the slide-valve, and this is applied by its open face to the well-polished plane on which, as mentioned before, the three ports open. The space BB, is called the valve or steam chest. The steam coming from the boiler by the pipe C spreads out freely in it, but the inside of the slide-valve, on the contrary, is always

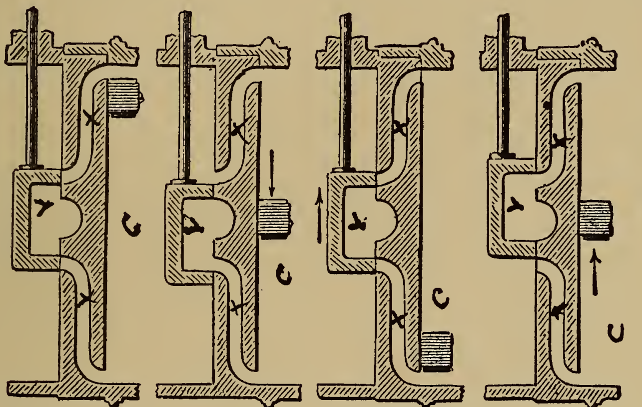


Fig. 32. Steam valves — different positions

closed to the entering steam, though constantly in communication with the escape pipe and also with first one then the other of the entrances to the cylinder. Lastly, the movement of the slide-valve is produced by the engine itself, aided by a rod and an eccentric fixed to the shaft of the fly-wheel.

By following the successive and alternating motions of the slide-valve, as represented in Fig. 32, we can easily comprehend the different phases of the distribution of the steam.

This is the machinery for the distribution of steam generally. There are other engines, such as rotary and oscillating, that are supplied by other contrivances, but most of these have fallen, or are fast falling into disuse, as they are not so satisfactory as the ordinary slide-valve. It will be seen upon examination of the sketch, shown in Fig. 32, how the steam enters and leaves the cylinder and the position of the piston under the various positions of the valves. The arrows show the direction of the slide, also the direction of the piston and its position when the slide covers the ports X, or leaves them open, or partly so. The ports for egress or ingress are shown at X, the slide-valve at V, and the cylinder at C. When the piston is near one end of the cylinder, the steam is admitted and forces the piston in the opposite direction, while the valve is so arranged that when the piston starts in that other direction, it begins to open the port at the other end of the cylinder through which the exhausted steam escapes. This makes the noise Jessie asked her father about. There are some engines so devised that the exhaust is made to assist in driving another engine.

Of course, there are many kinds of steam engines, but all are run on the same principle, or nearly so. As you know, steam is generated in boilers by fire being applied to the outside and the water made hot enough to raise steam. A steam engine is said to be externally heated, while gas, oil, and other similar engines are internally heated, because instead of the steam driving the piston, the gas, oil, or other explosive matter is admitted into the clearance or space between the piston and the end of the cylinder, where it is exploded by an electric spark from a battery provided for the purpose, and this is called the "ignition." The explosion causes the gas and air in the cylinder to expand, bringing a great pressure on the piston, forcing it to move toward the other end of the cylinder, and making the whole machine move. One great advantage of employing a gas engine is that no boiler is required, a very important matter, as boilers take up a great deal of space. The coal or wood necessary to keep up steam also takes space that could be used for other purposes, all of which make the use of steam objectionable when it is possible to employ suitable gas engines. Besides, the make-up of a steam engine is of such a character that it is very expensive, while the first cost of gas engines is much lower.

All gas, oil, or other explosive engines are internal heaters, because the heat is generated in the cylinder at each explosion, and this is one of the main features that distinguishes the gas from the steam engine. Of course, there are many attachments and connections to steam and gas engines that would take too long to describe, and in a great measure be unnecessary. A few items may prove both useful and profitable and it is well to know firstly: How to estimate the horse-power of an engine.

When steam engines were first introduced they were largely used to take the place of the horses previously employed for raising water from mines. Naturally people inquired, when buying an engine, what amount of work it would perform as compared with horses. The earliest engine builders found themselves very much at a loss to answer this question so they had to ascertain how much a horse could do.

The most powerful draught horses and the best of any then known were the London brewers' horses. These, it was ascertained, were able to travel at the rate of two and a half miles per hour and work eight hours per day. The duty, in this case, was hoisting a load of 150 pounds out of a mine shaft by means of a cable. When a horse moves two and a half miles per hour, he travels 220 feet in a minute, and, of course, at the speed named, the 150-pound load would be raised vertically that distance. That is equal to 300 pounds lifted 110 feet per minute, or, 3,000 pounds lifted 11 feet or 33,000 pounds lifted one foot high in one minute. That is the standard of horse-power, as we all know. It is much more, however, than the average horse can do, and therefore the builders were confident that the engines would take the place of fully as many horses as the horse-power would indicate that they should.

Of course, 33,000 pounds lifted 1 foot per minute is much more convenient for calculation than 150 pounds lifted 220 feet, and therefore the former rate has been adopted. The amount of work, or number of "foot-pounds," is the same in either case. A foot-pound represents the amount of power required to lift one pound one foot high. To find the number of horse-power in any engine, we multiply the area of the piston by the average pressure per square inch upon it; multiply this result by the distance which the piston travels per minute in feet and the result is the number of foot-pounds per minute which the engine can raise. Divide by 33,000 and the result will be the number of horse-power. The number of feet per minute travelled by the piston is twice the number of strokes per minute multiplied by the length of the stroke. This gives the amount of horse-power sufficiently accurate for all practical purposes.

It necessarily takes time to do work, but the amount of work done has nothing whatever to do with the time taken to do it.

If a man, weighing 150 pounds, walks up the 900 steps leading to the highest attainable level in the Washington Monument, 500 feet high, he does work against gravity equal to 75,000 foot-pounds, irrespective of the time taken in the ascent. Then the work done in a given time, divided by the time, is called the power of activity.

Power is the time rate of doing work. In the English gravitational system, the unit of power is the horse-power (H. P.); it is the rate of doing work equal to 33,000 foot-pounds a minute, or 550 foot-pounds a second.

In the centimetre-gramme-second (C.G.S.) system (in which the unit is 1 gramme moving at the rate of 1 cm. a second), the unit of power is the watt. It equals work done at the rate of one joule (10,000,000 ergs) a second.

One horse-power is equivalent to 746 watts.

A kilowatt (K.W.) is 1,000 watts.

It is therefore nearly 1⅓ horse-power.

To convert kilowatts into horse-power add one-third; to convert horse-power into kilowatts, subtract one-fourth.

For example, 60 K. W. equals 80 H. P. and 100 H. P. equals 75 K.W.

The expression foot-pound is in general use among English-speaking engineers, and as explained it is the unit of work done by a force of one pound working through a distance of one foot. It is not a fixed standard of measurement, since the weight of a pound is not the same in all heights above sea level, and on this ground it is open to objection. It is the nearest constant, however, we have yet discovered, hence its general adoption.

"Dry steam" is the steam in which no condensation is visible, and it may generally be obtained at a 10-pound pressure per inch, but no exact dividing line of pressure can be defined between dry steam and wet. If care is taken in covering pipes and cylinders, to prevent condensation, a pressure of 10 pounds should make steam as dry as gas, and if the steam pipe is carried through a good, hot fire at some point, the fire will superheat the steam and render it more dry. Wet steam, of course, is steam that can be seen, through having been more or less condensed by contact with air or cold. There can be no steam without heat, but steam does not require as much heat as is generally supposed. Suppose we take one pound of water at 32 degrees Fahrenheit and apply a fixed and known quantity of heat until it boils; we will assume that it takes 20 minutes, and we have supplied the water 180 heat units, which, added to the 32 contained in the water at the start, makes 212 degrees Fahrenheit or heat units, and is the sensible heat of steam at atmospheric pressure. Now let us continue the same quantity of heat per minute until all the water has evaporated into steam, and we will then find that it has taken five and one-third times as long, or 10 minutes to do this work. Consequently we have used five and one-third times 180 or 960 heat units; or, to be exact, 966 heat units. Now the temperature of the steam is the same as the water from which it has evaporated, or 212 degrees Fahrenheit, and this 966 heat units is the latent heat of steam at atmospheric pressure. All steam has a sensible heat corresponding with the temperature of the water it has evaporated from.

If you boil water under a pressure of five atmospheres, or 75 pounds pressure, the sensible heat is 306 degrees Fahrenheit, the boiling point at that pressure, but the latent heat has decreased by the same number of heat units that the boiling point increased, so the total is the same in all cases. In the first instance we have 212 degrees minus 32, plus 966, or 1,146; and in the second 306 degrees minus 32, plus 872 or, 1,146 heat units. This may be considered a fair description of latent heat.

The most useful quality of steam yet discovered is its power of expansion. It follows what is known as Marriott's Law of Expanding Gases, which means one-half the pressure double the volume. So if we let steam into an engine cylinder, at 80 pounds' pressure, and cut it off at one-fourth stroke, it is at 80 pounds up to the point of cut-off. At one-half stroke, because it has doubled its volume, it is reduced to one-half pressure, or 40 pounds; while at three-fourths stroke the volume has trebled and the pressure has dropped to nearly 27 pounds, and this is why it is economical to run engines that use steam expansively. Steam at 27 pounds' pressure is very much cooler than steam at 80 pounds, and this difference in temperature has been converted into mechanical work by our steam (heat) engine.

There are many other peculiarities about steam and steam engines that a young boy should know, and the information can readily be obtained from books in any good library.

The steam turbine, of which so much has been heard lately, is not constructed like an ordinary steam engine with cylinder, slide-valve and other attachments; but more like the Hero engine, with this difference that the steam jet or jets act on a wheel having vanes or blades, the expansion producing a velocity which rotates the wheel containing the vanes. A modern turbine, of the Parsons type, such as are employed on the great Atlantic steamers, is a tremendously high speed engine. It does not derive its power from the static force of steam expanding behind a piston, as in a reciprocating engine. In this case the expanding steam produces kinetic energy of the steam particles, which receive a high velocity by virtue of the expansion, and, acting upon the vanes of a wheel, force it around at a high speed of rotation in the same manner as a stream of water rotates a water-wheel. The expansion produces velocity in a jet of steam, and this is the main difference between the ordinary engine and the modern steam turbine.

Among gas and internal explosion engines there exist some differences, both in construction and in the manner of supplying fuel. The gas-producing engine may be considered the better class, though it has not as yet gained the popularity of the gasolene one. The gas by which this style of engine is operated is produced by a special process, namely, by passing air and steam through a fire of hot coals. After generation the gas passes over a flash-boiler and a portion of its great heat is withdrawn, thus permitting it to enter a scrubber — a cylinder filled with coke and saw-dust — while fairly cool. In passing over the flash-boiler the great heat raises all the steam necessary for the production of gas required in the operation of the engine and plant. In passing through the scrubber the gas is not only cooled, but is freed from particles of suspended matter, the coke removing the heavier particles, and the sawdust, the tar, or any other volatile matter that may be left.

One of the most important requirements in a gas-producer is that it shall be adapted to the work it has to do. Its construction should be compact and simple, so as to permit the easy removal of worn out parts. The feeding device should be such as to secure a uniform distribution of fuel.

The blast should be so introduced as to burn out all the carbon in the ash zone, and yet not produce localized combustion along the walls. The construction should permit the easy removal of ashes, and render the machine safe, while the entire process of gasification should be clean. The radiation loss should be low, and the producer must be made efficient to insure satisfaction.

It should be borne in mind that because of the presence of carbon monoxide, producer gas will always be more or less poisonous. The carbon monoxide has a specific toxic effect on the human system, and when inhaled enters into direct combination with the blood, and brings about very dangerous effects.

As water is always required for cooling purposes when running a gasolene engine, it is well to know about how much will be required. One authority says: "The quantity of water required at the ordinary temperature of 60 degrees F. inlet and 150 degrees outlet, to keep the cylinder of gas engines cool is 4.5 to 5 gallons per indicated horse-power-hour. The jacket pipe should be from 1 to 2 inches diameter for engines up to 20 horse-power, while for larger engines the sizes are generally 2 to 3 inches for the inlet and 2.5 to 3.5 inches for the outlet. Tanks for circulating the water are generally made with a capacity for furnishing 20 to 30 gallons per indicated horse-power. This rule may be taken as about correct, but, if anything, it is rather an over-estimation of quantity necessary."

All the foregoing was made as clear as possible to the listeners by Mr. Gregg before the children went to bed.

Next morning Fred called up his artist friend, and got him to come down to gild the name "Caroline" on the boat before the next coat of varnish should be applied. The artist made an outline of the name while George and Jessie stood by and watched the process with considerable interest. They saw him measure off each letter, outline it with a pencil lightly, and then paint inside the lines with a substance known as "gold size," obtained from any store dealing in painters' supplies. While the size was still sticky the artist applied "gold leaf," which he had brought in a little book along with him. Jessie was surprised to see him cut the gold with a thin pallette knife, having a blunt but smooth edge. She watched him pick up the small pieces of gold with a camel's hair brush, which he rubbed in his own hair now and again whenever it would not pick up the gold. The metal was applied bit by bit over and beyond the lines of the letters, and a light puff of breath forced it down to the size. When one side of the boat was finished, so far as laying on the coat of gold was concerned, Jessie was very much disappointed, as the name seemed merely a smudge. She could not make out the letters, but the artist told her to wait until to-morrow and he would show her how well they could be seen. Next day with a flat camel's hair brush he dusted away the surplus gold, and the letters showed up in good style, much to the gratification of Jessie and George. This part of the work being done, the boys took down their varnish pots, and gave the little craft another coat, to make her quite spruce and gay.

Fred, and Nick, who was still in the employ of Mr. Gregg, laid off a space on the ground for tables and seats to accommodate the young folks who were coming to the launch on the following Wednesday. Nick found a number of old cedar posts, and with a saw cut off 18 pieces about two feet long and as many more twice that length. The first were intended to place the seats on; the second lot were to sustain the tables. The spots for the tables were chosen, measured off, and small stakes driven into the ground to show where the posts were to be placed. Five posts were intended for each table — two at each end, two feet apart, and nine feet apart in the length of the table. The single post was placed in the centre of the table both ways. When the stakes were all in place, Nick made holes deep enough to take in the posts so that their tops measured just two feet and two inches above the level of the ground. The tables were to be two feet and six inches high when finished, as that is the regulation height. It was attained, in this case, as follows — First by the height of the posts from the ground, two feet two inches; then by a plank two inches thick laid across the two posts, making the height two feet four inches, and the table top, two inches thick, laid on these cross planks, which brought it up to the required height. A piece of plank the same thickness was nailed on the centre post across, so that it would support the table top. Planks that had been used in the loft of the old barn did service for the table tops, bearing pieces, and the bench seats. The last were constructed in the same manner as the tables, the short posts being let into the ground — three under each seat — and fourteen inches above ground so that when the plank seat was nailed on top of them, the seats were just sixteen inches, the regulation height of stools, benches, and chairs, though it is sometimes varied to suit conditions. The benches were placed about four inches out from the edge of the table and were found to be "just the thing."

When Nick had planted the first post for the tables and got it the right height, he took that one for his guide and by the aid of a long parallel straight edge which he laid on the guide post and the one he was setting, and also a spirit-level on the straight edge, he managed to get all the posts alike in height and this made the tops of the three tables nice and level. It was quite an achievement to have three large tables and six long seats placed in "picnic style" at so small a cost and with so little effort.

In order to have the tables and seats neat and clean, George turned on the garden hose and gave them a good wash off, and when they were dry again the place was as inviting as a country hotel dining-room. When Mrs. Gregg, Jessie, and Grace Scott had the tables set and garnished for the launch, the lay out was charming, none the less so because it was a little rustic.

Another coat of varnish, the third, was given the boat the day before she was to be launched, and Fred had a strong rope attached to the winch, with a heavy iron hook fastened to the end of it. A stout iron ring was bolted to the stern of the boat and made secure. Mr. Gregg had purchased a number of small flags and "burgees" and had one made with the name "Caroline" in large letters wrought on it, ready to be unfurled when the launch was made, and Walter Scott, his mother and sister Grace, and others had been invited to attend.

A number of temporary swings were fixed up by Nick and Fred to the trees, some for the large folks, others for the smaller ones, and everything was at last ready for the great event, which was to take place the next day at two o'clock.

VI

PROPELLER AND OTHER SCREWS

WEDNESDAY morning was light and sunny and the boys were up and dressed somewhat earlier than usual, so, while waiting for breakfast, they took a stroll down to the river, where they found their father looking over the grounds and examining tables, benches, swings, and particularly the foot-bridge; for, as he told Fred, "it was very likely all the guests might be on the bridge at one time and the combined weight would be rather trying if it had not been securely put together." He satisfied himself, however, that the bridge was strong enough to support three times the weight it would be called upon to sustain. Everything else seemed to be sufficiently strong, to apprehend little danger, no matter how much the children romped.

Nick had the grounds nicely raked off; the decayed branches and shrubs he moved, and made everything about the place as clean and as neat as possible. Flags and other decorations were hung or placed about the grounds, on the trees and buildings, but particularly about the tables and the boat house. Newspapers were spread over the tables, linen covers above them, and the whole surroundings took on a most festive appearance.

It was just 11 o'clock when *The Mocking-Bird* arrived and tied up to the new dock. On board were Mrs. Scott, Grace, and the maid, who came to help, besides several of the invited guests whom Walter had brought down with him. All were welcomed by Fred, Jessie, and George and then the women visitors went to the house to assist Mrs. Gregg.

Mr. Gregg came home from his office earlier than usual and took a half holiday in honour of the occasion. The guests, in little groups, arrived on time, and before the clock struck two Nick had everything prepared for the launch. He and Fred and George had the *Caroline* nicely placed on the skid, ready to "let go" the winch, and a flag pole was fixed up on the bow of the boat. To this the flag with the name on it was lightly tied, in such a manner that when a string was pulled it would unfurl, and show the name. The string looping up the flag was left long enough to enable Mr. Gregg, standing on the dock, to hold the end in his hand,

and by pulling it to loosen the flag as soon as the boat touched the water.

Everything being ready, Walter Scott invited as many of the young people to get into the *Mocking-Bird* as could crowd on board with comfort, and each was provided with a whistle or a horn, as he ran his boat half way across the river. The children on shore were also given horns and whistles, and all were told to blow as loud as they pleased when the boat touched the water. Mr. Gregg, having Mrs. Gregg and Mrs. Scott standing beside him, gave the word, "Ready!" Nick and Fred answered, "Aye, aye, sir!" and the master of ceremonies called out in a loud voice: "Let her go!"

Nick freed the winch, Fred and George gave a little push, and the *Caroline* slid down the skids, into the water, without the least hitch. The horns and whistles made a great din, and when the flag was let free to open up and show the name "Caroline" there was another blast of noise by horns and whistles, mingled with voices of the younger people, who cried out with all their might, "Hurrah for the *Caroline!*"

The launch being over, and everything having gone all right, the young people were called to lunch. They all sat at the tables which were nicely garnished and well supplied, and there was plenty of small talk, and much laughter and jollity. After lunch, Fred, Walter and George boarded the *Caroline* supplied her with gasolene, and tried to run her. They found a little difficulty in starting, but after the engine was warmed up a little, she went off beautifully, and answered her tiller in fine style. The boys ran her up and down the river for a while, then tied her to the dock, and Walter and Fred invited all the girls to "Come and have a sail." The boys were promised one when the two boats returned, which they did in the course of half an hour. The swings were put in use, dancing and romping began, and the afternoon was passed in fun and frolic.

In the evening, Mr. Gregg, Jessie, and the boys took a trip, and Mr. Gregg was well pleased with the boat's performance, particularly with the working of the screw. In mentioning this, he awakened the curiosity of George, who reminded his father that he had not yet explained to them about the screw as a mechanical power.

That evening George was told to bring his blackboard and equipment into the den, and the father at once began explaining the mechanical qualities of the screw. He told of its great usefulness in the industrial arts. As one of the mechanical powers, it may be considered an inclined plane, wrapped spirally round a solid cylinder. The advantage gained by it depends on the slowness of its forward or backward progress, that is, on the number of turns or threads, as they are called, in a given distance. It is always used in combination with a lever of some sort. When employed as a lifting machine it has great power, and is used to produce compression or to raise or move heavy weights. If a screw is formed on the inside surface of a hollow cylinder, it is called a nut, and used to overcome a resistance; either the screw or the nut may be fixed and the other movable. The acting force is generally applied at the end of a lever or wrench or rim of a wheel. Fig. 33 represents a screw and nut operated by a lever or length of radius *r*; *p* is the pitch of the screw or height of the inclined plane for one revolution of the screw. W is the resistance at the nut and P is the force at the end of the lever *r*. Remembering that, while the resistance W

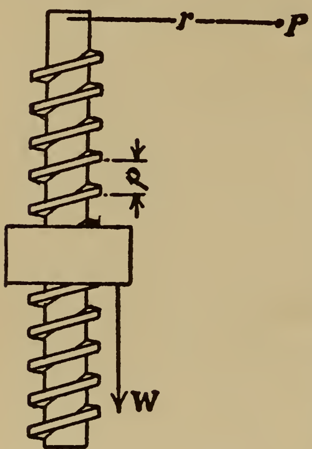


Fig. 33. Theory of screw

is raised the distance p the force P revolves around a complete circle and moves a distance $2\pi\nu$. Let us now apply the condition Σ work=0 and we have $P2\pi\nu - Wp = 0$ or $— = \frac{p2\,\pi\nu}{p}$ [6.]

The worm gear (Fig. 34) is a special case of screw and nut, where the latter is replaced by a toothed wheel called a worm wheel. The teeth work in with the thread of the screw or worm, and thus, as the worm revolves, the worm wheel revolves about its axis. P is the force acting on the worm at a radius r. r' is the pitch radius of the teeth in the worm wheel and r'' is the radius of the drum on which W acts. Let K, corresponding to W in equation W P [6], be the force at the pitch circle and worm threads due to the force P; then $K = \frac{P2\,W}{p}$ [7.]

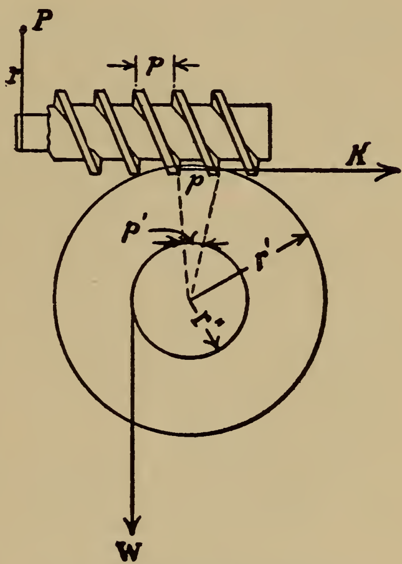


Fig. 34. Worm wheel and screw

Now apply $\Sigma m = 0$ to the worm wheel and we have $Kr'' = Wr''$ or $K = wr''$ (8). Substituting the value of K in (7) in equation (8) we have $P2\pi\nu = Wr''$ or $P2\pi\nu = Wr''p$ [9]. Now it is evident that the distance p' moved by W while K moves through the distance p is to p as r'' is to r' or $p' : p :: r'' : r'$ or $\frac{p' = pr''}{r'}$ (10). Substituting this value of $\frac{p\,r''}{r'}$ in equation (9) we have $P2\pi\nu = W\,p'$ or the condition Σ work $= 0$, since $2\pi\nu$ is the distance moved by (P) while W moves the distance p'.

No provision for friction has been made in any of the examples given, so that allowance must be made for this propensity whenever any of the foregoing rules are applied to practice. The amount of allowance required will vary and must be made to suit conditions.

An endless screw is sometimes used as a component part of graduating machines, counting machines, etc. It is also employed in conjunction with a wheel and axle to raise heavy weights. The distance between the threads of the screw is called the pitch or step. These threads are sometimes square, sometimes acutely pointed or edged, sometimes rounded off on the edges. Power is often applied by means of a lever or other contrivance attached to the end of the screw, or by a long handled wrench (a monkey wrench for instance), which, when turned, moves forward in the direction of its axis, overcoming resistance. In the case of the screw-jack, it may be used to raise a heavy weight. The relation between the force applied and the resistance to be overcome is important to note, for every time the screw performs one revolution it moves forward through a distance equal to the space between one thread and the next.

The Archimedian screw we have read and heard so much about is simply a hollow pipe wound around a cylinder. It was often used in olden times for raising water, but is now only occasionally applied. The lower end of the spiral pipe is, of course, left open and immersed in water, as shown in the illustration (Fig. 35), a device for raising water, the supply stream being the motive power. The oblique shaft of the wheel has extending through it a spiral passage, the lower end of which is immersed in water; and the stream, acting upon the wheel at its lower end, produces its revolution, by which the water

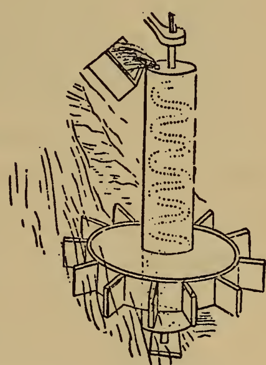


Fig. 35. Archimedian screw

is conveyed upward continuously through the spiral passage and discharged at the top. An arrangement like this could easily be constructed at the edge of most rivers to raise water to irrigate the grounds, if so desired, and the little flutter wheel at the bottom of the inclined shaft would be powerful enough to lift all the water required. Fred thought that would be a great scheme, and determined to try his hand at it one of these days, but he was told that a wheel of that kind could only work at intervals, as the river's flow was often running in opposite directions owing to the inflow of the tidal water.

These Archimedian water raisers are often fitted with a crank handle on top, and a man, standing on a platform, turns the crank and thus lifts up all the water the machine will carry. The Archimedian screw is used for many other purposes than raising water. With wide, thin wings, similar to the construction shown at Fig. 36, and enclosed in a case or jacket, it is employed by millers to convey grain and other mill requirements, and it is also good for moving coal, ore, gravel, and like material, but when used for these coarser purposes the propelling

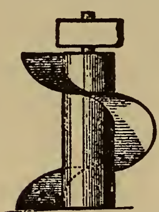


Fig. 36. Spiral conveyor

blades are made of steel, riveted or bolted to a strong iron shaft. The case or jacket containing the revolving blades, if horizontal, need not be covered on top, as the blades will propel the material without jamming or clogging, if the jacket is smooth inside, and fits fairly close to the blades.

This style of a screw may be used as a sort of turbine water wheel, if cased in a cylindrical penstock or tube, and a body of water allowed to fall into the upper end of the tube. The force of the water will give a rotary motion to the blades and shaft, and, the latter having a geared wheel or pulley attached to its top, motion is imparted to other shafts and wheels.

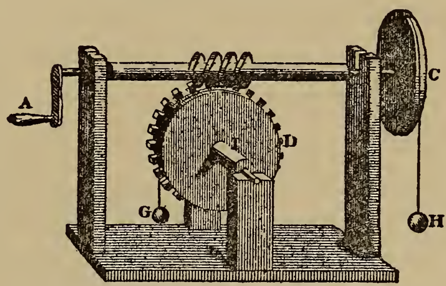


Fig. 37. Theory of screw and gear

Another application of the screw is shown at Fig. 37, where one is arranged on a shaft or axle to give a rotary motion. This device is called a "worm and wheel," and is frequently used in the make-up of machine engines and mathematical instruments. The illustration shows how the power or force of a screw may be conceived. For instance, suppose the wheel C has a screw on its axis working in the teeth of the wheel D, having 48 teeth. It is plain that for every time the wheel C and screw are turned round by the handle or crank A, the wheel D will be turned once round. Then, as the circumference of a circle, described by the crank A, is equal to the circumference of a groove round the wheel D, the velocity of the crank will be 48 times as great as the velocity of any given point in the groove. Consequently, if a line C goes round the groove, and has a weight of 48 pounds hung to it, a power equal to one pound at the handle will balance and support the weight. To prove this by experiment, let the circumference on the grooves of the wheels C and D be equal to one another; and then if a weight H, of one pound, is suspended by a line going round the groove of the wheel C, it will balance a weight of 48 pounds hanging by the line G; and a small addition to the weight H will cause it to descend, and to raise the other weight.

If a line C, instead of going round the groove of the wheel D, goes round its axle I, the power of the machine will be as much increased as the circumference of the groove exceeds the circumference of the axle, supposing which to be six times 8, then one pound at H will balance 288 pounds, hung to the line on the axle; thus showing the advantage of this machine as being 288 to 1. A man who can lift by his natural strength alone, 100 pounds, by making use of this combination, will be able to raise 28,800 pounds alone, and if a system of pulleys were applied to the cord H, the power would be further increased to an amazing degree.

When a screw and wheel are attached, as shown, the screw is sometimes called a "worm" and sometimes an "endless screw."

The propeller wheel (Fig. 38) is a screw having a large helical dimension. The example shown has four blades, each of which, when rotated, may be said to make one quarter of a revolution and when at work in the water has the same effect as the working of a nut, producing motion in direction of the axis and so propelling the boat or vessel. The action of the wheel pressing backward against the water tends to push the craft forward.

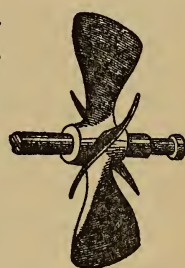


Fig. 38. Complete screw propeller

This figure shows a propeller with four blades, but two and three bladed ones, particularly for small craft, are mostly used. The *Caroline* carries a two bladed screw and her performances will be entirely satisfactory.

The blades, of course, are exactly in line with each other on the shaft, and equally balanced, or of equal weight. A three-bladed propeller should have its extreme points in a horizontal plane, so that they will form an equilateral triangle.

The principal features of a propeller may be described as: diameter, pitch, area, speed of revolution, and slip. The diameter is that of the circle described by the tips of the blades. The pitch, considering the propeller to be a portion of a screw, is the amount which it advances in one turn, supposing it to travel in a solid medium. The blade area is the actual area of all the blades.

The speed of the revolution is customarily reckoned in turns per minute. The slip is the difference between the amount which the propeller actually advances per turn and the amount which it would advance if turning in a solid medium. For example, if the pitch of a screw is 30 in. it would advance 30 in. at each turn if there were no slip. Suppose that it only advances 20 in. per turn, then the slip is 10 in. per turn, or as usually figured, 33⅓ per cent. As a further example, suppose a propeller of 30 in. pitch, turning 300 turns per minute, drives a boat at the rate of 6 miles per hour. The advance of the propeller in feet per minute is $\frac{30}{12} \times 300 = 750$ while the advance of the boat is $\frac{6 \times 5,280}{60} = 528$ ft. per minute. The slip is then $750 - 528 = 222$, or as a percentage, $\frac{222}{750} = 29.6$ per cent. It might seem at first sight, that a perfect screw propeller should have no slip; but this is a practical and theoretical impossibility.

The most important dimension, from the standpoint of the absorption of power, is the blade area. A certain blade area may be obtained by a relatively wide blade on a small diameter, or by a narrow blade on a relatively large diameter. In the former case the area of the blades bears a greater proportion to the area of the circle through the tips than in the latter case. There are certain limits for this proportion of [blade to disc area for well-designed wheels, beyond which it is not well to go. These are as follows:

For two blades .20 to .25.

For three blades .30 to .40.

For four blades .35 to .45.

This means that for a 24 in. diameter propeller, whose disc area is 452 sq. in. the blade area should not, for ordinary use, be made greater than these proportions, as the blades then become so wide as to interfere one with another. Of course where a propeller, for shallow draft, must be unusually small in diameter, the proportion of blade area can be increased, but with some loss in economy. Strictly speaking, for a well balanced propeller, the blade area fixes the amount of power which the propeller can deliver, while the pitch, combined with the turns per minute, governs the speed. As a matter of fact, for the average propeller the two are closely related, each having a certain influence upon the other. To illustrate, a propeller may have a small blade area and so great a pitch that the blades act somewhat like fans and simply churn the water, offering great resistance and absorbing the power of the engine, but doing little effective work toward driving the boat.

To get the measurements for a wheel required to perform a given service, say a three-bladed propeller for a small boat or tug of 20 nominal or 75 indicated horse-power:— assume that the size determined on is 4 ft. 6 in. in diameter and 7 ft. 6 in. pitch, the diameter of loss may be assumed to be 8 in. swelled to be 11 in. in the middle, and 11 in. long. The tug would be, say, 60 ft. long, 12 ft. beam, and 7 ft. deep. First delineate the path of the point and root of one blade through half a revolution as in Fig. 39. This should be drawn to a scale of not less than 1½ in. to 1 ft. by the ordinary method of projecting a screw thread. The semicircle shows the half plan with twelve equal divisions, and the half elevation is divided into the same number of equal parts. The helix or thread is then obtained by drawing the curves through the intersections of similar divisions. Then *a b* will be the helix for point of the blade, and *c d* the helix for the root of the blade. These will be found to be practically straight lines which might have been obtained in a simpler manner if intended for a working drawing only; but it is useful to have demonstrated the proper nature of the full curve.

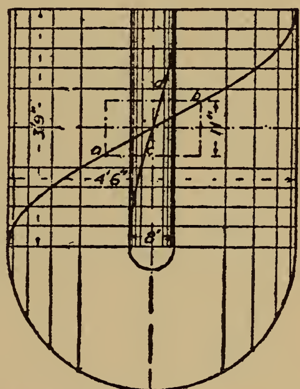


Fig. 39. Diagram screw lines

The practical way of setting off the blade follows: First for dimensions: as 20-in. (pitch) is to 11 in. (length of boss and therefore virtual length of propeller), so is 169.6 in. (circumference due to outer diameter) to the length of circumference occupied by the blade, $\frac{169.6 \times 11}{9} = 20.73$, say $20\frac{3}{4}$ in. In Fig. 40 describe a circle equal to the diameter of the propeller, and on each side of the centre line step off $20\frac{3}{4}$ in. to half the scale, making the whole length of arc to scale $20\frac{3}{4}$ in. Draw vertical lines from the ends of the arc, and from the arc on the centre line set up a height of 11 in. and draw horizontal lines. Join *a b*, and this will be the angle of the end of the blade. On the elevation of the propeller circle describe a small circle equal in diameter to the faces of the boss; draw radical lines from the ends of the arc first found, and from the intersection with the boss circle draw vertical lines to cut the horizontal lines of the plan of boss. Join *c d*, and this will be the angle of the blade at the root.

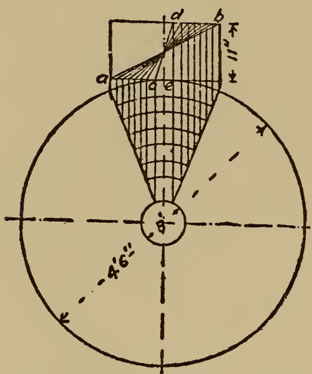


Fig. 40. Part of screw blade

Now describe an arc at every three inches from the circumference within the radical lines; or for large propellers every 6 in. Draw vertical lines from the intersections of the arcs with the radical lines to meet *a c* and *b d*, as shown, and joining the points thus found, the diagonal lines will represent the plan or angle of the blade to each 3 in. difference of radius — in other words, its real width at the different points, supposing it to be a plain geometrical portion of a screw thread. As a matter of fact, the blades are always more complex than this, the edge being curved to enter the water more easily, to avoid vibration, and also to lessen the risk of fracture in the event of striking any object in the water. Sometimes the blades are curved in the opposite direction, as if the points were being left behind while the blade is advancing.

The next step is to draw a flattened elevation or development of one of the blades, in order to give the actual curves of its outline, and afterward its thickness at various points. Draw a horizontal line from *c* and *f* (Fig. 41), and through this a centre line. This will give the length of the blade from the boss, and the centre line of the propeller shaft may be added below. Then take the lengths *ab* and *cd* from Fig. 40, and set them off on Fig. 43, as shown, joining all four points.

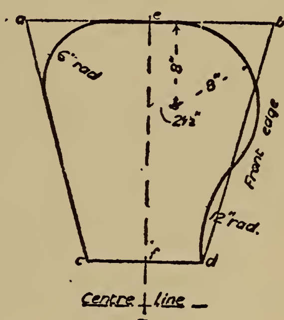


Fig. 41. Plan of screw blade

This figure would be the true outline of the blade if there were no curves. The actual outline is found by drawing the curves according to the dimensions.

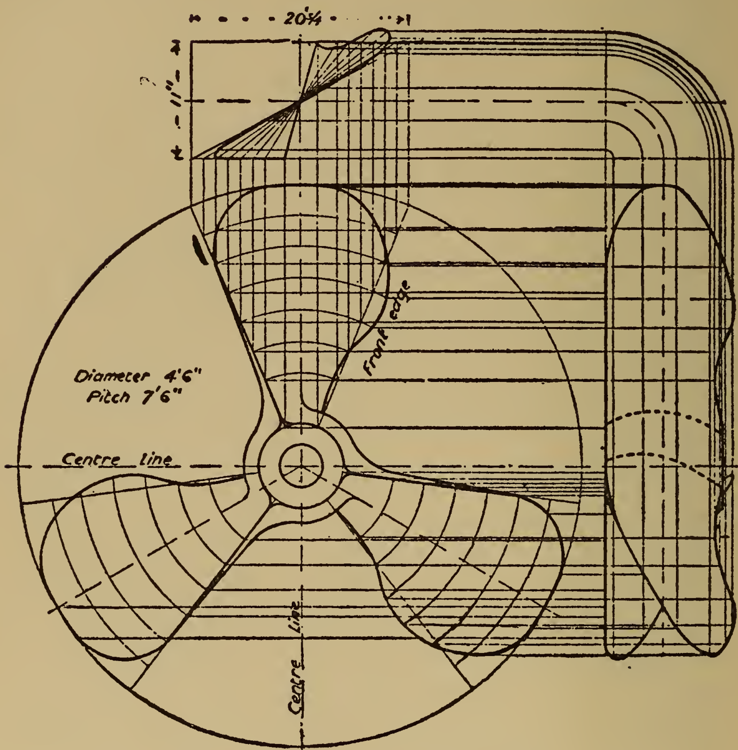


Fig. 42. Propeller lines complete

Lay out the propeller, as shown in Fig. 42, which will give the elevation of the blades, all being alike.

To find the area of a propeller blade, mark it off in parallel lines, say 3 in. apart, and note the width at the centre of each portion. Add the widths together, and divide by the number of widths. This will give the mean width, which must then be multiplied by the length of blade to obtain the area. If the measurements are all in inches, the result should be divided by 144 to give the area in square feet, and then be multiplied by the number of blades to give the total area.

To measure the pitch of a propeller, lay it down on a level surface, hold a straight edge level across centre of blade with a square up from the lower edge, as in Fig. 43. Measure the distance B and H and the radius R from the centre to the part where the measurement is taken; then B : 2wR :: H to pitch, P or $P = \frac{2wRH}{B}$ The measurements may be made in more than one place and the average taken, as the blades are sometimes twisted slightly.

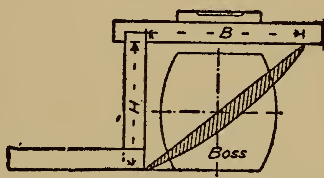


Fig. 43. Angle of propeller blade

Scaling only from the drawing, $P = \frac{2wRH}{B}$

$\frac{2 \times 3.1416 \times 1.6 \times 1}{1.27}$ =7.74, say 7 ft. 9 in. pitch, whereas the intended pitch was 7 ft. 6 in.

A good illustration of the use of the screw may be seen in the carpenter's auger, used for making or boring holes in wood. These tools are provided with a small tapered screw on their points, and this is followed by cutting edges and a larger spiral. The larger spiral is for the purpose of drawing up the chips or shavings. Another tool is made having two blades attached to the bottom of an iron bar formed like the blades of a propeller, which is sometimes employed for boring or digging post holes in clayey or soft soil. The machine is turned by a cross handle on top, and is frequently drawn up to bring out the soil until the hole is deep enough. The ordinary wood screw is one of the most useful of contrivances for fastening wood together, and for attaching to surfaces, hardware, ornaments, or other materials. The adhesive strength of nails is already shown, and the adhesive strength of wood screws, according to Bevan, is set down as follows:

WOOD SCREWS

The following are the thicknesses or diameters corresponding to the list numbers. Other thicknesses can be interpolated, each size varying in succession $\frac{1}{64}$ in.—

No.	00	0	1	5	10	14	18	22	27	32	40
Thicknesses in parts of inches	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{10}$	$\frac{1}{2}$	$\frac{5}{8}$

An ordinary 2-in. wood screw, driven through a ½-in. board into hard wood, was found to be 790 lbs., and a force of about 395 lbs. was required to extract it from soft wood.

When screws are hard to drive or screw in place, a long screw-driver should be used, as screw-drivers with long handles seem to have a much greater leverage than short handled ones in driving screws home. Screws, however, are often split at the head, if care is not taken when using a long driver.

If a screw is rusted, hard to move or withdraw, it can be loosened by applying a hot iron to the head and making it hot. The heat expands the screw and, of course, makes the hole larger, and when the screw cools it contracts a trifle so that it may be withdrawn quite easily.

VII

AEROPLANES

GEORGE and Fred were so much interested in the *Caroline* that they neglected to do some work Mr. Gregg had suggested, but a hint or two from him reminded them that sailing the new boat every day would get so monotonous it would cease to be a pleasure. Fred, therefore, set to work to put the new property in apple-pie order, by cleaning up the grounds, burning the rubbish, and tidying the place generally. Nick, not being needed longer, was allowed to go, with the promise that whenever a man was required about the place, he would be chosen. His departure left all the work to Fred and George, both of whom gladly accepted the duty.

The first thing was to set up three or four long benches on the river bank. These were built exactly in the same manner as the seats alongside the tables. Three short posts were let into the ground for each seat, and a good, sound plank spiked solid to their tops. One of the seats was made four or five inches lower than those at the tables, so as to accommodate the smaller children. The two boys did the work well, though they found it a little hard to dig the holes in the ground and saw off the posts. George's hands became a little blistered and sore, but his mother soon cured them, though she warned him against working too hard or too long at a kind of labour to which he was not accustomed.

After tea was over, it being a fine, warm, spring evening, the whole family went down to the river's edge to sit on the new seats and enjoy the view. Noticing the current of the river, Jessie questioned her father about its going one way sometimes, and then turning in the other direction. Her father explained that it was the movement of the tide that made the water flow against the stream at times, and that when there was no tide, the current took its natural course. This explanation did not seem to satisfy Jessie, and she asked why there were any tides. So Mr. Gregg promised to explain all that was known about tides to her in the near future. "I wish you would," said George, "and tell us about kites, balloons, and flying machines."

"Oh, yes," said the father, "I'll try to do that to-morrow night."

"I'm glad, father," said Fred, "as I want to try and make a model for George before the Fourth if I can, so he can have one to fly across the river that day, instead of fooling with fire-crackers and other dangerous fireworks."

"That's a good idea, Fred," said the father. "A model aeroplane, decorated with silk flags would give a great deal more real pleasure than firing off all the fire crackers in the state. It would be quite easy, now you have a boat, for one of you to be on this side of the river, the other on the opposite side, and to keep a number of little machines going to and fro across the water."

George seemed delighted at the prospect. Walter Scott had also been stricken with the aeroplane fever, and was busy making models, though, as yet, he had not finished any. Both Fred and George were anxious to hear all their father had to say concerning these machines, as they knew he would be thorough, and make it all plain. Mr. Gregg told the boys that to explain fully the theory and practice of building an aeroplane of any kind would take some time, but he would willingly give it for their benefit, and would discuss the subject of aeronautics at length so as to give them some pointers

THE MONOPLANE MODEL COMPLETE

"A Model Aeroplane, Decorated with Silk Flags Would Give a Great Deal More Pleasure Than Firing off All the Fire Crackers in the State"

about the design and practical making of flying machines.

On the following evening, Jessie did not forget to remind her father of his promise to tell them all about "air-ships and things," as she put it.

"All right, my dear," said Mr. Gregg, "I'll take you all into the 'lion's den' shortly after tea. But tell me, why is it you are so anxious to know all about 'air ships and things'?"

"Oh! that's all right, papa; Fred is going to build a great big ship, as soon as he knows how, and he has promised to take me up to the clouds in it for a ride."

"Well, my dear, it will take some time to tell you all about these things but I will make an attempt. For ages man has wanted to fly, and the Greeks tell us of a mythical personage named Icarius, and another named Dædalus, who flew to the sun. There have been many attempts to fly, both with and without mechanical aid, but history gives us nothing definite on the subject until about the year 1785, when two Frenchmen, named Montgolfiers, built a balloon sixty feet high and forty-three feet in diameter, and filled it with heated air. Attached to the bottom was a light cage made of wicker-work, into which were placed a lamb, a duck, and a rooster. The balloon was cut from its moorings and rose to a height of over 1,400 feet so that these animals were the first that ever went up in a machine made by hands.

"The Montgolfiers attained considerable notoriety, and out of their experiments grew the present dirigible Zeppelin, which measures 446 feet in length, over 42 feet in diameter, and is capable of carrying eight able-bodied men a distance of over 900 miles. This great machine is charged with gas, and driven by four three-bladed propellers, which are run by two gas engines of 110 horsepower. This is simply a monster balloon, suspended in the air by 529 to 700 cubic feet of hydrogen, or coal gas, which is much lighter than ordinary air.

"It may be said there are four distinct kinds of flying machines, each unlike the other in construction and in principle. The first is the old-fashioned balloon which has an envelope or covering of some air-tight fabric, and is inflated with a light gas. To it is attached a framework of some kind called a Nacelle, that carries the aviator, the steering gear, and the necessary engines to operate the propeller or propellers.

"The second kind of flier is the aeroplane, which, as its name indicates, is supplied with 'air planes,' that give it the power of rising and falling at the will of the operator when the machine is in motion. These planes play a very important part in the successful operation of the machine, as I will explain later. The first type of machine is classed as a 'lighter-than-air' machine or a balloon, while the planes of all kinds are classed as 'heavier-than-air' machines. Among other types of 'fliers,' there is the helicoptere, which is raised by screws or propellers on vertical shafts. These revolve rapidly, and drive the machine upward, just as the propeller on the *Caroline* drives her forward when in rapid motion. Another type, nearly abandoned, is called the ornithoptere, or 'wing flyer.' These machines are built to operate like the wings of a bird, and are provided with the necessary contrivances to work the wings, both vertically and horizontally. This type, like the helicoptere, is not considered practicable, and is virtually abandoned, so that the field is now left altogether to the 'lighter-than-air,' and the aeroplane machines. I do not intend giving you any instruction regarding balloons, or dirigibles, as I think such is unnecessary, but will confine myself altogether to the discussion of aeroplanes.

"It must not be supposed because of the name aeroplane, that the so-called plane is a real plane; it is not. The front edge of an airship plane must always be curved, as shown in Fig. 44, so that the air strikes the under surface and is forced under the plane, to buoy up the machine as it moves forward; or, to put it another way, there must be a current of air either natural or artifical on which the machine must float, or it will be drawn by gravitation to the earth. While we cannot see air or wind, we know from experience that it has great power, and for thousands of years ships have been propelled across the seas by this force, acting on sails of some kind. We know how difficult it is to travel against a high wind, and it is this quality in the air that makes it possible to travel through it. The resistance of the atmosphere makes it

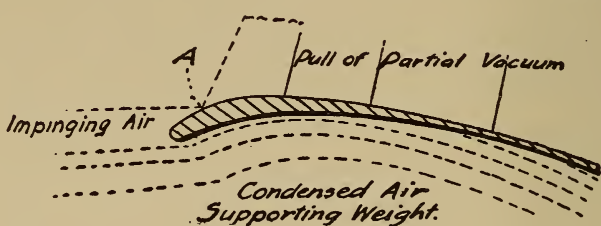


Fig. 44. Aero-curves

possible for the aviator to hold his machine suspended in opposition to the laws of gravity, and to drive it forward and upward by means of the revolving propeller acting against this resistance, the motor acting on the same principle and manner as the wheel or propeller of a boat when it is urged forward. If, as I have seen George do, we take a flat stone, a piece of slate, or flat metal, and throw it along the face of the river, in such a manner that its flat surface strikes the surface of the water, it will skim along, striking the water at intervals in its course, until the force given by the hand that threw it is exhausted, when it will drop and sink. The water, though lighter in equal bulk than the stone, is aided by the force given by the hand to buoy up the stone until the force is expended. The curve on the front edge of the planes, when the machine is in motion, really takes in more air than the space allowed for it under normal conditions, and it may be said to be compressed to some extent. If the wind be blowing in the 'teeth' of the machine, the resistance of the air will be greater, and the buoyancy of the machine increased. So, also, if the machine is travelling rapidly, the motion will increase the resistance and the buoyancy at the same time. The moment the propellers stop, gravitation grasps the machine, and if the planes are kept evenly balanced it will quietly and gently descend to the earth. You must particularly bear in mind that wind blowing in the face of a machine tends to hold it up, and that a machine flying rapidly makes its own wind, so that the results are the same.

"The curve on the front of the planes may be called an 'aero-curve,' and much of the success of the machine depends on this curvature of the planes, which gives to the inside of the plane a concave shape of a peculiar character, and to the outside a convex form.

"If you examine the rough drawing I made for you on the blackboard (Fig. 44) you will notice that the upper or convex curve is different from the under or concave one, and it is upon this difference in curvatures that many of the flying qualities of the machine depend. This little section showing the different curves is the one used by many of the successful aviators, though some prefer the form invented by Sir Hiram Maxim, shown in Fig. 44*a*, which does not differ very materially from the previous section shown. In all cases, however, the accepted plane is one of a curved vertical section in which the convex side is uppermost and the upper surface more curved than the lower. Al-

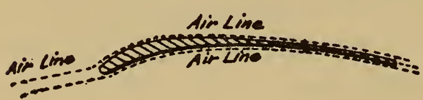


Fig. 44*a*. Maxim's aero-curve

though different authorities disagree as to why this shape of plane is best, all agree that it is so. Sir Hiram Maxim's theory is that the air follows both the upper and lower surfaces of the plane, as shown in Fig. 44*a*, while Phillips holds that the air follows the lower surface of the plane, and, striking the hump, shown at A, Fig. 44, is reflected off the upper surface of the plane, thus forming a partial vacuum on the upper surface, which gives an additional upward pull to the plane. There is, however, little doubt that most of the work is done by the force exerted on the lower surface of the plane.

"Another consideration that enters into the design of the plane is the aspect ratio, or the ratio between the depth of the plane fore and aft, and the width or span. Authorities do not agree about this latter consideration. A practical aspect ratio, one states, is 6 to 1, as, for instance, a plane 39 feet spread by 6 feet 6 inches in depth. In Santos Dumont's *Demoiselle* the aspect ratio is only 3 to 1. The ideal plane, however, would be a plane of great length and little depth, but this is impossible in the practical machine, as a plane of excessive length would greatly weaken the construction of the machine. Again, the different authorities do not agree as to the shape of the ends of the planes. Lanchester says that an efficient plane must be of rectangular form, and the Voisin and Curtiss planes are rectangular, whereas the wings of the Blériot and the Wright planes are decidedly curved at the tips.

"I will show in other illustrations the method of placing the planes on such machines, as made by Curtiss and some other noted aviators.

"I think I have said sufficient to give you a fair idea of the reason why an aeroplane can be made to navigate the air, but I have not told you how its direction can be controlled. No doubt, if the air were always still and not subject to change, there would be but little difficulty in controlling the direction of the machine, but, unfortunately, this is not the case, so provision has to be made to meet various changes as they occur. A downward current of air causes the plane to change its inclination to the horizontal, so that it will not support the weight, and the machine falls to the ground. To overcome this unsatisfactory state of things, small auxiliary planes are used to counteract the effect of varying air currents. They control the movements of the main planes so that they always bear the same inclination to the horizontal, and they are also used to elevate the machines so as to clear small obstacles. If any great increase in altitude is desired, the speed of the engine must be increased and the planes driven more rapidly through the air, thus giving them more lifting power.

"It may be that in a short time, additional balancing planes will not be necessary, as some other scheme may be invented that will regulate the balance of the aeroplane. Already an Australian inventor, called Roberts, has applied the gyroscope to the aeroplane in order to solve the problem of making it balance automatically. It exerts a balancing force equal to 300 pounds, placed 18 inches on either side of the centre of gravity. The gyroscope is driven by electricity, and controlled by a pendulum which swings right or left, according to the tilt of the aeroplane. Mr. Roberts is also working on a small aeroplane which is to be controlled by wireless telegraphy. His inventions are being tested by the British War Office. There are many other inventors on three continents busily employed in trying to solve the balance problem.

"A very important matter in the construction of the aeroplane is the position of the screw propeller. Sir Hiram Maxim advocates placing it at the rear of the planes, and this construction is carried out in the Wright, Curtiss, Voisin and Baldwin-McCurdy machines, while the tractor screw is used on the Blériot, Antoinette, and Roe fliers. Sir Hiram's theory is that if the screw is placed in front, the backwash strikes the machine, which offers a good deal of resistance to the passage of the air, and retards action; but if the propeller is placed in the rear, the resistance of the machine imparts a forward motion to the air with which it comes in contact, and the screw, running in air that is moving forward, has less slip, and is, therefore, more efficient than the tractor screw.

"While the construction of the aeroplane is yet in an experimental stage, it is progressing quite rapidly, and though no definite rules covering the whole ground of construction and management can yet be laid down, the following points may be well considered before any steps are taken in making or using any make of aeroplane: (1) That it is useless to construct the planes of flat vertical section, as much lift is lost in doing so, and they are best constructed after the manner shown in Figs. 44 and 44a. (2) That the most practical aspect ratio is about 6 to 1. (3) That the angle of incidence of the inclined planes ought to be somewhere between 1 in 10, and 1 in 20 (*i. e.*, the angle by which they are inclined to the horizontal, the forward or entering edge of the plane of course being the higher). (4) That a reliable motor, one that is immune from involuntary stoppages, is absolutely essential to prevent accidents. (5) That automatic stability of the machine is the theory of aeronautics that all inventors should study most carefully.

"The illustration I show here (Fig. 45) represents the monoplane in which the Frenchman,

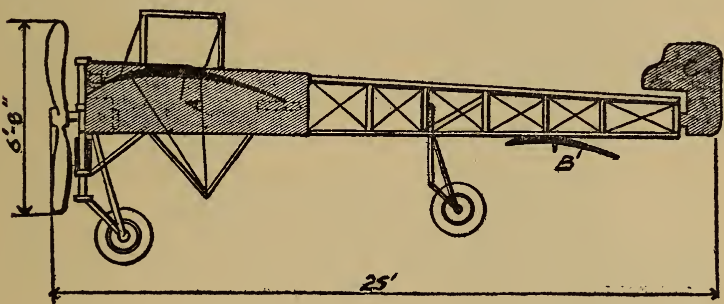


Fig. 45. Blériot monoplane

Blériot, crossed over the sea from France to England. The thick curved lines, shown at A, exhibit the main plane which gives the machine its name of "monoplane" — one plane — and B shows the rear auxiliary plane, which is also of curved section and curved ends. The plane A has an area of 150 square feet, and B has an area of 17 square feet, while the rudder C has an area of 4½ square feet. The total length of the machine is 25 feet, the sweep of the rudder 6 feet 6 inches. The rudder is a plane, pure and simple, and may be constructed of any light material that is strong enough to stand a reasonable wind pressure.

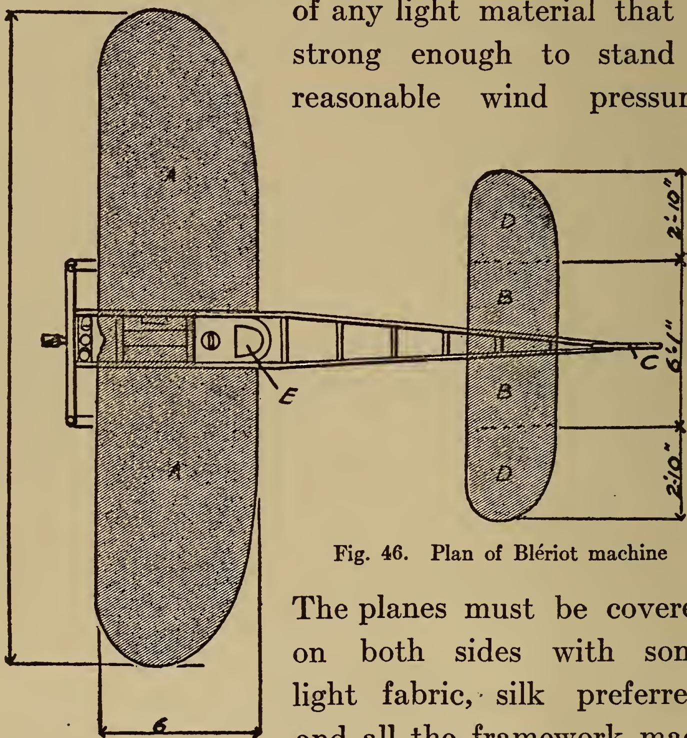


Fig. 46. Plan of Blériot machine

The planes must be covered on both sides with some light fabric, silk preferred, and all the framework made as light as possible, consistent with safety.

"The plan I show at Fig. 46 will give you a good idea of the form of this machine, if you were looking from above at it. E is the point where the aviator sits, and where the 30 horse-power engine is placed. The ends of the planes are rounded off, and the ends of the rear plane at DD, are made adjustable so that the machine may be made easier to manage when in motion.

"All engines used in aeroplanes are of the internal combustion type, made purposely for aerial flight, and are as strong and as light as it is possible to make them.

"The biplane, or two plane machine, is fitted up on somewhat the same lines as the monoplane, having two planes one above the other, as I show you in Fig. 47. The dark portion A A, shows the

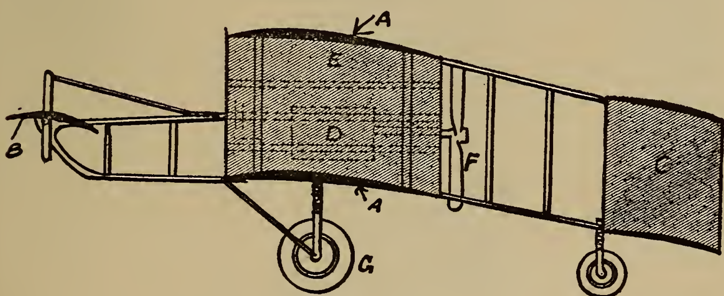


Fig. 47. Biplane

positions and curvature of the planes. The plane B is called the elevator because it keeps up the head of the machine. C shows the tail with a single plane. D is the part containing the mechanism and the aviator's seat. E shows the vertical planes, made of some light fabric stretched over a bamboo frame. The propeller is shown at F, and it is about six feet in diameter. The two carry-

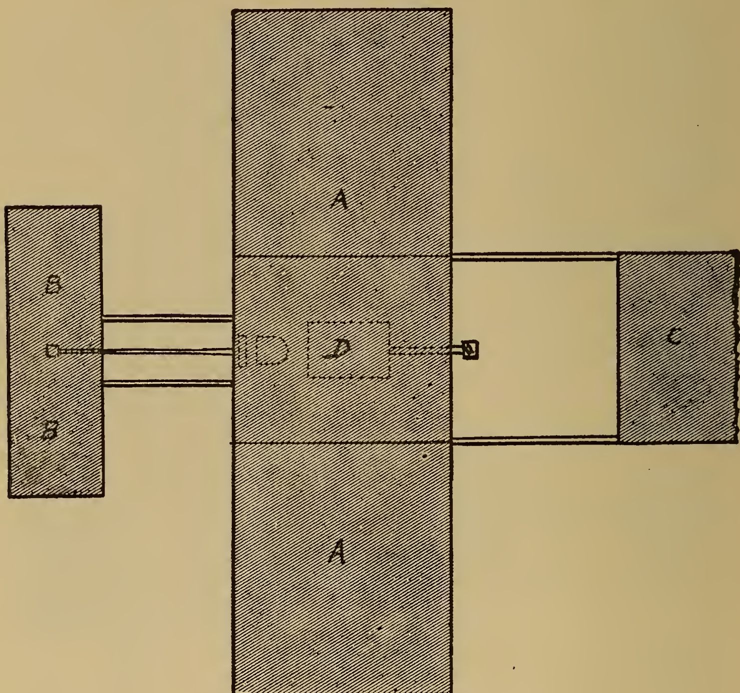


Fig. 48. Voisin biplane

ing wheels, shown at G G, are simply light bicycle wheels which tend to ease the landing of the machine when it comes to the earth. It will be seen that machines may differ in the style of construction and yet, so long as they contain the principles I have described, they will fly with more or less success. The illustration, (Fig. 48), shows the plan of the biplane, which is somewhat different in arrangement from the monoplane. This sketch is of the Voisin biplane and shows the tail-piece, something not used in machines of the Wright type. The Voisin machine is quite popular in Europe, particularly in France. It is not very difficult to construct or easy to control; at least, it has that reputation.

"The Santos Dumont monoplane, *Demoiselle*, shown in Fig. 49, is said to be the smallest and lightest known practical machine, and there are no patents on it, the inventor having published sketches and drawings of all its details. Contrary to the usual plan, the aviator, in this machine, sits below the motor, so that the propeller blades cut across the line of sight; but as it revolves very rapidly the vision is not affected. The whole machine, when complete, weighs only about 250 pounds. Its length is about 20 feet and its total width over the planes 18 feet, and it is about 7 feet 6 inches high. It is quite easy to build, as the framework, or chassis, is fixed to a bent piece of ash or elm — like a sleigh runner — which answers very well, because when the machine begins to move the rear end rises first. If desired, the frame can

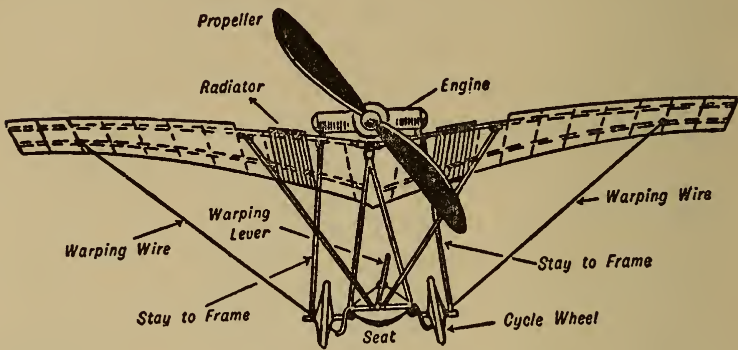


Fig. 49. The Santos-Dumont monoplane

be made so that the whole thing can be taken apart. Sockets, like those used on finishing rods, may be attached at the joints and junctions to hold the structure together. The two spars that constitute the main support of the planes are formed of ash, this having been found the best material for the purpose, as it is also for the making of the propeller blades. One of the spars should be fixed about nine inches from the front edge, and the other about twelve inches from the back. Bamboo cross pieces are fastened about nine or ten inches apart between the two main spars. All is covered with oiled silk, applied in two thicknesses. The area of the main plane is some 115 square feet, and that of the tail-piece about 50 square feet. To cover all this would require about 400 square feet of silk.

"I have heard it said that aeroplanes are hard to manage, difficult to drive, and extremely dangerous. This is not true entirely, but there is some truth in it. An amateur has to go through a 'course of sprouts' and must learn all about his machine before beginning to use it practically. Once he becomes master of it and can keep it well under control, he need not fear accidents, if he does not lose his head, nor venture out in half a gale. When we consider the number of experiments that have been made from time to time with imperfect machines, we find that fatal accidents have been very few, less, indeed, than the number recorded in the early stages of automobile history.

"I have been compelled to draw a number of the points I have given you from many sources, particularly from the writings of Messrs. Fetherstonhaugh and Lanchester, which does not detract from what I have told you, but rather guarantees its correctness.

"Well, children — it is getting late, but, before bidding you good-night, I think I should finish my talk on aeroplanes by showing you how to make a small model of a flying machine, if you are not too tired to listen further?"

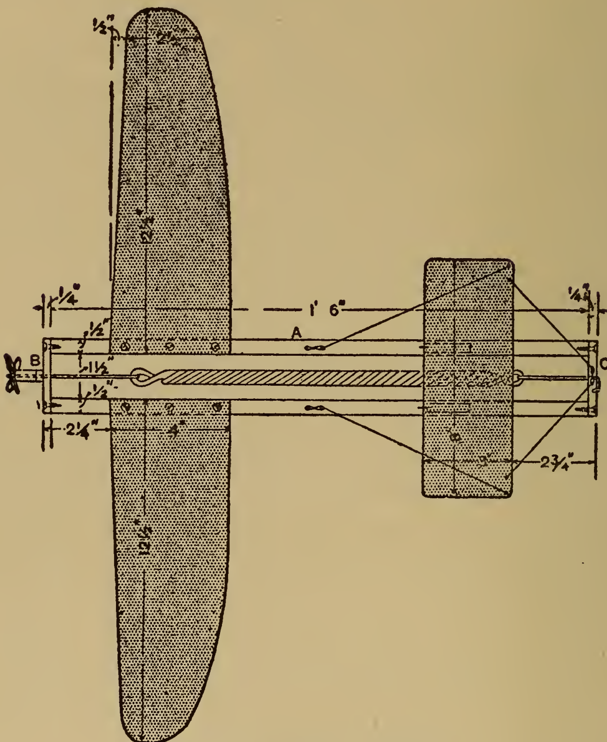


Fig. 50. A model aeroplane

"Please, father," said Fred, "do keep on." George, also, wanted to hear more, so Mr. Gregg decided to continue.

"I have given you an outline of the reason why an aeroplane can be made to rise from the ground and navigate the air; but I have not told you of all the kinds of machines that can be made to fly, for there are many others than those I have spoken of. One is the glider, which does not carry an engine, but, as its name indicates, glides along in the air at a distance not far from the earth. These are not capable of travelling very far and, therefore, are not likely to come into general use. They have to be started either by gliding off a high tower, by sliding down a hill or by being propelled by hand or towed by some rapidly moving machine.

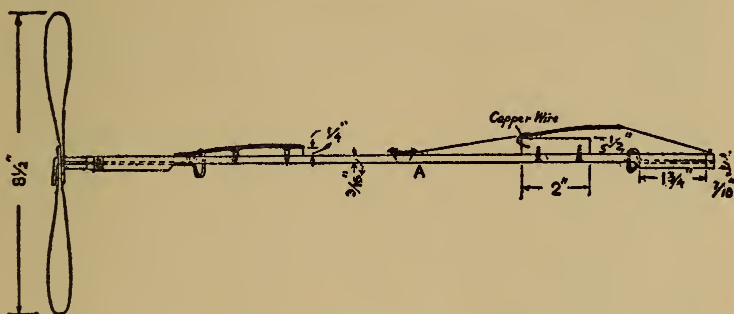


Fig. 51. Section model aeroplane

Some day, perhaps, a machine will be evolved on the same or similar lines as the glider, that can be propelled by natural forces, but the time is not yet. Beside the monoplane and the biplane, there is the triplane, constructed on the same lines as the other flying planes, that is to say, the three planes used on the machine are made the same as the planes on the others, each having a convex and concave side of different curvatures.

"The monoplane which I am about to describe and illustrate, and which I show in Figs. 50–51–52, can be easily and cheaply made, and can be guaranteed to fly, after a little experimenting to get the correct balance and angle of the planes. The frame A will first be treated. Get two pieces of yellow or white pine (the lightest and most easily procured wood), cut them to the shape shown, 1 foot 6 inches long, ½ inch by 1³⁄₁₆ inches in the middle, and thickened at the ends to take the screws from the end bars B and C (Fig. 50). Take great care to make them exactly alike. The end pieces B and C, which are 2½ inches by ⁷⁄₁₆ inch by ¼ inch can then be screwed to the side pieces A, and a rectangular frame is the result. Should the screws split the wood in the slightest degree, new pieces must be

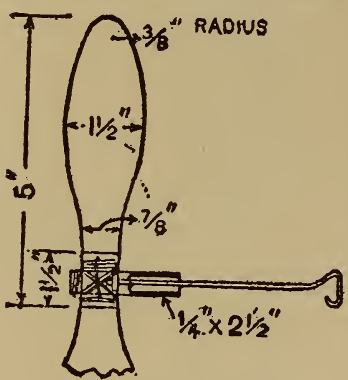


Fig. 52. Blade of propeller

Photograph by Brown Brothers

MAKING AN AEROPLANE MODEL

"If the Screws Split the Wood in the Slightest Degree, New Pieces Must be Made"

made, as the plane is sure to get rough usage in falling on the ground a few times.

"The planes are also made of yellow pine. They must be exactly equal to one another in weight, one being right handed and the other left. The wood must not be more than 1/22 inch thick, and, if possible, even thinner. A large circular chip box will be the best thing from which to make these. Gum a piece of tracing cloth on top of the planes, and allow about 2 inches to overlap at the large ends, to twist and glue round the main frame when fixing. The cloth will fulfil two useful and necessary purposes. It will strengthen the planes and curve them to a very large extent. This curvature is essential to the flight of the machine. A wooden block curved to suit, and inclined at about 5 degrees, is fixed between the back planes and the frame.

"The front or small plane is 8 inches by 3 inches, and made in the same way as the others. It must be adjustable, and is, therefore, mounted on two wooden blocks, 2 inches by 1/4 inch by 1/2 inch and fastened by means of copper wire which acts as a hinge. Four silk cords are fixed to the movable end of the plane, two being fastened to nails at the rear end of the frame and two to the front, to hold the plane at any desired angle.

"The propeller blades (Fig. 52) are made of thin aluminum. Two sheets are cut out the same size and shape, and placed with their ends overlapping (see Fig. 53). A piece of steel wire 1/16 inch in diameter is bent and placed between them to form the shaft. The whole is then fixed in a piece of light copper tube, which is slotted by means of a hack saw or fret saw to receive them. The blades are bound crosswise to the tube by means of thin wire or strong thread; then twisted to a pitch of about 6 inches. It is also advisable to place a washer between the copper tube and the end bar of the frame.

Fig. 53. Connections of propeller blade

"This method of fixing the propeller blades is not the same as that shown in Fig. 50 but it is the better way.

"The drive for the propeller is elastic (a rubber band), which, when twisted and released, will rapidly revolve the shaft for a short time. The best kind to use is the gray variety, and when in the form of bands, say 3/8 inch by 1/16 inch by 6 inches, is ready for use without jointing. The wire carrying the elastic should be made so that the elastic is just in tension when untwisted.

"The monoplane, when complete, should be tested without the propeller until it will glide perfectly. The front of the plane will need weight added if there is a tendency to somersault; but if the back rises ahead of the forward end, more weight is necessary there. The best glide to be expected is about a 1 in 6 slope. The propeller should then be tried, and a flight of 50 or 100 feet, or more, should result. If there is a tendency to twist, owing to the side pull of the propeller, a a screw should be fixed to the end of the plane to counteract it.

"A much longer flight can be given the model, if the spring is made so that the tension may continue a longer period. Sometimes a rubber attachment can be applied and twisted so that the propeller can be kept running long enough to carry the machine a much greater distance than here stated. The dimensions of all the parts of the machine are marked on the illustrations, so that you will find no difficulty whatever in making a model monoplane that will fly from the start. In the making of little models of this kind, you will encounter many things that will tax your skill and ingenuity, as amateur workmen.

"Now, children, I have told you all about aeroplanes that I intended, though I may take up the subject again, when I try to explain the recognized theory of flight, and the making and flying of kites."

VIII

KITES, SUNDIALS, PATENTS

THE next day, just as Mr. Gregg returned from his office, Fred, Jessie, and George landed on their new dock from the *Caroline*. They had been for a sail on the river, and Jessie was quite enthusiastic over the trip. "Fred was a real good captain. Why, papa, he let me steer the boat all by myself, and taught me so well I didn't have any collisions."

An hour or so later the boys, Jessie, and Mr. Gregg, retired to the den.

After questioning the boys regarding the previous talk, to discover if they remembered the main points, Mr. Gregg said he would now tell them something of kites and kite flying.

"The highest kite ascent yet recorded was made at the aeronautical observatory at Lindenburg, (Prussia) on November 25, 1905, 21,100 feet being attained. Six kites were attached to one another with a wire line of nearly 16,000 yards in length. The minimum temperature recorded was 13 degrees, F.; at starting the reading was 41 degrees. The wind velocity at the surface of the earth was eighteen miles an hour, and the maximum altitude it reached was fifty-six miles an hour. The previous height record by a kite was nearly 1,100 feet lower, and it had been reached from a Danish gunboat in the Baltic. These ascents were wonderful, for it is not an easy matter to train a kite higher than a given altitude, for several reasons. The higher a kite rises the more string it will require, and this tends to weight down the plane or kite.

The wind, too, acting on the string, tends to retard the upward flight and to cut short further ascent. When an ordinary kite reaches a height of 1,200 or 1,500 feet, it is doing very well; and few exceed this height. When Benjamin Franklin angled in the clouds for lightning, his kite did not attain an altitude of more than 1,000 feet, which was quite sufficient for the purpose he had in view. When Franklin flew his kite, he was so afraid of ridicule that he took a small boy with him to carry the kite and string, in order to prevent his neighbours from thinking he was going 'kite flying.' In these days when a man is seen flying a kite, people very naturally imagine him to be an aeronaut, studying the science for the purpose of improving or inventing a flying machine of some kind — for which there seems to be ample room.

"The first thing a beginner in the science of aeronautics will want to know is, 'Why does the kite or machine lift itself off the ground?' If you take a kite and hold it in an inclined position, the wind on the lower side will have a tendency to blow it backward; but as it is held by the kite string, this movement is impossible, and so it is inclined to rise in the air (see Fig. 54). If we construct a large plane and equip it with a motor operating a screw which pushes or pulls the plane

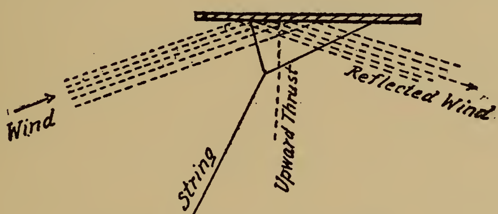


Fig. 54. Science of kite-flying

along through the air, the result is the same as if the plane were anchored, and the wind hits the lower surface of the inclined plane, thus forcing it up. Also, we find, within certain limits, the more you incline a plane the more lift or upward thrust will it give; but it will take more power to drive it through the air, and the faster the plane is driven through the air the less surface is required to support the weight. A matter of great importance in the construction is the shape of the plane, and the shape of the vertical section through the same. The shape of these planes has been explained in Figs. 43 and 44, and the reasons were given why these shapes were considered the proper ones for the purpose.

"It does not follow," said Mr. Gregg, "that all kites should have the same kind of a surface or plane, though the flat planes of the toys of our school days were all of the flat surface kind; these being of various shapes and sizes from the lozenge to the square, bow top, octagon, and many others, according to the whim or skill of the maker. One of the conditions of these planes or flat kites, was that each one must have at least one tail attached to the bottom of it. This tail was flexible, simply a piece of string having paper similar to 'curl papers' tied to it at intervals. The tail was a necessity, for without it the equipoise would be impossible. In China and Japan, where the natives have been kite-flying for more than twenty centuries, they make kites that fly and maintain the aerial equipoise without having tails hung to them, no matter whether the shape be that of a dragon, a lion, or an eagle.

"A kite is simply an aeroplane on a small scale, and should be considered as such, as it has a fixed fulcrum in the belly band, a constant pressure when flying, and an angle which is varied in proportion to the load it may have to carry. The common kite is easily made, but it does not always fly as desired; for it seems almost impossible to make two kites that will fly in the same manner under similar conditions. Box kites are the most reliable, and not so very difficult to make, as you will discover by examining Figs. 55, 56, and 57 and following the directions I give you. First, procure four straight strips of light wood, preferably spruce, 2 ft. 6 in. by ⅜ in. by ⅛ in.; these dimensions should be full (see Fig. 55.) Obtain also four other pieces, each 1 ft. 7½ in. long, but ¹⁄₁₆ in. wider and thicker than the foregoing, and halve their ends to a depth of ⅛ in. by ¼ in., in order that when the false end A (Fig. 56) is tightly bound on, these cross sticks will firmly grip the long pieces edge-

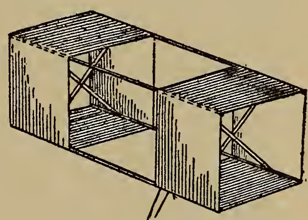


Fig. 55. Box kite

wise, the sides of the cells being indicated by the dotted lines. The long sticks should be notched at a distance of 4 in. from their ends to receive the forks of the cross sticks.

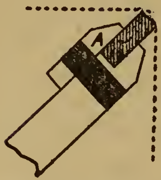


Fig. 56. Making a kite

"The width of the cloth or paper cells should be 8 in., and they should be separated by a distance of 1 ft. 1 in. or 1 ft. 2 in., their edges being bound with fine twine. The easiest way to make the cells is to cut two strips of the material, 10 in. wide and 4 ft. 8 ½ in. long. Turn over the edges ½ in. along each side, and insert fine strong twine! If paper is used, glue the fold; if cloth, stitch the hem. When completed, either glue or stitch the ends of the strip with a ¾ in. lap, so as to form a continuous band. By folding, divide this accurately into four equal parts and at each of the creases glue one of the long sticks edgewise (see Fig. 56). When dry, the whole can be put together and the flying line attached, without a bridle, as in Fig. 55. For additional clearness an enlarged detail of one end of the kite is shown at Fig. 57.

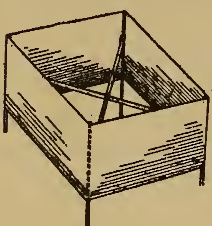


Fig. 57. Single box kite

Photograph by Brown Bros

MAKING KITES

"Box Kites Are the Most Reliable, And Not so Very Difficult to Make"

"It is advisable in all cases to make the cross pieces a trifle too long, to insure their straining the band tightly. They may also be shortened by cutting away the shoulder formed by the halving.

"These kites are easy to fly. Avoid an enclosed space, where the wind whirls in invisible eddies; having let out 20 yds. or 30 yds. of line, get some one to throw up the kite in the usual fashion. If several large kites are sent up in tandem, steel wire should be used.

"Another kind of a kite, known as the cellular kite is shown in Fig. 58. This is made by forming two square frames N. O., divided into nine compart-

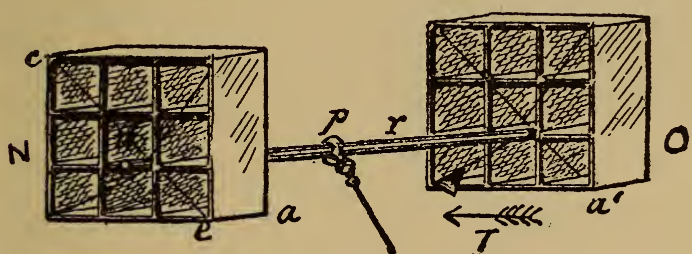


Fig. 58. Square cellular kite

ments each and connected together by a light rod at *r*, the fulcrum or string being at P, the air pressure at T. The whole forms a good, strong kite, but it is not able to carry much weight, on account of the equipoise being self adjusted in accordance with the constant pressure and surface. The equipoise is due to the current being cut by the edges *a a′*, and diverted into the cellular divisions of each area. This being the case, any upward or downward tendency of *a a′*, would be counterbalanced by the effect on the other side and the kite would naturally adjust itself on the opposite side. We are not dependent upon any particular shape for obtaining a good serviceable kite — like the plane made kite, the cellular one may be of any shape. I show you one here, at Fig. 59, having a circular rim, with thin tubes inserted in such a manner that the current of wind will rush through when the machine is in the air. The two portions, A and B, are held together by a rod in a similar manner to the square kites, and the cord or fulcrum is fastened to the rod at R.

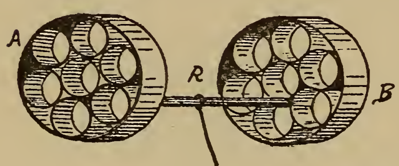


Fig. 59. Circular cellular kite

"A number of kites may be sent up at once, all attached to the same string, if properly adjusted. Here are six square cellular kites looped together, shown at Fig. 60. They may be made of any suitable size, but need not be all of one size, though each pair would be better if made the same size.

They may be looped up, as shown, and the point S may be loaded lightly; it will help to steady the kite and keep it from swaying.

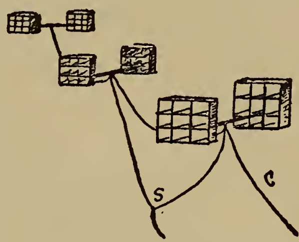


Fig. 60. Group of kites

"A peculiar kite, called 'a war kite,' is very popular in some parts of Europe, and in some parts of our country also. It is easily made and gives good results. It is on the principle of the 'cellular' or 'box' kite, being cubical or box shaped, and, when used for carrying weights, usually has several cells built together, or several kites may be coupled when a heavy load, such as that of a man, is to be raised. These kites are made of light wood or cane covered with nainsook or fine cotton, and strengthened with cross pieces which hold the frames tight and keep the kite in shape. They can be taken to pieces and the covering material rolled up so that they occupy very little space. Two forms of box kites are shown in Figs. 61 and 62, and it will be seen that an attachment is made each side of the frame. This is fine steel wire, very light compared with its strength, wound on a drum by means of a small engine. Large kites of the ordinary form can be used for the same purpose, but their lifting power is not equal to that of the box kite. A small box kite is used for taking photographs, a camera being carried by a separate wire connection to the attachment wire,

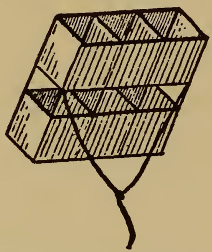


Fig. 61. Sextuple kite

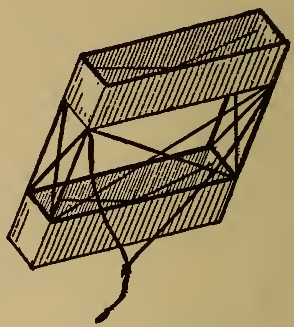


Fig. 62. War kite

and the shutter released at the proper time by an ingenious arrangement, similar to the pieces of paper called 'messengers' which boys used to send up on the cords of ordinary kites. This kite is a little more expensive to make than most of those shown, but it gives an excellent result when properly handled.

"In making kites of any kind, the lightest materials consistent with sufficient strength, should be employed. The frames should be split bamboo or cane. The joints may be lashed together with fine wire or silk thread, and the envelope in each case should be fine silk or similar material that would be close, light, and strong, These qualities, in all sorts of kites and aeroplanes, are absolutely essential to accomplish the best results.

"Before leaving the subject of aeronautics, I think it would not be amiss to tell you something of bird flight. There are different modes of flying, just as men have different gaits in walking or running.

"Rapid wing movement does not always imply speed in flight, any more than does rapid leg movement imply speed in walking or running. With us it is the length of the stride that tells ultimately. What tells, correspondingly, in the flight of the bird is not known.

"Speaking broadly, long-winged birds are strong and swift fliers; short-winged birds are feeble in flight. When we consider that a cumbrous, slow-moving bird like the heron moves its wings twice per second when in flight, it is evident that many birds have a very rapid wing movement. Most small birds have it, combined with feeble powers of flight. The common wren and the chipping sparrow, for instance, have a flight like that of a young bird.

"What can give one more exquisite pleasure than to watch seagulls swooping round the edge of a cliff, to see them drift down wind with wings motionless, then suddenly dart downward, turn to meet the breeze, and beat up against it with all their ingenuity and skill?

"The beauty of a ship depends on the way it glides through the water. Watch a liner, and you can see that it is being driven by its screws, but look at a racing yacht: there is no sense of effort whatever. She seems to move like a bird, by natural means.

"Here is the secret of the beauty of the aeroplane. It seems to be completely master of the element in which it moves. It flies with no visible effort and at a little distance one could imagine it endowed with magic power, moving by natural force, like a bird.

"All the early attempts at flying were made on the theory of wing motion, and the failures resulting were doubtless due to careless study of what nature could teach. There was a great deal more to be learned from nature than from mathematics. An examination of the different types of birds testifies, among other things, to their rigid backs, and to the fact that nearly all their bones are hollow and have air cavities. An erroneous deduction had been drawn from this that the hollows were purely for the sake of lightness, and that the cavities were for hot air to make the bird light when it wanted to fly. The amount of lightness so obtained, however, was so small as not to be worth consideration. The passages are simply reservoirs for air, and they allow the bird more energy than a less freely breathing animal. The wing of the bird does a double duty: it is an aeroplane and a propeller combined. The valvular action has nothing at all to do with the flight. Some explanation of how a sparrow can rise from the gutter to the eaves may be seen by the difference in the construction of its wings from those of the swallow, which cannot rise from the ground like a sparrow, but has to get initial velocity. The swallow, however, has much more mastery over its movements in the air than the sparrow has. These, and many other things in connection with bird flight, under proper methods of scientific investigation, may show us the whole theory of aviation. I am inclined to think that scientific men will soon be able to solve the problem, and to give us better control of the coming aeroplanes, or even direct their flight by the aid of electric waves or other natural forces.

"In kite-flying, it is well to know something of the wind and its pressure, and, in this connection, the following short table will give some idea of the force exercised on objects in its path: A light air current presses 0.004 lbs. per square foot.

Light wind has a pressure of . .	0.125 lbs per sq. foot
Light breeze	0.246 lbs. per sq. foot
Moderate breeze	0.406 lbs. per sq. foot
Strong breeze	2.00 lbs. per sq. foot
Moderate gale	2.98 lbs. per sq. foot

"This last should be the limit, as a kite or aeroplane of any kind will find it hard to manœuvre in a breeze stronger than a moderate gale. Of course, there are winds sometimes that have a velocity of 60 to 75 miles an hour, and a pressure of over 40 pounds to the square foot, but these would prove disastrous to any kind of a flying machine, if it was in action."

"Father," asked Fred, "how can one tell the velocity of the wind, without one of those expensive machines I see at the weather office, an anemometer, I think it is called?"

"I am glad," said the father, "that you have noticed those and other instruments for gauging and foretelling weather conditions. It is an indication that you keep your eyes open when you visit such places, and to learn by observation is almost as effectual as to obtain knowledge by experience.

I have in mind a very simple contrivance you can make yourself, for measuring wind pressure from a couple of ounces to four pounds to the foot. I will make a sketch of it, which I am sure you will understand.

"It consists of a light pine or cedar wood frame on a strong stand, supporting on a centre two bent wires, carrying at one end a 3-in. square of thin wood, A, and on the other a thin bar of wood, to the centre of which is attached a fine string tied to a spring balance scaled to ⅛ of an ounce and up to 4 ounces (Fig 63). As the square of 3 inches is the 16th of a foot, each ounce on the spring is equal to 1 lb. pressure on the square foot. The latter balance slides in the V-frame at the back so as always to keep the square parallel to the face of the frame, whether the wind is strong or light, and the balance must be slidden in or out until the face of the square is so placed before registering the force of the wind. By attention to this it will register very truly up

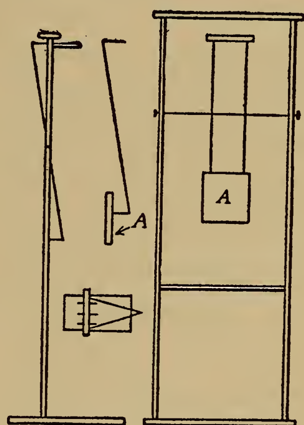


Fig. 63. Wind gauge

to 4 lbs., which is the extent of an ordinary spring balance. There is also a front view, a side view, and a bird's-eye view, also one of the bent wires and the 3-inch square. I think this requires no further explanation."

Fred was satisfied with the description of the register and promised to make one at an early date.

The following evening when they were all sitting on the river bank, Fred suddenly asked his father if it was difficult, or costly, to secure patents. He wanted to know, because he had been thinking of making a kite on a new principle — that of a funnel, and he was so sure it would prove a success that he would like to have it patented.

Mr. Gregg thought the scheme rather an ambitious one, but, while he could not see it as Fred did, he determined not to say anything that would be likely to discourage the boy. So he explained, as well as he could, the patent laws: "In order to apply for a patent it is necessary to file in the Patent Office at Washington, D. C., a petition, affidavit of invention, drawings, and specifications, all of which must be prepared in legal form and in accordance with official rules and practice of the office.

"This can best be done by a reliable attorney but an applicant should understand some of the requirements as well.

"The Patent Office does not require a model to be furnished in order to apply for a patent, but if the attorney is not near enough to see the one made by the inventor, then one should be sent him, unless good photographs and drawings can be supplied.

"Since the drawing attached to the specifications and claims is to be on a sheet of a special size, no attention need be paid to having the original sketches of a uniform size. When ready to apply for a patent, secure as much evidence as possible of the reliability of some attorney you have heard of and consult him about the matter, explaining as much as is necessary for him to prepare an outline that will suffice for a preliminary search through the records in the Patent Office to see that no interference will take place should the application be made.

"This usually costs $5.00, and an attorney often supplies copies of existing patents that look the most like the one in question.

"If it is thought that there will be no interference, the case is then prepared for the examiners, and the application duly made.

"The drawings should be made and lettered, so that the specifications can be written up, including the proper reference to the different parts.

"The drawings should be made upon paper stiff enough to stand in a portfolio, the surface of which must be calendered and smooth. The best kind is patent office bristol, though there is a style on the market printed with margin and headings all ready for use, but the surface is not of the best.

"The size of the sheet on which a drawing is made should be exactly 10 x 15 inches with margin lines one inch from all the edges, leaving a clear space of 8 x 13 inches.

"One of the smaller sides is regarded as its top, and measuring downward from the margin, or border line, a space of not less than 1¼ inches is to be left blank for the insertion of title, name, number and date, to be put in by the patent officials.

"All drawings must be made with the pen only, using the blackest India ink. Every line and letter, including the signature must be absolutely black.

This applies to all lines, however fine, to shading and to lines representing cut surfaces in sectional views. All lines must be clean, sharp, and solid, and they must not be too fine or crowded.

"Surface shading, when used, should be left very open. Sectional shading should be by oblique parallel lines, which may be about one-twentieth of an inch apart. Drawings should be made with the fewest lines possible consistent with clearness, for the drawings are subjected to photographic reduction, which decreases the space between the lines.

"Shading (except on special views) should be used only on convex and concave surfaces, and there sparingly, or it may be dispensed with if the drawing is otherwise well made.

"The plane on which a sectional view is taken should be indicated on the general view by a broken or dotted line.

"Heavy lines on the shade sides of objects should be used, except where they tend to thicken the work and obscure the reference letters.

"The light is always supposed to come from the upper left hand corner, at an angle of forty-five degrees.

"Imitations of wood or surface graining should not be attempted.

"The scale to which a drawing is made ought to be large enough to show the mechanism without crowding, and two or more sheets should be used if one does not give sufficient room to accomplish this end; but the number of sheets must never be increased unless it is absolutely necessary.

"Sometimes the invention, although constituting but a small part of a machine, has to be represented in connection with other and much larger parts. In a case of this kind, a general view on a small scale is recommended, with one or more of the invention itself on a much larger scale.

"Letters or figures may be used for reference, but they should be well made, and when at all possible should not be less than one eighth of an inch in height, that they may bear reduction to one twenty-fourth of an inch; or they may be much larger when there is sufficient space.

"Reference letters must be so placed in the close and complex parts of a drawing as not to interfere with a thorough understanding of the same, and to this end should rarely cross or mingle with the lines.

"The illustrations on pages of current topics under the head of new patents show the manner of putting in the reference lines from the letters to the part indicated.

"These are carried out some distance, but if placed on the face of the object where sectioned, a blank space should be left in the shading for the letter.

"If the same part of the invention appears in more than one view, it should always be represented by the same letter.

"Great care should be exercised in the matter of drawings, or they will be returned to the applicant, but, at his suggestion and cost, the officials will make the necessary corrections.

"The time required to procure an allowance of a patent averages from six weeks to two months.

"United States patents are granted for a term of seventeen years, and cannot be extended. The patent remains good whether the invention is worked or not, and no additional payments are required beyond the cost of first taking out the patent. Patents are not subject to taxation. Reissues of patents are granted whenever one is inoperative or invalid, by reason of a defective or insufficient specification, or by reason of the patentee claiming more than he had a right to claim as new, provided the error arose by inadvertence, accident, or mistake, without fraudulent intent. A fee of $30.50 must be forwarded upon application for patent.

"As stated before, a patent is obtained by a petition to the Commissioner of Patents accompanied by a description, including drawings and a model, when the invention will admit of these. A fee of $15 is required when the application is made, and a further fee of $20 when the patent is issued. Postage on model is at the rate of 1 cent per ounce.

"A patent for a design is granted to any person who has invented or produced any new and original design for the printing of woollen, silk, cotton, or other fabrics; any new and original impression, ornament, pattern-print, or picture to be printed, painted, cast, or otherwise placed on or worked into any article of manufacture; or any new, useful, and original shape or configuration of any article of manufacture, the same not being known or used by others before this invention or production thereof, or patented or described in any printed publication, upon payment of the duty required by law, and other required proceedings the same as in cases of inventions or discoveries. These are granted for three and one-half years, seven years or fourteen years, for which the respective fees of $10, $15, and $30 are paid the government.

"A caveat is a provisional protection to any person who has thought of an invention and desires the time to complete or perfect the same. It is procured at an expense of $10, and runs for one year with the permission of renewal from year to year.

"In Canada the patent office is a branch of the Department of Agriculture, and the Minister of Agriculture for the time being is the Commissioner of Patents.

"Any intending applicant for a patent who has not yet perfected his invention, and is in fear of being despoiled of his idea, may file in the patent office a description of his invention so far, with, or without plans, of his own will, and the Commissioner, on payment of the prescribed fee, shall cause the said document, which shall be called a caveat, to be preserved in secrecy, and, if application is made by any other person for a patent interfering in any way therewith, the Commissioner shall forthwith give notice, by mail, of such application to the person filing such caveat, who shall, within three months thereafter, if he wishes to avail himself of the caveat, file his petition, and take the other steps necessary on application for a patent. The application for the patent must be made within one year from the filing of caveat, otherwise the Commissioner is relieved from the obligation of giving notice.

"The following fees are payable: Full fee on patent for 18 years, $60.00; partial fee for 12 years, $40.00; partial fee for 6 years, $20.00; on filing caveat, $5.00; on registering assignment patent, $2.00; for copy of patent, with specification, $4.00.

"The disbursements for filing an application in Great Britain are $25.00; France, $20.00; Germany, $5.00, and $7.50 before issuing patent; Australia, $20.00; Russia, $75.00; British India, $20.00. The German and French patents cover not only Germany and France but their colonies also. The Russian patent extends to all of the Russian possessions.

"The disbursements for filing an application in the Australian states, namely, Queensland, Victoria, New South Wales, South Australia, Western Australia and Tasmania are $5.00 on filing the application, $10.00 on allowance of same, and $25.00 for preparation of the sealing of patent; New Zealand, $20.00; Mexico, $75.00; Natal, $50.00; Japan, $75.00; Jamaica, $150.00."

This talk on patents was quite interesting to Fred, and very instructive to George, and they thanked their father for it.

"Boys," he said to them next morning, "why not try your hands on a sundial? You will find it

Photographs by C. M. D'Enville

A SUN DIAL MADE OF CONCRETE

An excellent illustration of the possibility which concrete offers in ornamental as well as practical construction. This sun dial, complete, cost approximately ten dollars, and may be duplicated by any clever boy. See formula for concrete on page 20.

easy to make, and if properly set up it will keep accurate time. There is a nice place for one near the bridge on the new grounds, as there is a stump there, the top of which can be cut off smooth, and it stands out full in the sun.

"Go to our jeweller in the city and get him to give you an old tin clock-dial, like the one shown in Fig. 64. If you cannot get one, make a dial out of cardboard yourself, printing the hours in ink. Slit the dial from the centre to a point directly underneath the number 12, if you have Arabic numerals on your dial.

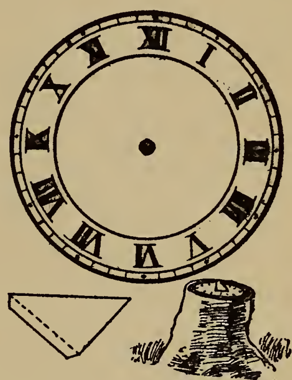


Fig. 64. Sundial

"Then cut out a triangular blade or gnomon, like the one shown. If your dial is of tin, make the blade of tin, or cardboard if your dial is of cardboard.

"Insert the blade in the slit of the dial and secure it to the top of the stand you have selected — with tacks if your dial is cardboard, with small nails if it is tin. Then your sundial will be completed and ready for business.

"At 12 o'clock, there will be only the shadow of the thin edge of the blade over the dial, but as the sun moves, so will the shadow, so as to tell always the correct time of day. You will find this not only a useful but a quaint and artistic addition to the grounds, and not at all expensive."

"Papa," said George, "mamma wants a flower-bed made in the front garden, and she would like to have it an oval or elliptical shape. I have promised to make it for her, but I do not know how to make the shape, and I wish you would tell me."

"Certainly, my boy, I will show you, It can be done easily with a string and two wooden pegs. Follow the lines I make on the blackboard. First we must decide on the length and width of the oval or rather ellipse required. Then draw two straight lines, A B and C D, Fig. 65, equal to the two axes, and bisect or halve each at right angles. Set off from C half the length of the great axis at E and F, which are the two focii of the ellipse. Take an endless string, as long as the three sides of the triangle, C E F, fix two pins or nails in the two focii, one at E and one at F. Lay the string around E and F, stretch it with a marker G, and it then will describe the desired ellipse.

"This is not at all difficult, and will answer for any kind of an ellipse, short or long, narrow or wide. This is called the "gardener's method." The main thing is to get the two points, E and F. This distance is always half of the long diameter A B, no matter what that may be, and this distance is then transferred by taking C as the starting point, measuring from there until the other point of measurement cuts the long diameter, as at E and F.

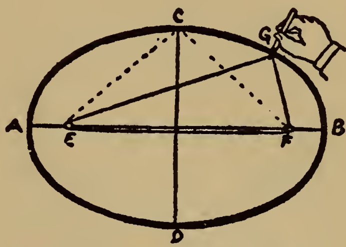


Fig. 65. Drawing an ellipse

"The ellipse has many peculiar and useful qualities, which you will doubtless discover before long."

IX

TIDES

"NOW, papa!" said Jessie the following evening, after Mr. Gregg and the family had strolled down to the river bank to enjoy the cool air, "you promised to tell me about the tides and the moon — when you could spare time. Haven't you got time now?"

"I may as well say all I intended now, my dear, and leave some other matters for future consideration. As this subject may tax your patience, I hope you, Fred, and George, will give me your earnest attention.

"In order to have a clear understanding of the movements of the tides and their supposed causes, you must know something of the moon's influence over them; as this knowledge will aid you very much in remembering what I am about to say.

"The earth is a globular body. One reason for this belief, among many others, is that sailors or others who go to sea soon observe that as they sail from shore, the lower portions of mountains, steeples or other high objects, are gradually lost sight of while the higher parts do not so soon disappear. Persons on shore first notice the upper portions of masts, and the smoke-stacks of approaching vessels, which would not be the case, if the earth were a plane, but is very easily accounted for, on the supposition of its being a sphere, as you can readily understand by looking at Fig. 66. Several navigators have sailed completely round the earth by continuing in the same direction, and coming at last to the same place from which they started.

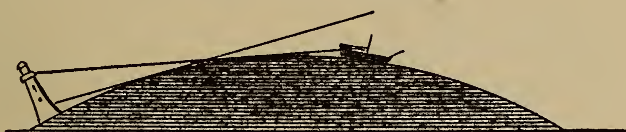


Fig. 66. Proof of earth's rotundity

The earth, however, is not a perfect sphere but a spheroid like an orange; having its equatorial longer than its polar diameter or axis. It is flattened at the poles, and more protuberant at the equator. The diameter at the equator is 7,977 miles, and at the poles 7,940, a difference of 37 miles.

"You know that the cause of day and night is the rotation of the earth on its own axis. It shows a large portion of its surface to the sun continually, or in other words, the sun is always shining on some portion of the earth's surface. You are also aware of the earth and its satellite, the moon, both being held in their orbits by the sun's attraction, the moon being further kept in her orbit by the attraction of the earth. Now the earth is composed of three main elements, air, water, and land, and if you consider, for a moment, that the daily rotatory movement of the earth is something like 1,000 miles an hour, this rapid speeding through space must have some effect on air and water in assisting or retarding their flow.

"Nature has divided time, and man has named and subdivided it into years, months, and days. The natural month, however, does not consist of four weeks, nor is the natural year made up of the twelve calendar months given us by the almanac. A natural, or lunar, month is the time the moon takes to perform her journey round the earth, which is 27 days 7 hours, and 43 minutes; this is called the periodical month, while the average calendar or synodical month consists of 29 days 12 hours and 44 minutes. The light of the moon is borrowed from the sun, for if it were her own light, she would shine all the time and not be subject to her present phases. The moon is seen by means of the light which comes to it from the sun being reflected from it. Its changes, or phases, depend upon its relative position to the earth and the sun. When the moon is in opposition to the sun at A (Fig. 67) the lighted side is turned toward the earth, as A, and it appears full. When the moon is in conjunction at E with the sun, its dark side is turned toward us, and it is invisible, as at *e*. As it proceeds in its orbit, as at F, a small part of the light side is seen, and then we have what is called a new moon; and we continue to see more and more of the light side, as the moon approaches at G and H, to the state of opposition or full moon. The waning or decreasing of the moon takes place in the same manner, but in a contrary order. The earth must perform the same office to the moon that the moon does to us; and it will appear to the inhabitants of the moon (if there be any), like a very magnificent moon, being to them about thirteen times as large as the moon is to us and it will also have

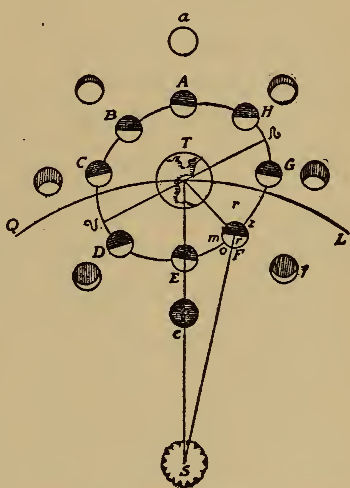


Fig. 67. Phases of the moon

the same changes or phases. Hence it is evident, that one half of the moon is never in darkness, the earth constantly affording it a strong light, during the absence of the sun; but the other half has a fortnight's light and darkness by turns.

"The moon's orbit is elliptical, and she also rotates on her axis and takes the same time to circle the earth, consequently every part of the moon is successively presented to the sun, yet the same hemisphere is always turned to the earth. This has been discovered by observation with good telescopes. The length of a day and night in the moon is more than twenty-nine and a half days of ours; and while her year is the same length as ours, being measured by her journey around the sun with us, so she has but twelve days and a third in a year. Another remarkable circumstance is that the moon's hemisphere next the earth is never in darkness, for when it is turned from the sun, it is illuminated by light reflected from the earth in the same manner as we are lighted by a full moon. The other hemisphere of the moon however, has a fortnight's light and darkness by turns. If there are inhabitants in the moon, which is doubtful, the satellite will appear to them to be about thirteen times as large as the moon does to us, and when it is new moon to the earth, it is full earth to the moon.

"There are many things regarding our relationship to the moon that would be of interest, if I had time to explain them, such as eclipses, the moon's surface as seen through telescopes, its supposed influence on the weather, etc., but I fear too much moon might prove tiresome. Beside I have shown you sufficient to enable you to understand the relationship existing between the moon and the tides, generally accepted as the true theory.

"If we agree that the tides are occasioned by the attraction of sun and moon, more particularly the latter, we can readily understand their dependence on some known and determinate laws. Our almanacs published long in advance give the exact time of high water at any prominent port in the United States on the morning and afternoon for every day in the year; and seafaring men can tell you when the tide will be high or low, notwithstanding the fact that these movements are not fixed. They know from experience that the time of ebb and flow varies about three quarters of an hour each day.

"The first person who clearly pointed out the accepted cause of the tides and showed its agreement with the effects, was Sir Isaac Newton. He discovered a relationship between the moon and the tides, and by the application of his new principles of geometry, the attraction was made clear.

"The ocean, it is well known, covers more than one half the globe; and this large body of water is found to be in continual motion, ebbing and flowing alternately, without the least intermission. For instance, if the tide is now at high water mark, in any port or harbour which lies open to the ocean, it will presently subside, and flow regularly back for about six hours, when it will be found at low water mark. After this it will again gradually advance for six hours; and then recede in the same time to its former situation, rising and falling alternately twice a day, or in the space of about twenty-four hours. The interval between its ebb and flow is not precisely six hours, for there is a little difference in each tide; so that the time of high water does not always happen at the same hour, but is about three quarters of an hour later each day, for about thirty days, when it again recurs as before. For example, it is high water to-day at noon, it will be low water at eleven minutes after six in the evening; and, consequently, after two changes more, the time of high water the next day will be at about three quarters of an hour after noon; the day following it will be at about half an hour after one, the day following that at a quarter past two, and so on for thirty days; when it will again be found to be high water at noon, as on the day the observation was first made. This exactly answers to the motion of the moon which rises every day about three quarters of an hour later than upon the preceding one, and by moving in this manner round the earth, completes her revolution in about thirty days, and then begins to rise again at the same time as before.

"To make the matter still plainer; suppose, at a certain place, it is high water at three o'clock in the afternoon, upon the day of the new moon; the following day it will be high water at three quarters of an hour after three; the day after that at half an hour past four; and so on till the next new moon, when it will again be high water exactly at three o'clock. as before. By observing the tides continually at the same place, they will always be found to follow the same rule; the time of high water, upon the day of every new moon, being exactly at the same hour, and three-quarters of an hour later every succeeding day.

"The change of the tides is in such exact conformity with the motion of the moon that, independently of mathematical calculations, a thoughtful person would certainly be induced to look to her as their cause.

"The waters at Z, on the side of the earth, A, B, C, D, E, F, G, H, next the moon M, (Fig. 68) are more attracted by the moon than the central parts of the earth, O, and the central parts are more attracted by her than the waters on the opposite side of the earth at *n;* and therefore the distance between the earth's centre and the waters on its surface under and opposite to the moon will be increased. Let there be three bodies at H, O, and D; if they are all equally attracted by the body M, they will all move equally fast toward it, their mutual distance from each other continuing the same. If the attraction of M is unequal, then that body which is most strongly attracted will move most quickly and will increase its distance from the other body. M will attract H more strongly than does O, by which the distance between H and O

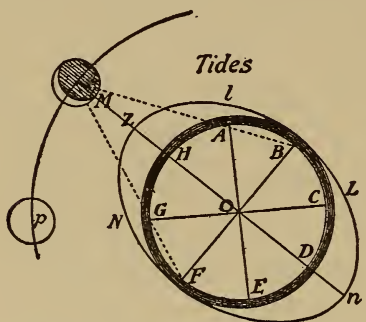


Fig. 68. Theory of the tides

will be increased, and a spectator on O will perceive H rising higher toward Z. In like manner, O being more strongly attracted than D, it will move farther toward M than D does; consequently the distance between O and D will be increased; and a spectator on O, not perceiving his own motion, will see D receding farther from him towards N; all effects and appearances being the same, whether D recedes from O, or O from D.

"Suppose now there is a number of bodies, as A, B, C, E, F, G, H, placed round O, so as to form a flexible or fluid ring; then, as the whole is attracted toward M, the parts at H and D will have their distance from O increased; whilst the parts at B and F being nearly at the same distance from M as O is, these parts will not recede from one another; but rather by the oblique attraction of M, they will approach near to O. Hence, the fluid ring will form itself into an ellipse Z, *n*, L, N, whose longer axis *n*, O, Z, produced will pass through M, and its shorter axis B, O, F, will terminate in B and F. Let the ring be filled with fluid particles, so as to form a sphere round O; then, as the whole moves toward M, the fluid sphere being lengthened at Z and *n* will assume an oblong or oval form. If M is the moon, O the earth's centre, A, B, C, D, E, F, G, H, the sea covering the earth's surface, it is evident, by the above reasoning, that whilst the earth by its gravity falls toward the moon, the water directly below at B will swell and rise gradually toward her; also the water at D will recede from the centre, (strictly speaking, the centre recedes from D) and rise on the opposite side of the earth; whilst the water at B and F is depressed, and falls below the former level. Hence as the earth turns round its axis from the moon to the moon again in 24¾ hours, there will be two tides of flood and two of ebb in that time, as we find by experience.

"That this doctrine may be still more clearly understood, let it be considered that, although the earth's diameter bears a considerable proportion to the distance of the earth from the moon, yet this diameter is almost nothing when compared to the distance of the earth from the sun. The difference of the sun's attraction, therefore, on the sides of the earth under and opposite to him, will be much less than the difference of the moon's attraction on the sides of the earth under and opposite to her; and, for this reason, the moon must raise the tides much higher than they can be raised by the sun. The effect of the sun's influence, in this case, is nearly three times less than that of the moon.

The action of the sun alone would, therefore, be sufficient to produce a flow and ebb of the sea; but the elevations and depressions caused by this means would be about three times less than those produced by the moon.

"The tides, then, are not the sole production of the moon, but of the joint forces of the sun and moon together. Or, properly speaking, there are two tides, a solar one and a lunar one, which have a joint or opposite effect, according to the situation of the bodies which produce them. When the actions of the sun and moon conspire together, as at the time of new and full moon, the flow and ebb become more considerable; and these are then called the spring tides. But when one tends to elevate the waters while the other depresses them, as at the moon's first and third quarters, the effect will be exactly the contrary: the flow and ebb, instead of being augmented, as before, will now be diminished; and these are called the neap tides.

"To explain this more completely, let Fig. 69 represent the sun, Z, H, R, the earth, and F and C the moon at her full and change. Then, because the sun S, and the new moon C, are nearly in the same right line with the centre of the earth O, their actions will conspire together, and raise the water above the zenith Z, or the point immediately under them, to a greater height than if only one of these forces acted alone. But it has been shown that when the ocean is elevated to the zenith Z, it is also elevated to the opposite point, or nadir, at the same time; and therefore in this situation of the sun and moon, the tides will be augmented. And again, whilst the full moon F raises the waters at N and Z, directly under and opposite to her, the sun S, acting in the same right line, will also raise the waters at the same point Z and N, directly under and opposite to him. Therefore, in this situation also, the tides will be augmented; their joint effect being nearly the same at the change as at the full; and in both cases they occasion what are called the spring tides.

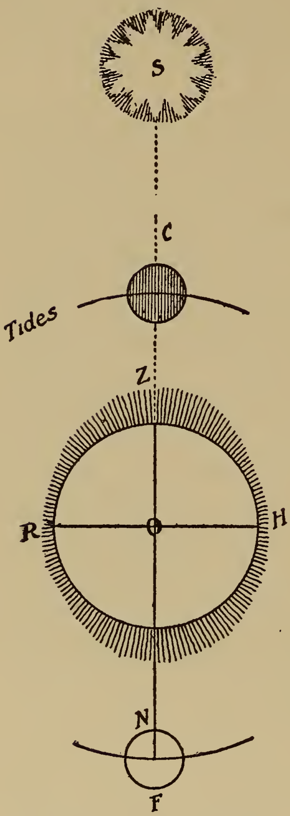


Fig. 69. Attractions of the moon

"On this theory, the tides ought to be highest directly under and opposite to the moon; that is, when the moon is due north and south; but we find that in open seas, where the water flows freely, the moon is generally past the north and south meridian of the place where it is high water. The reason is obvious; for though the moon's attraction were to cease altogether when she was past the meridian, the motion of ascent communicated to the water before that time would make it continue to rise for some time after; much more must it do so when the attraction is only diminished. A little impulse given to a moving ball will cause it still to move farther than otherwise it could have done; and experience shows that the day is hotter about three in the afternoon than when the sun is on the meridian, because of the increase made to the heat already imparted.

"Tides do not always answer to the same distance of the moon from the meridian at the same place, but are variously affected by the action of the sun, which brings them on sooner when the moon is in her first and second quarters, and keeps them back later when she is in her third and fourth; because, in the former case, the tide raised by the sun alone would be earlier than the tides raised by the moon; and in the latter case, later.

"The sea, being put in motion, would continue to ebb and flow for several times, even though the sun and moon were annihilated, and their influences at an end, on the same principle that if a basin of water is once agitated, the water will continue to move for some time after the basin is left to stand still. A pendulum, put in motion by the hand, continues to make several vibrations without any new impulse. When the moon is at the equator, the tides are equally high in both parts of the lunar day, or time of the moon's revolving from the meridian to the meridian again, which is 24 hours 50 minutes. But as the moon declines from the equator toward either pole, the tides are alternately higher and lower at places having north or south latitude. One of the highest elevations, which is that under the moon, follows her toward the pole to which she is nearest, and the other declines toward the opposite pole; each elevation describing parallels as far distant from the equator, on opposite sides, as the moon declines from it to either side; and consequently the parallels described by those elevations of the water are twice as many degrees from one another as the moon is from the equator; then increase their distance as the moon increases her declination, till it is at the greatest, when these parallels are, at a mean state, 47 degrees from one another; and on that day the tides are most unequal in their heights. As the moon returns toward the equator, the parallels described by the opposite elevations approach toward each other, until the moon comes to the equator, and then they coincide. As the moon declines toward the opposite pole, at equal distances, each elevation describes the same parallel in the other part of the lunar day which its opposite elevation described before. Whilst the moon has north declination, the great tides in the northern hemisphere are when she is above the horizon; and the reverse whilst her declination is south.

"In open seas, the tides rise to very small heights in proportion to what they do in wide-mouthed rivers, opening in the direction of the stream of tide. In channels growing narrower gradually, the water is accumulated by the opposition of the contracting bank — like a gentle wind, little felt on an open plain, but stronger and brisk in a street; especially if the wider end of the street is next the plain, and in the way of the wind.

"The tides are so retarded in their passage through different shoals and channels, and otherwise so variously affected by striking against capes and headlands, that in different places they happen at all distances of the moon from the meridian, consequently at all hours of the lunar day.

"There are no tides in lakes because they are generally so small that when the moon is vertical she attracts every part of them alike; and, therefore, by rendering all the waters equally light, no part of them can be raised higher than another. The Mediterranean and Baltic Seas suffer very small elevations, because the inlets by which they communicate with the ocean are so narrow that they cannot, in so short a time, receive or discharge enough to raise or sink their surface sensibly.

"Air being lighter than water and the surface of the atmosphere being nearer to the moon than the surface of the sea, it cannot be doubted that the moon raises much higher tides in the air than in the sea. Therefore many have wondered why the mercury does not sink in the barometer when the moon's action on the particles of air makes them lighter as she passes over the meridian. But we must consider, that as these particles are rendered lighter, a greater number of them are accumulated, until the deficiency of gravity is made up by the height of the column; and then there is an equilibrium, consequently an equal pressure upon the mercury as before; so that it cannot be affected by the aerial tides. It is probable, however, that stars seen through an aerial tide of this kind will have their light more refracted than those which are seen through the common depth of the atmosphere; and this may account for the supposed refractions of the lunar atmosphere that have been sometimes observed.

"You see now how the tides are caused; while there may be some influences at work other than those exerted by the sun and moon, the latter are the chief ones, so I will not attempt to explain any other.

"Here, on the Passaic River, we do not have excessive tides, as the highest on the coast near us seldom rise over ten or twelve feet. As a rule, tides rise highest and strongest in those places that are narrowest. In the Black Sea and the Mediterranean, the tides are scarcely perceptible, while at the mouth of the Indus, in the Bay of Fundy, and other places, they rise thirty or more feet at times. The general rise, however, in mid-ocean, is from eleven to twelve feet.

"The diameter of our moon is nearly 2,200 miles, and her distance from the earth is about 240,000 miles; so you see it is not her size, but her proximity to the earth that gives her so much influence over the tides; for the sun, which is many times larger than the earth and moon combined, because of its being some ninety-three millions of miles away, exerts only one sixth of the attraction on the earth that the moon does.

"These facts, children, should be remembered, as you may often be called upon to make use of them.

"Oh, papa!" said Jessie "how many wonderful things there are in this world."

"But I have not told you all, my dear. There is much more to learn, but I hope the knowledge you have now acquired will act as an incentive, and cause you to pursue this study further."

Next morning Fred asked his father to enlighten himself and George regarding the making of a few simple meters, such as barometer, hygrometer, and a thermometer. He also wished to know if it would be possible for him to make a boomerang. Mr. Gregg told him he would be pleased to help him, and that there would be no difficulty in making a boomerang if he went to work at it earnestly.

On the arrival of his father that evening, the subject was again introduced, and Mr. Gregg using the blackboard, laid out the following drawing and wrote the accompanyig instructions.

"The best hygrometer of absorption is (according to Deschanel) that of De Saussure, consisting of a hair deprived of grease, which by its contractions moves a needle. When the hair relaxes, the needle is caused to move in the opposite direction by a weight which serves to keep the hair always tight as seen in the illustration, Fig. 70. The hair contracts as the humidity increases. In the accompanying illustration A A and B B represent the frame; e f, the scale; a, screw for tightening the hair; b, the hair; O, weight; H, thermometer.

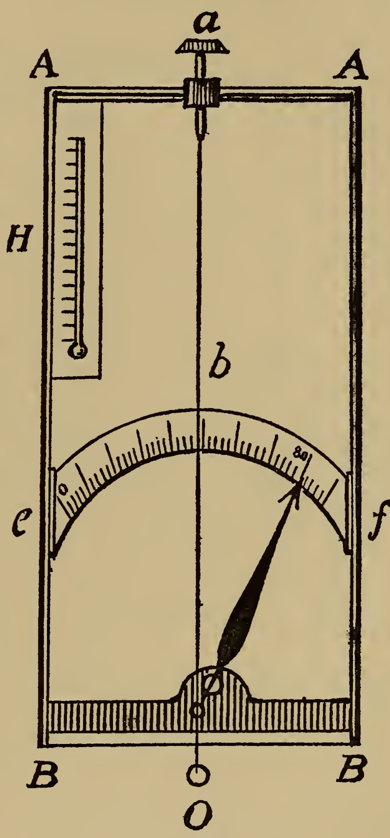


Fig. 70. Hygrometer

"A neater hygrometer, and one on the same principle, may be made by taking an old tooth powder box (as deep a one as possible, since the longer the string, the more sensitive it is), and boring a hole through the centre of the top and bottom. Paste a kind of dial in paper on the top of the box; take a piece of catgut, or small fiddle string, and push it up through the hole in the bottom and out at the one in the lid. Glue the bottom end immovably, and let the top end move freely: make a small index of a strip of whalebone (Fig. 71); bore a hole in the centre, and fix it on the catgut with glue. Wet the catgut, see which way it turns, and mark 'wet' and 'dry', accordingly on the dial.

Fig. 71. Index of Hygrometer

"So much for the hygrometer. Now about that curious thing, the boomerang. If the following directions are closely adhered to, and the proper shape followed, a regular Australian boomerang will result. It is not difficult to make. Take a piece of hard wood, the natural shape of one of the segments of an ordinary wheel felloe, or bend in the wood; let it be ¼ inch thick, shaped as at Fig. 72, to be held in the right hand at A, which shows the way the edges of the side facing the left hand must be bevelled off. It requires a slight curve on the flat side; so that, if on a table, each end would turn about ⅛ inch. It is then a part of a very fine pitch screw, in motion similar to a piece of slate jerked into the air, the sole difference being due to the slight curve in the back, which gives the screw motion, in conjunction with the forward and rotatory motion given by the hand. Sheet-iron would not do, as there would not be thickness to show the bevelled edge. The boomerang was made in the form of a cross, with four legs of equal length, bevelled, but it does not work as well as the regular form. You must be careful in throwing it as it may strike you on return."

Fig. 72. Boomerang

George asked his father to describe one and to explain its uses. Mr. Gregg told the boys that a boomerang, as used by the aborigines of Australia for a weapon or missile of war or in the chase, consisted of a flat piece of hard wood bent or curved in its own plane, and from 16 inches to 2 feet long. Generally, but not always, it is flatter on one side than on the other. In some cases the curve from end to end is nearly an arc of a circle; in others it is rather an obtuse angle than a curve, and in a few specimens there is a reverse curve toward each end. In the hand of a skilful thrower, the boomerang can be projected to a great distance, and made to ricochet almost at will. It can be thrown in a curved path, somewhat as a ball can be "screwed" or "twisted," and it can be made to return to the thrower, striking the ground behind him. It is capable of inflicting serious wounds.

"It is very good of you, father," said Fred, "to tell and show us all these things; I'd like very much to have a very common, every-day matter explained: the theory of the pump." The following questions also were asked by one or another on the same line: What is the greatest distance or height a pump of any type can be placed away from the water? Is there any limit to the length of the delivery pipe to the tank? What is the difference between a lift and a plunger or force pump? Is it the sucker of the pump that draws the water up, or does it flow because the air being drawn out of the pump barrel and forced on the water outside, causes it to flow into the pump?

Mr. Gregg started in at once to give them the facts desired: "Theoretically, the greatest height a pump can be fixed above the water level depends on certain conditions: the atmospheric temperature, and the altitude the pump is to be fixed above the sea-water level. The higher the temperature, and the greater the altitude, the less distance the height of the pump can be above the water. The height to which water can be drawn from the source to the top of the bucket, or under side of a piston or plunger, when at the top of the stroke, or what is termed the 'height of suction,' cannot reach more than about 33 feet when the pump is at the sea level. If a tube about 34 feet long is immersed in a well, and the air is extracted by means of an air pump at the upper so that a vacuum is formed, the water will not rise in the tube until the air is expelled, when it will not rise more than 33 feet, even though there is a complete vacuum formed in the upper end of the tube. The reason why the water will not rise in the tube higher than this, is that the height of the water counterbalances the pressure of the atmosphere. This height is the theoretically greatest height that water will rise in a suction pipe. For the pump to discharge water, it is necessary for the water to be in motion, and to set and keep it in motion a portion of the water will rise, due to the atmospheric pressure. The shorter the suction pipe, the more certain the pump is of being completely filled at every stroke of the pump handle.

"The action of the pump is as follows: The bucket on moving upward attracts the air, so that the atmospheric pressure on the surface of the water in the well causes the water to follow the bucket up the suction pipe, through the suction valve, into the working barrel. On the return stroke, the suction valve will close, the valve in the bucket will open, and the water which before was under the bucket will pass through it to the top side. When the bucket is again raised, the water will be lifted through the delivery valve into the delivery pipe. There is practically no limit to the height of lift, which may be any height consistent with the strength of the pump and the available power. The ordinary pump used for raising water to the level of the top of the bucket, is termed a lift pump; for raising water above this, a force pump or a plunger pump must be used, when the water is displaced by a solid plunger on its downward stroke, when the quantity of water raised will be equal to the volume of the plunger. This system may be repeated when water is to be lifted more than ordinary heights.

X

WALL MAKING AND PLUMBING

A FEW evenings later, Mr. Gregg and his little family were gathered together on the river's bank, watching the movements of a number of pleasure boats and launches, when a good-sized tugboat came along and made quite a "wash" as she steamed past the Gregg domain. Mr. Gregg noticed that this had actually carried down a portion of the bank near the new pier, and he called Fred's attention to it. The two, followed by George, walked to the pier, and, to their alarm, found that quite a piece of the bank had been carried away by the current, the tides, and the frequent wash of passing steamers.

"This will never do," said Mr. Gregg. "We must protect the bank at this point, or the water will soon undermine and demolish our pier, for you see it is only near the landing where the bank shows signs of injury, and it is as badly damaged on one side as the other. This is caused by projection of the pier into the river, which prevents the water from flowing in its regular course, and causes it to rush into the angle formed by the junction of the pier with the bank, thus cutting away the latter."

"Perhaps it will be best to build a sort of retaining wall against the bank for ten or twelve feet each side of the pier to prevent this rush of water from cutting away the earth. If we had field stones enough on the ground, it would be cheaper to use them, though they would not make as good a 'job' as either cut stones or concrete; since we haven't the stones, we'll build it of concrete, as you have some knowledge of that material, and I will engage Nick to help you."

The next day Mr. Gregg ordered Portland cement and all the other materials required to build the wall, and engaged Nick, who promised to come the following morning. In the evening, Mr. Gregg had the boys in his den, and explained to them how to go about constructing the wall. He decided to have it built of concrete blocks about 12 x 24 x 12 inches, to be faced with good, strong, cement mortar on the face and ends, which would give the exposed wall a nice, smooth appearance. Mr. Gregg explained that there must be a foundation of stone under the concrete, formed by large bowlders or "fielders," laid as closely together as possible, the joints filled in with smaller stones and, when possible, cement mortar, to bind the whole into a solid mass — as shown by dotted lines in the illustration which he made on the blackboard. The blocks for the work were to be cast in wooden moulds or forms, which Fred and George could easily make out of boards taken from the dismantled barn.

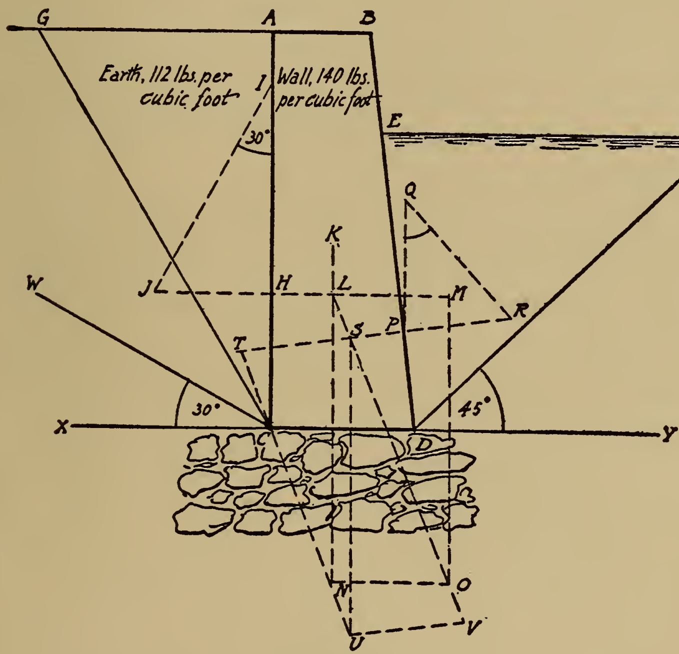


Fig. 72a. Retaining wall

At the points where the wall was wanted, the bank was about 8 feet high from the bottom of the river, and it was determined to make the wall 8 feet high, 2 feet wide at the top and 3 feet at the bottom, with the batter on the water side, the weight of the wall being 140 pounds per cubic foot. It is always best to have the inclined surface on the side of the wall where the water will be. The water at high tide rises to a level of 6 feet above the base C D.

"In designing such a retaining wall," said the father, "for water one side, and earth the other, or determining its stability, the principles generally followed may easily be worked out by Fred, or even by George.

"Taking the earth side first, as shown in diagram Fig. 72 *a*, W C X, angle of repose of earth to be retained — 30 degrees; G C, the line of rupture; G C A, the wedge of earth at 112 pounds per cubic foot to be accounted for, the weight of which equals—

$$\frac{GA \times AC}{2} \times 112 \text{ lb.} = \frac{4' \ 7'' \times 8'}{2} \times 112 \text{lb.} = 2{,}053 \text{ lb.}$$

"This will act at a point one-third the height of the wall H. From H erect a perpendicular H I equal to 2,053 lb. Set out the angle H I J equal to angle of repose, 30 degrees. From H erect a perpendicular to A C, cutting I J in J. Then J H equals the direction and magnitude of the weight of the earth acting on the wall.

"Produce J H through the wall toward the water side. Find centre of gravity of wall in K and the weight of the wall, which in this illustration equals —

$$\frac{AB \times CD}{2} \times AB \times 140\text{lb.} = \frac{2-3}{2} \times \frac{8}{1} \times 149 \text{ lb.} = 2{,}800 \text{ lb.}$$

"From where J H produced meets a vertical line drawn through the centre of gravity, K, in L set of L N equal to 2,800 lb.; make L M equal to J H; complete parallelogram L M O N, when L O equals resultant of earth and wall.

"The magnitude and direction of P R can be found as in the first part of this article. Produce R P through the wall, and from where it cuts the resultant L O in S make S T equal R P. Let the diagonal L O now be produced so as to make S V equal to L O. Complete the parallelogram S T U V, when the resultant S U equals the combined resultant of earth, water, and wall, and as it passes within the middle third it can be considered safe.

"Now, boys," said Mr. Gregg, "I have not only told you how to build a retaining wall, I have also told you how to make all the necessary calculations for designing it, as the same figuring and diagraming, on this principle, will answer for any sea wall requiring like conditions.

"I know you both understand figures and geometry enough to make such calculations, if you are ever called upon to do so."

The next morning, before the boys had finished their breakfast, Nick was on hand ready to go to work, equipped with a pair of hip rubber boots which would enable him to wade in water two feet deep and remain dry.

Fred and George were soon ready and Mr. Gregg went out to tell them the proper way to commence. The foundation was the first consideration, so an examination of the site and was made, the length of the proposed walls measured off. While waiting for the tide to ebb to its lowest point, Nick and the boys busied themselves gathering up stones for the foundation and wheeling them to the point nearest where they were to be used.

After gathering all the stones thought necessary, the question of making the moulds for the concrete blocks was considered, and, as the greatest bulk of the blocks would be simply blocks with square ends and square faces, the moulds for these would be a box having inside dimensions of 12 inches deep, 12 inches wide, and 24 inches long. These dimensions would then allow of blocks being made in the moulds that will contain exactly 2 cubic feet. The mixed concrete was dropped gently in the mould and lightly tamped so as to make it solid. The mixture consisted of not less than 3 of cement, 5 of sand, and 7 of very fine gravel or broken stone, no piece being larger than a white bean. It was mixed in the same manner and in accordance with the rules given for making concrete for the sidewalk in Chapter I.

The mould should rest on a smooth block of stone, wood, or other suitable material, while being filled and tamped, and when full the surplus should be levelled off, by a straight-edge — wood or iron — drawn over the top of the mould, until all the surplus is removed. The mould is then allowed to stand a little while until the concrete "sets" fairly hard, when the mould may be removed. To make it easy to take the block out of the mould, the inside should be well sprinkled with neat cement before the concrete is put in, and the box itself might be made slightly tapering to permit the block to move out easy. This method, however, is not to be recommended, as the blocks do not fit so well in a wall as when left perfectly square. There are a number of devices for making moulds so that delivery of blocks may be easy. One of the best is to hinge one corner of the mould with heavy hinges, while the opposite diagonal corner is left loose but held in place by a strong hasp and staple. When the box or mould is full and the block ready to remove, the hasp is loosened, the mould opens across at the two corners and frees the block. Should there be any holes or defects on the face of the blocks, they can be filled with cement mortar made with 2 of cement and 3 of clean sand. Blocks of this size should season not less than 4 or 5 days, to set hard before being used.

A portion of these blocks must have a bevel face on them to form the batter on the front of the wall. There must also be a proper proportion of them having their ends bevelled to the batter of the wall, to use as "headers." A header in brick, stone, or concrete, is a unit, or piece, that is laid in the wall with its ends showing through on the face, while a "stretcher" shows its whole length on the face of the wall. Other portions of brick or stone, when built in a wall, are called "closers."

The batter on the blocks is formed by making one side of the mould lower than the other. In this case, the difference in the width of the sides of the mould would be 1½ inches; because the height of the wall being 8 feet, the blocks 1 foot thick, and the batter 1 foot, there would be a falling off on each block of 1½ inches in order to have the top front of the wall 12 inches back from the bottom front. The ends of the header blocks may be battered by placing in the ends of the mould a piece of wood 12 inches wide, and the lower edge 1½ inches thick, and the top edge planed to a thin wire edge. The end or section of the plank will then have the appearance of a wedge 12 inches long, 1½ inches thick on one end, and tapered to nothing at the other end. When the block is taken from the mould, and the wedge piece removed, the block will show the same batter on its end as the stretchers do on their face, and they can be built in together without showing any difference in the slope, if the work is carefully done.

Nick, who had had some experience in this kind of work, found no difficulty in understanding the whole process.

At low tide he set to work to make a solid bed for the foundation, while the boys handed him the stone and the prepared mortar as he required it, so that before the tide rose one side of the stone foundation was ready to receive the concrete blocks. During the interim between tides, Nick and the boys made the moulds, prepared for mixing the concrete, and got old timbers and lumber for a temporary scaffolding. After the moulds were made and some concrete mixed, Nick began on the blocks. It was not long before he had a sample, which seemed all right, and before he stopped quite a number of them were ranged on boards "setting."

On the sixth day after it had been commenced, the job was entirely finished. The joints in the wall had been nicely "pointed" up with cement mortar by aid of a fine-pointed trowel. The back, or ground side of the wall was filled in with earth, and danger to the pier was entirely removed.

That night Mr. Gregg told the boys and Jessie — who had watched closely the growth of the wall — quite a lot about Portland cement and concrete, which interested them very much. Portland cement as we have it now was unknown a hundred years ago, but an Englishman invented the method of making it and properly proportioning the various materials used. Fifty years ago there was scarcely any made in this country, the little that was used being imported from England, and later from Belgium; but now more of it is made and used in the United States than anywhere else in the world. He pointed out that the building of the Panama Canal was made much easier and less costly because of cement, and that the largest dam ever built had just been suggested, to dam the Mississippi near

Keokuk, Iowa. This would be over 5,800 feet long and nearly 40 feet high and from 25 to 35 feet thick. He told of the various big storage dams being built and comtemplated by the United States, in Montana, Arkansas, Nebraska, Wyoming, New Mexico, Dakota, Texas, and many other places, at a cost of hundreds of millions of dollars — which never would have been attempted if concrete had not been available, He also made mention of the great wall that now protects Galveston from the ravages of the sea. It is not many years since Galveston was almost destroyed by tidal waves that caused an enormous loss of life, and destruction of property amounting to over $17,000,000. The wall was built to prevent a recurrence of similar disasters. It is 17,503 feet long, 17 feet high, and 16 feet thick at the base. Another recent work is the enormous dam built by English engineers across the river Nile at Assiout, about 250 miles above Cairo in Egypt, which increases the area of good land some 300,000 acres. Ancient Babylon is again to blossom and become a beautiful country to live in, for British engineers are laying out plans for building storage dams and irrigating canals in these now sandy and barren lands. All, or nearly all, of these works and proposed works would never have been thought of, if Portland cement had not been in existence.

Mr. Gregg, after finishing his talk on concrete, noticed that George had two fingers on his right hand tied up, and on inquiry was told that George had his fingers hurt by a concrete block falling on them just as the retaining wall was being finished. The father insisted on seeing the bruised fingers and found they were not badly hurt, though the skin in one place was broken. George explained that his mother had washed his hand, dressed the wound, and applied an antiseptic to it, so that it was all right now and did not pain him.

"You were wise to go to your mother and have your bruise attended to immediately, otherwise you might have had something serious happen to you, as lockjaw frequently comes from wounds of that kind, if deep enough and not attended to immediately. It is often said that lockjaw or tetanus is caused by a wound made by a rusty nail. It is certainly bad to be wounded with a rusty nail — or any other rusty iron — and tetanus may follow; but it does not follow because the nail is rusty, but because the tetanus microbe that may be on the nail, or on the skin when the wound is made, is carried into a favourable place for development.

"This tetanus microbe, which has a long name, is very plentiful and is scattered broadcast by every gust of wind. It is a microbe of dirt, and the ground and street abound with it. Its first home and breeding place is in the intestines of horses and other domestic animals, but its greatest danger to the human family is when it gets into the blood by way of a wound. Cleanliness, in this as in many other cases, is both a preventive and a cure."

"Father," said Jessie, "I saw a very funny thing to-day while watching Nick and the boys finish the wall. The train across the river came to a standstill for some reason or other, and, as I was watching it, I saw three puffs of steam go out of its boiler, and a short time after I heard three loud whistles. This seemed to me quite curious, but while I was thinking over it, there were three more jets of steam, followed by three more 'toots.' How was it that I saw the toots before I heard them?"

"This is a question, my dear, that will require some little time and thought to answer properly. In the first place, you must understand that light travels very much faster than sound and that sounds do not reach you until some time has elapsed, if you are a little distance away. You see a flash of lightning, and a little while after you hear the thunder; and if you count 1, 2, 3, in the ordinary way, between seeing the flash and hearing the thunder, you may be fairly satisfied the source of the thunder is well on to three miles away. This, of course, is not exactly correct, but approximately so. Every time you count one, it stands for a mile. According to science, light travels 186,000 miles a second, while sound only travels at the rate of 1,090 feet per second at a temperature of 32 degrees Fahrenheit, or freezing, its velocity being increased at the rate of one and one tenth feet per second for every degree above this temperature. So you see light travels nearly a million times faster than sound, and this accounts for your seeing the puffs quite a little while before you heard the 'toots', as you call them. There are many curious and interesting things about light and sound which I'd like to describe to you sometime.

"Sound travels in dry air at 32 degrees, 1,090 feet per second, or about 170 miles per hour; in water, 4,900 feet per second; in iron, 17,500 feet; in copper, 10,378 feet; and in wood, from 12,000 to 16,000 feet per second. In water, a bell heard at 45,000 feet, could be heard in the air out of the water but 656 feet. In a balloon, the barking of dogs can be heard on the ground at an elevation of four miles.

Divers on the wreck of the Hussar frigate, 100 feet under the water, at Hell Gate, near New York, heard the paddle wheel of distant steamers hours before they hove in sight. The report of a rifle on a still day may be heard at 5,300 yards; a military band at 5,200 yards. The fire of the English, on landing in Egypt, was distinctly heard 130 miles. Dr. Jamieson says he heard, during calm weather, every word of a sermon at a distance of two miles. The length of the sound waves in the air is sometimes many feet, while the length of the longest light wave is not more than .0000266 of an inch, it is no longer a mystery why we can hear, but cannot see, around a corner."

The children were greatly interested by these familiar marvels and made their father promise that he would resume the talk some other evening and tell them about thermometers and barometers.

The late afternoon next day was taken up with an excursion on the *Caroline* down the river to Newark, where Fred induced his father to purchase a full soldering outfit, as the boys wanted to try some plumbing and soldering work. There had been a plumber at the Gregg home nearly all that day doing repair work of various kinds, and Fred, who had watched the workman, concluded he could have made the repairs himself if he had had the proper tools.

An hour or two in the city, then a pleasant sail home, proved a fine ending for a day's labour.

The next day, after school, George and Jessie assisted their mother "making garden," planting flowers, trimming bushes, and destroying weeds, while Fred gave the *Caroline* another coat of varnish, and finished painting his little workshop, which now looked very snug and tidy. He soldered up all the leaks in every kitchen utensil he found defective, much to the delight of his mother and the maid. Fred found many things about the house wanting more or less attention, so he determined to try to put them in order. He discovered that to make a good job of soldering, he must first make the metal to be fastened together, perfectly clean and free from rust, dirt, or grease, the parts around the leak being scraped bright and smooth. He found some little difficulty in getting the solder to the exact place he wanted. In the outfit his father bought him, was not only a soldering iron, — which is not iron but copper — but a scraper, a lump of solder, a box of rosin, a piece of chamois leather, a bottle of muriatic acid, and a piece of sal-ammoniac, to be crushed fine and dusted over any surface that is to be finished bright. Fred had no trouble in soldering holes of small size in teakettles, tins, or such things as he could handle easily, for the impaired portions could be placed in a horizontal position before him and the solder applied readily. A leak in an upright water pipe in the shed, however, gave him a hard time, for he could not get the solder either to run up hill or to stay on the place where it was put. He got over this difficulty, however, by making a clay dam, a "tinker's dam" — mixing clay until it was soft, then winding a strip of it around the pipe just below the leak and applying the solder until the hole or crack was entirely covered, when a good solid job resulted. Of course, before applying any solder, all the water was drained from the pipe, and the defective part was thoroughly scraped. When the work was done, there was an edge of solder left projecting from the pipe, which Fred rasped away with a course rasp, leaving just enough solder to cover the leak properly. He then sand-papered the work and it looked almost as "good as new."

It is easy enough to solder across the work when level, even if the article being soldered is round, because the metal can be worked across the top and down the sides; but on the under side, it may be necessary to make use of a clay dam. A plumber's work covers a lot of things, among which may be mentioned metal roofing, wall flashings, water-pipes of all kinds, drain connections, hot water and steam fittings, hot-air and ventilation fittings, stove and range settings, and many other things connected in some way or another with the foregoing. Many times an offensive odour is noticeable in the cellar, or near the line of drainage, and it is often difficult to locate the source, so that expensive excavations are made before the trouble is remedied. Plumbers and drainage men often use what is termed "the peppermint test," to find where the leakage exists, and this is particularly suitable for the examination of existing soil pipes and drainage fittings. This test consists in pouring a small quantity of oil of peppermint or other substance possessing a pungent, penetrating, and distinctive odour, into the pipe or drain. The defective pipe or joint is then located by the escaping odour.

It is very important that defects of this kind should be located and repaired immediately, for odours emanating from drains or soil pipes carry with them germs of the kind most dangerous to human health and life.

Some taps in the bath room and over the kitchen sink were not working freely, and others were "dropping" a little. Fred, after cutting off the water from the main, unscrewed these and put new rubber washers in some, wound cotton twine around the plugs of others, and made the tight ones work easy by removing worn out washers and cut strings. He also fixed the hydrants on the lawn in the same manner, and made all the taps in and about the house work tightly and smoothly.

When Mr. Gregg arrived home, Fred told him all he had done, showing the tin pans and the leaky pipe he had soldered, and he straightened up with pride at being told that he was already "quite a plumber."

After tea, the family went down to the river's bank and chatted awhile on home matters; then shortly after the sun went down, they adjourned to "the lion's den."

"Now," said George, "father will tell us about barometers and thermometers, as he promised."

"Well," said Mr. Gregg, "I'm pleased to know you are so ready to listen to my talks, and I hope you'll remember some of the facts I've been telling you.

"There are many kinds of barometers, but all are constructed about on the same principle, and on the old theory that 'nature abhors a vacuum'. There may have been some kind of an instrument that did service as a barometor in the early ages, but we have no knowledge of it. The instrument as we now know it had its beginning with Galileo, Torricelli, and Pascal, but was not perfected until about 1650. Good barometers require the greatest possible care in their construction, and there ought to be two or more standing together as checks on one another in order to obtain correct results. The mercury used must be pure and good, free from all other substances and from air bubbles or films of air on the sides of the bulb. Simple barometers, suitable for ordinary purposes, can be easily made. I will describe one, and make a sketch of it on the blackboard.

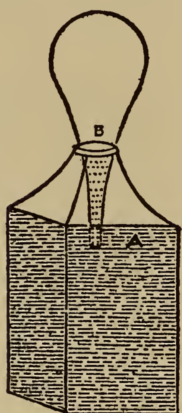


Fig. 73. Simple barometer

"This simply consists of a wide-mouthed glass bottle filled with ordinary drinking water up to the point indicated by the letter A (Fig. 73); in this is dipped an inverted glass flask, or an incandescent light bulb, the extremity of the neck being allowed to dip just below the surface of the water.

"The flask should be inverted quite empty during wet weather, and as long as the atmosphere remains in a stormy condition, no change in the water takes place; but immediately the weather becomes finer, the water will rise in the neck of the inverted flask, and, if a continuance of fine weather be probable, will rise to the point indicated by letter B.

"I have found this simple contrivance to give sure and early warning of the approach of rain, and I need hardly remark that the principle upon which this little weather glass acts is exactly similar to that of the ordinary mercury barometer, for the rise and fall of the water is due to the respective increase or decrease of atmospheric pressure.

"By dividing the neck A B into six or eight divisions, with the aid of a diamond or piece of flint, and then marking the lines so cut, with ink, an approximate graduation of degrees of pressure may easily be obtained.

"I show you a water barometer here, (Fig. 74) that is somewhat less hard to construct than the one I have already described, as the parts are easier to obtain.

"It consists of a bottle, containing water, inverted and suspended with its mouth in the jar of the same fluid. It is capable of roughly indicating atmospheric changes in a similar way to the mercurial barometer. When the atmosphere becomes denser, the greater pressure on the surface of the water in the jar causes it to rise in the bottle; while with a lesser density it falls. As with the mercurial barometer, temperature makes a slight difference, which, strictly speaking, should be allowed for; but, as the arrangement is of such a simple character, this may be ignored. Water, also, is more subject to evaporation than mercury, besides going stagnant, and will require occasional changing and replenishing.

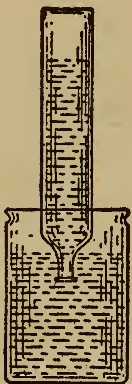


Fig. 74.
Barometer

"A barometer of a more scientific character, and more presentable, is, I think, within your range of skill, and it may be made as follows: Obtain a glass tube, closed at one end, about two feet ten inches long and three eighths of an inch thick, with a bore of about three sixteenth inch. A circular turned wood box, one and one half inches in diameter and one and one fourth inches deep, is required for the cistern. Cut out the bottom and glue on instead a piece of leather, sagging loosely. Then cut the lid in two, and make an opening in the centre to receive the tube.

"The mahogany base, shown in two halves by A and B (Fig. 75), is 3 feet 1 inch long, 3¾ inches at its greatest width, 2 inches at its least width, and ¾ inch thick. Make a groove down the centre to admit the tube, and cut an opening 2 inches square right through the wood at the round end. Glue at the back of this a circular piece of pine or cedar, 3 inches in diameter and ½ inch thick, and screw a semicircular piece of the same thickness at the other end, with a ring for hanging.

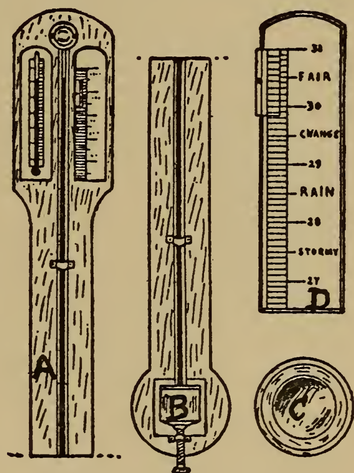


Fig. 75. Thermometer

"Fill the tube by degrees with pure mercury, boiling each portion, as introduced, by holding the tube in a nearly horizontal position over a spirit lamp, taking care not to crack it by too sudden heating. Half fill the wooden cistern with mercury.

and when the tube is full, place a finger over the end, carefully raise it to a vertical position, and lower the open end below the surface of the mercury in the cistern. While some one holds the tube, glue on the two halves of the box lid and seal up the opening round the tube with wax or cement. Then fasten the tube to the base with brass clips and screws, and secure the cistern from shifting by gluing in wedges of wood. A thumb screw, with washer, for regulating the height of the mercury, is fixed at the bottom; this presses on a cork washer glued to the leather of the cistern.

"A hollowed hardwood boss is screwed over the top end of the tube, and a hollowed circular turned boss of mahogany, C, is glued over the bottom. The ivory or cardboard scale D, is of inches and tenths, from twenty-six and one half inches to thirty-one inches, the distance being measured approximately from the surface of the mercury in the cistern. A vernier having a scale of eleven-tenths of an inch, divided into ten parts, works in a slot on the scale and should be attached as shown at D.

"Before screwing on the scale, fix its correct position by comparison with the standard barometer.

It is usual to place a small thermometer on the other side.

"With regard to the thermometers, it would be quite out of place here to discuss them at length, or to offer you a scientific explanation of the principles governing their construction. I may say however, that, as the barometer is intended to measure the different degrees of density of the atmosphere, so the thermometer is designed to mark the changes in its temperature, with regard to heat and cold. The first thermometers, so far as we know, were made less than three hundred years ago, and water, spirits of wine, or alcohol, and oil were used to fill the bulbs, in the order given. It was the great Halley, of 'Halley's Comet' fame, who first made use of mercury or quicksilver in these instruments, because of its being highly susceptible to expansion and contraction, and capable of showing a more extensive scale of heat. It is owing to this quality of expansion and contraction that the degrees of heat and cold can be measured. If you put your thumb on the bulb, you will notice the quicksilver in the little tube gradually rise until it reaches the limit of the thumb's heat. Thermometers, in this and nearly all English-speaking countries, make use of the Fahrenheit scale, which is different from those used in some other places; and this often causes trouble and annoyance.

"The scale of Reamur prevails in Germany. He divides the space between the freezing and boiling points into 80 degrees. France uses that of Celsius, who graduated his scale on the decimal system. The most peculiar scale of all, however, is that of Fahrenheit, the renowned German physicist, who, in 1714 or 1715, composed his scale, having ascertained that water could be cooled under the freezing point without congealing. He, therefore, did not take the congealing point of water, which is uncertain, but composed a mixture of equal parts of snow and sal-ammoniac, about fourteen degrees R. This scale is preferable to both those of Reamur and Celsius, or, as it is called, Centigrade, because: (1) The regular temperature of the moderate zone moves within its two zeros and can, therefore, be written without + or —. (2) The scale is divided so finely that it is not necessary to use fractions whenever careful observations are to be made. These advantages, although questioned by some, have been considered so weighty that both Great Britain and America have retained this scale, while nations on the Continent of Europe use the other two. The conversion of any one of these scales into another is very simple. (1) To change a Fahrenheit temperature into the same given by the Centigrade scale, subtract 32 degrees from Fahrenheit's degrees and multiply the remainder by 5/9. The product will be the temperature in Centigrade degree. (2) To change from Fahrenheit to Reamur's scale, subtract 32 degrees from Fahrenheit's degrees and multiply the remainder by 4/9. The product will be the temperature in Reamur's degrees. (3) To change a temperature given by the Centigrade scale into the same given by Fahrenheit, multiply the Centigrade degrees by 9/5 and add 32 degrees to the product. The sum will be the temperature by Fahrenheit's scale. (4) To change from Reamur's to Fahrenheit's scale, multiply the degree on Reamur's scale by 9/4 and add 32 degrees to the product. The sum will be the temperature by Fahrenheit's scale. A handy table can easily be figured out from the data given."

Mr. Gregg concluded his conversation for the night at this point, but promised to take it up again the first available evening.

Two or three nights afterward it was very wet and dreary. The boys and Jessie were called into the den by Mr. Gregg, where a brisk fire, made of limbs and branches gathered by the boys, was burning in the little fireplace, and the room looked bright and cheerful. The young folks all drew up around the fire to listen.

"I have so many things to talk to you about," said he, "that I scarcely know where to begin; however, I promised to tell you something concerning springs, so I will make these useful contrivances my theme to-night."

"There are many kinds of springs, but I will only talk of steel or other metal springs; and even then must limit myself to a few. The carriage or laminated spring is probably the most in use, as it is an important factor in the construction of all classes of railway trucks and carriages, locomotives, automobiles, road carriages and light wagons of all kinds. These are also much used in the manufacture of invalids' chairs, children's perambulators, and many other things. The springs used in the construction of the largest locomotives are big affairs and often weigh over 500 pounds. These are bearing springs and carry the whole weight of engine and boiler. There are, of course, a number of these springs to each engine. Springs on the coaches and carriages are somewhat lighter and more flexible than those on the heavier trucks.

The double spring, shown at Fig. 76, is known in railroad parlance as a 'draw-spring.' One of these is secured at each end of the car, and used to attach or couple the cars together, or to attach the engine to the train, the object being to lessen the bump or impact of the blow when the engine and cars come together. The effect is the same when the engine starts a train; the springs in the first car draw out, then the springs on the second car do likewise, and this causes the load of the whole train to fall on the engine gradually, a matter of great importance in railway economy. If it were not for bearing springs on the trucks and carriages, it would be almost impossible to use railroads for passenger traffic or for carrying fine goods, as the jolting and pounding on the iron rails would shake things to pieces, destroy the carriages, and pound the roadbed and bridges to bits in a very short time. Now, by the aid of steel springs, you ride in a Pullman as smoothly almost as

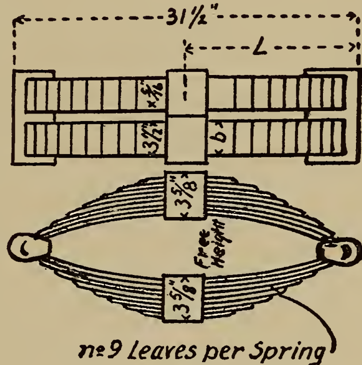


Fig. 76. Car-spring

in a boat, so you see how useful springs are to mankind.

"There are many kinds of bearing springs, but all are built in the same manner, of steel leaves, made of different dimensions to suit conditions. As you will see in the diagram, the sheets of steel are laid over each other, like the scales of a fish, and made shorter as they approach the top. All the leaves are fastened together by having an iron buckle driven onto the middle, as shown, while hot, and when this cools, it shrinks and clasps the whole so tight it cannot be taken off until heated or cut. I could tell you of many other kinds of springs — watch springs, gun springs, trap springs, spiral springs — used for various purposes, but I will end this subject by describing to you something you can make for yourself, if you wish; namely, a cross-bow, which is very simple. I make on the blackboard a diagram, (Fig. 77), with A representing the stock, 5 feet long; B, the bender, 6 feet long, which should be made in four pieces. The front piece should be ¾ inch thick, the three inner pieces ½ inch thick. C are brass ferrules to keep the leaves of the bender from shifting; D the string, which should be very strong. The bender should be cut out of straight wellseasoned ash, rock elm, or hickory. Instead of brass ferrules, strong brass or copper wire can be used, properly twisted at the joints.

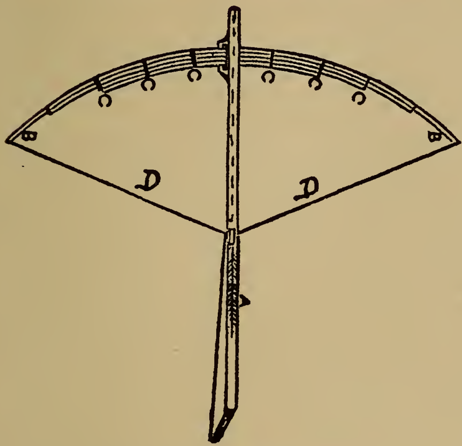


Fig. 77. Cross-bow spring

"The gyroscope has become quite famous of late, because of its having been employed as a steadier for the monorail car, and proposed as a regulator or governor for aeroplanes, so that I think it will not be amiss to tell you that a study of this toy is well worth any time and labour you may spend on it. There are great possibilities within this little instrument and its applications. I do not intend dealing with its principles, or with rotation problems generally, as they would, I fear, be beyond your present comprehension, but I will confine myself to describing the toy and showing you how it can be made, though it would be much cheaper to buy one from a dealer. The instrument consists of a ring of brass or other metal, like a curtain ring, and a smaller brass ring attached to a thick disc of white metal, or a metal disc with a thickened rim, as shown in Fig. 78. This disc is securely fixed to a metal pin, which is passed through two holes in the outer brass ring, and at one side a small rounded nut or ball of brass is screwed on the outer ring. The metal disc is at right angles to the outer ring. If a cord is wound several times round the metal pin, the outer ring held in the left hand, the pin and metal disc will revolve at a very high speed, while the outer ring remains stationary. The gyroscope can be placed on the knob, and while the disc is revolving the outer ring can be placed at any angle, and will remain stationary. It is also possible to balance it at any angle on the top of a support, such as the tip of a stick."

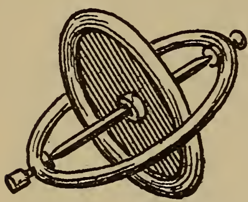


Fig. 78. Gyroscope

PART II

EVERYDAY MACHINES

I

SOME PRACTICAL ADVICE

SOME of our inventions and some of our discoveries are of comparatively recent date, but most of them had their beginnings centuries before historical times, as many of our greatest inventions are the result of gradual growth and development. The early discovery, by some unknown persons or persons, of the making of bronze and the hardening of it, led up to stone and woodcutting, perhaps to the breaking-up and smelting of iron ore, and the extraction of the metals. This again opened the way for the making of steel, a discovery that placed in the hands of man a source of power which enabled him to overcome many natural difficulties. One improvement led the way to another, and made other improvements possible. Take locomotives and steamboats for instance. The making of a raft, no doubt, suggested the canoe, and this led to the built-up boat, and the ship. The paddle and the oar doubtless led up to the side-wheeler, and the scull to the propeller. The crude steam engine of Hero very likely suggested the steam engines now in use, and this new power rendered it easy for Stephenson and Fulton to perform their work; but, if either of these inventors were to come back to the earth and examine the great steamers of to-day, or the perfect and powerful locomotives now in use, they would be surprised to think that the present tractable monsters, were the outgrowth of their early efforts.

In the same manner may be traced the same gradual growth in all the arts and sciences; for step by step, in every department of life, have completeness and perfection come to us. It is not yet one hundred years since Congreve invented or rather completed the invention of the "Parlor match," called in his day, the "Lucifer match." This grand achievement was accomplished after many failures in the efforts of chemists for ages. The perfection of the match was a great blessing to humanity, as the old methods of making a light or fire were tiresome and very uncertain. So it is with many of the blessings we enjoy to-day: they are simply the results of the struggles of many unknown minds, the threads of which were gathered up and pieced together by one master mind, so as to be made useful and profitable to mankind.

In the early and middle ages, the inventor was looked upon as a wizard, a sort of inferior demon, or, at best, an uncanny kind of man, and a proper subject for the stake. When, by superior wisdom and skill, he invented some machine or device, or discovered some new and better method of accomplishing a useful end, he was at once looked upon as a necromancer in league with his Satanic majesty, and, therefore, unfit to associate with or be recognized as a Christian. History records many instances of inventors and progressive men being persecuted — and executed — because of their having discovered or invented something which would interfere with some vested or imaginary rights. The new inventions must be destroyed or put away out of sight and hearing, and the most powerful influences were employed to bring about this result. The stories told of Friar Bacon, Papin, Crompton, and hundreds of other inventors, give us a few of the reasons why so little progress was made in the arts and sciences previous to the sixteenth century.

Down to a period within the past few years the term invention has been considered almost synonymous with the word chance. An inventor, was a lucky individual, who had happened to hit upon some new idea, not so much by his own great ability as by good fortune, similar to that which brings success to the purchaser of a lottery ticket.

In many cases this was really the true state of affairs. Men who experimented in various mechanical pursuits often stumbled upon results, which they perceived to be useful and valuable, and, if they protected the invention by patent, they often became wealthy.

At the present time this meaning of the word invention must be greatly modified, if not altogether abandoned. The law which controls the action of the forces of nature is becoming so well understood among all classes of mechanics that chance invention, in the early sense of the term, has almost become an impossibility. Success can be assured only to the man who has tried to win it by the acquirement of the necessary knowledge, to be obtained by steady application and hard study. In the pursuit of discovery, the old saying, "knowledge is power," never has had more force than when applied to unravelling the tangled web of nature's mysteries. "Science," says Lord Brougham, "is knowledge reduced to a system."

A man may have a lifetime of practical experience and amass a fund of knowledge of great use to himself, but entirely unavailable for others. But if his experience be combined with that of other men and systematized into a regular order, it becomes part of the science of that branch of industry, and although the person himself may have a profound contempt for science and theory his work may be quite scientific.

Ignorance, in the past centuries, was another great factor in preventing mechanical progress. New machines and labour-saving devices were looked upon by the great mass of workers as contrivances designed to deprive them of the means of making an honest livelihood, and this point of view caused the people to smash and burn many machines that had cost great labour and expense to the unfortunate inventor. But, as public schools became more numerous and learning increased, the way of the inventor became smoother. The more enlightened nations encouraged inventors and inventions, and now our country has on its statute books laws for this purpose, the most liberal in the world.

The opportunities for obtaining mechanical and scientific knowledge and technical instruction are now so many and so easy of access that inventors have but little trouble in acquiring the data and facts essential to their purposes. The earliest students had nothing but their own observations and experiences to build on, and even as late as the eighteenth century, men had to grope in the dark for the data required to carry out their ideas. A brief examination of the early treatises on mechanics and the rude illustrations in the works of Leopold, Amoutons, and Desaguliers will reveal the germs of many modern machines.

The inventor of to-day, however, must proceed by a different path from his predecessor, if he expects to succeed in the present advanced state of mechanical arts. The demonstration of the mechanical equivalent of heat, the discovery of the correlation of the physical forces, and the development of the sciences of thermo-dynamics have furnished powerful weapons for the advancement of mechanical science, and he who does not use them is at a woeful disadvantage in the fight. There is no "royal road" to success for the inventor, and I hope you will always bear this in mind when attending to your studies, for you must remember that it is nearly always necessary to use formulæ and symbols to express relations, which are hardly within the range of words, and often a combination of data obtained from different sources may be used to derive entirely new relations.

It is here that invention, in the modern sense of the term, comes in to hold a place midway between theory and practice, and may be properly called a science.

THE LAWS OF GRAVITATION

Suppose a one-pound weight is suspended by a string: there is a tensile stress in the string, varying slightly at different parts of the earth, but always the same at the same place, say, Newark, for the variation is very slight within a pretty wide area. If we take a spring balance and graduate it in pounds at Newark, such a balance will accurately indicate forces in pounds wherever it may be used. The stress produced in a string carrying a one-pound weight at Newark is the unit of force. If the string with its weight is hung from a nail, the nail is pressed on its upper side with a force of one pound. The same pressure may be produced by pushing the nail downwards from above, using a short piece of stick; in such circumstances, the stick bears a compression stress of one pound. This is a good, common-sense definition of force, though it does not by any means cover the whole subject. The word force is used in a different sense by persons who speak of the force of gravity. When a one-pound weight is suspended by a string, as stated in the foregoing, the attraction between the mass of the weight and the mass of the earth is balanced by the stress in the string. We can double the stress by doubling the weight, and in this way, by adding weights, we can make the force of gravity very great. But the force of gravity is spoken of as an invariable thing, and it is said to be equal to 32 (roughly). If any weight whatever be allowed to fall freely (for reasonable heights and neglecting the effect of the resistance of the air) it will be found that at the end of the first second it will have a velocity of 32 feet per second; at the end of the second second it will have a velocity of 64 feet per second; and generally at the end of any number of seconds its velocity will be 32, and the rate of increase of velocity (acceleration) is 32 feet per second, all of which has been previously explained. It is found convenient to call this acceleration gravity — it is inaccurately called the force of gravity, it varies at different places on the earth. It is usual to designate the acceleration by the letter g, and we speak of the g, or gravity, of the place. This seems to cover the point of inquiry completely.

The subject of specific gravity is a far-reaching one, and includes the testing of liquors for revenue purposes and many other things of a scientific nature; but when we speak of specific gravity in an ordinary way we mean the comparative weight, bulk for bulk, of water at a certain temperature. The specific gravity of a substance like coal can be ascertained experimentally. By means of a specially adapted and delicate balance, the sample of coal is first weighed in the ordinary way, after which it must be weighed suspended in a vessel of water. Weighed in water, it will be found the coal does not weigh so much. If the loss of weight, or the difference between the first and second weighings be taken, and the first weighing divided by this loss of weight, we obtain the specific gravity of coal. For example, suppose a sample of coal weighs in the ordinary way 20 ounces, and in the water only four ounces, showing a loss of weight of 16 ounces. Divide 20 by 16, and we get the specific gravity of the sample of coal, viz., 1.25.

The use of specific gravity is of great importance in mining, with regard to analysis of the minerals worked, for with a class of coal having the same relative composition, qualities, and calorific power per ton of coal employed for different purposes, yet having a higher specific gravity, the room required for storage or transport will be less. This is an important factor, where there is limited space, as in depots and naval vessels. It is also employed in the arts and industries for many purposes, and is particularly useful to workers in precious metals, as the amount of alloy or baser metal may be determined by it that have been used in the manufacture of jewellery, plate, and similar articles.

To put it briefly: Specific gravity is the ratio of the heaviness of any substance to that of water. The specific gravity of water is taken as unity, and that of any other substance is expressed as a decimal. Tables of the weight and specific gravity of substances can be found in any good hand-book of engineering.

HOW TO ADJUST SEWING MACHINES.

Sewing machines often get out of order, and it is not always that an expert is at hand to adjust them, so a few general observations on the subject of these household machines may prove useful and interesting to every one who is at all mechanically inclined.

There are several distinct types of machines, but we shall confine our remarks to the Singer vibrating shuttle, the hook shuttle types, and one or two others. To secure a perfect stitch in the vibrating shuttle machine, and to keep it from puckering thin goods, such as Japanese silks, muslins, and voiles, though possible, is difficult. Success depends entirely on the careful fitting of parts and the skilful adjustment of the machine to the particular fabric. In the first place, it is essential that a machine should work quite freely, a point not of such great importance if it is used for rougher classes of work.

Machines used for domestic purposes, like the V. S. (vibrating shuttle), often stand unused for weeks together, so that the oil thickens and makes a machine run somewhat heavily and unevenly. This may indirectly affect the regularity of the tension, especially with thin goods. Therefore, it is important to keep a machine clean and regularly oiled. Important parts are often overlooked during the operation; in fact, many users of machines do not know how nor where to oil one properly. Therefore Figs. 79 and 80 will be helpful, as they show the location of oil holes and parts to be oiled, and the illustrations will serve as a guide to other machines. In these figures, it will be seen that there are a number of parts to oil which could very easily be overlooked. When a machine has been unworked for a length of time, the application of a little paraffin will cleanse the parts which should afterwards be oiled thoroughly with a good quality of machine

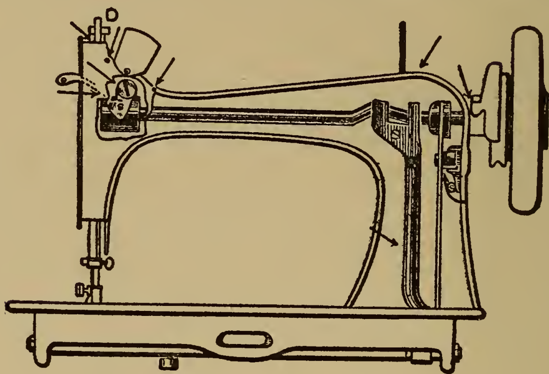


Fig. 79. Section showing oil holes

oil. The shuttle raceway, where the shuttle works, should be wiped out with an oily rag. Any lint or dirt which has accumulated inside the shuttle at the nose end should be withdrawn, as such might retard the unwinding of the bobbin. It is imperative that the cotton should pull evenly, that is, free from jerks; this refers to the upper as well as to the lower tension.

For silk and similar materials, best results can be obtained if fine cottons are used. Numbers 60, 70, or 80 would be preferable to No. 40. A good quality of fine silk is even better. It must be remembered that when working on thin silk, say two thicknesses, a coarse cotton cannot be locked centrally. Fine cotton will need a fine needle, which necessitates a fine hole needle plate.

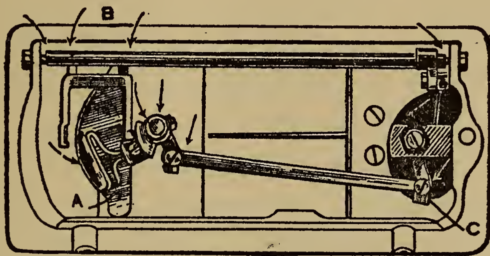


Fig. 80. Action of shuttle in the race

If, after the foregoing points have been attended to, the machine runs easily, the parts fit properly, there is no end play to the upper shaft and the cottons pull evenly, yet the tensions are erratic, attention should be given to the loop as it draws off the shuttle heel. In machines of the C. B., O. S., and especially the V. S. class, there is a tendency for the loop to hang on the heel of the carrier, or to become trapped between the shuttle and the carrier heel. In the two former types of machines, the heel of the carrier should be rounded so as to induce the cotton to pass off as freely as possible. Sometimes it is necessary to time the shuttle a little later, that is, put the carrier back a little to allow the loop to draw off more in a line with the hole in the needle plate.

In V. S. machines the carrier is already rounded off at the heel. By referring to Fig. 80, the action of the shuttle in the raceway can be seen, which is from A to B. The shuttle, having just entered the loop, is about to move to B. This movement can be regulated by an eccentric screw and nut (Fig. 80). When a machine has been taken to pieces and cleaned, this screw is not always replaced to the best advantage. If the shuttle moves too much toward B, the loop is carried by the heel of the carrier, and, at the same time, the shuttle cotton, by bearing tightly on the needle plate, pulls the shuttle toward the carrier heel, thus making it difficult for the loop to release itself. More tension is applied, perhaps more pressure is put on the take-up spring, yet the uneven tension is not overcome, and owing to the softness of the fabric, it is drawn up or puckered. The remedy is to turn the screw C (Fig. 80), until the carrier is in a position to allow the loop a free exit.

For such soft materials as mentioned it may be necessary to slacken both tensions. It should be remembered that the upper tension is generally somewhat tighter than the under one, and this should be a guide to the adjustment of the latter, according to the fabrics to be stitched.

To prevent puckering when the tensions are correct, reduce the pressure of the foot by loosening the thumbscrew D (Fig. 79). Use a small size stitch — set the feed so that the teeth are just above the needle plate. Do not have the teeth too sharp, and if necessary, rub off the knife edge with F emery-cloth. Make the foot to bear squarely on the needle plate, and the feed square to the presser foot. Round off all sharp edges from the under side of the foot, especially the back edge. Special feeders are made for silk goods in machines used for factory work, which overcome the difficulty of puckering.

By attention to the foregoing instructions, a machine should work easily, especially if the fabric is slightly pulled from behind the pressure foot.

In C. B. machines, attention should also be given to the loop as it passes over the bobbin case and off the stop pin, it being necessary sometimes to round off the latter. If the tension spring screw projects too high or is rough, it may occasionally catch the cotton.

The machine shown at Fig. 81 is of the "Rotary Hook"—zigzag type. Its uses are similar to that of the oscillating shuttle type, but its construction is rather more complicated.

The machine may be said to consist chiefly of an upper and a lower shaft, each having two cranks. In the vertical portion of the arm are two links which connect the shafts, causing them to work in unison with each other. The upper shaft gives

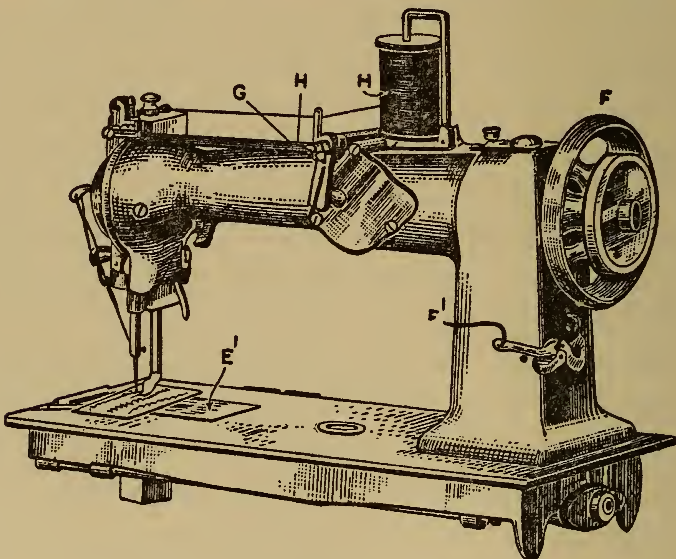


Fig. 81. Rotary hook—Zigzag type

motion by means of a cam and link to the needle bar and take-up lever; while the lower shaft, by means of three gear wheels, gives the rotary movement to the hook or shuttle, and by an eccentric cam and segment lever the necessary motion is given to the feed or stitch mechanism. Figure 82 shows the rocking frame into which the needle bar is fitted at A and B, while, at C and D, it is recessed to receive the taper ends of two screws, which pass through the face plate end of the machine arm. These screws are held secure by lock nuts, so screwed in as to allow the frame to rock freely. A ball-headed screw is fitted at E, to which is fastened a connection rod extending to a switch lever situated about the centre of the arm. This lever, by means of a cam movement, gives the vibrating motion to the needle bar, which can be regulated according to the relative position of the connection rod and lever. When the rod is at the bottom of the lever, a wide throw is obtained. By raising the rod a narrower throw is given, and if raised to the position shown in Fig. 81 no vibration will be given to the needle bar. The needle bar can be raised or lowered by loosening the screw that secures it to its link collar, which will be better seen by removing the face plate. Most needle bars have two marks upon them, and they should be set as follows: Remove the face plate, and turn the

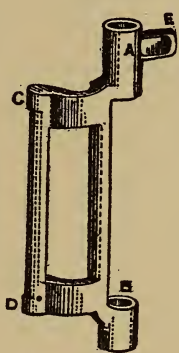


Fig. 82. Rocking frame

hand wheel F (Fig. 81) toward you until the needle bar link has reached its lowest point of travel.

Loosen the set screw of the needle bar collar, and set the needle bar so that its highest mark will be just level with the bottom of the rocking frame (Fig. 82). Then tighten the set screw, give the hand wheel a spin round, and again examine the position of the mark when the needle bar has reached its lowest point of travel, to make sure that no mistake has been made. Of course, it is necessary when parts are badly worn to set the needle bar a trifle lower, but this can be done after the foregoing rule has been adopted and proved a failure. In case of any unnecessary looseness in the middle bar or any of its connecting parts, they should be taken out and new parts fitted. The position of the needle may be altered to the right or left by loosening the screws G and H (Fig. 81), and adjusting the connection rod. Care should be taken not to set the connection rod too low down, or the needle may strike on the needle plate and cause trouble.

Fig. 83 shows the face plate removed from the machine arm, A being a tension release lever. When the presser foot is lifted to its highest position, the end of the lever goes between the tension disc, thus releasing all tension, so that materials can be taken from the machine without drawing slack cotton, or putting any unnecessary strain on the needle. When the presser foot is lowered, this lever should withdraw itself from the disc, thus allowing the proper tension to be put on the cotton. In some machines the withdrawal of this lever depends on a stud screw, fastened to the needle bar and projecting through the face plate. In the downward course of the needle bar this stud screw touches a spring, and causes the lever to trip backward. Should the spring become strained, or the stud screw become raised up a little, the release lever may remain between the disc and cause trouble. Sometimes it is necessary to bend the lever forward or backward to ensure its proper action.

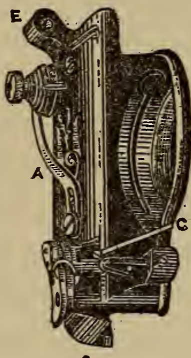


Fig. 83. Section showing face plate removed from machine

The hook or shuttle is rotary in motion. The hook (Fig. 84), is fitted to a ring, which is fixed to the hook guide (Fig. 85) by means of three small pins, and it is prevented from falling out by a steel cap secured with two screws and springs. The hook is carried round by a driver (Fig. 86). Much depends on the hook, driver, and hook guide, so that a little detailed information is necessary. The hook driver must be a perfect fit in its bearings and free from sharp places where it comes in contact with the hook. The body of this driver is generally hardened, but the prong J (Fig. 86) is left soft so that it can be bent to meet requirements. When a machine is stitching, the hook driver rotates, and the prong J draws a given amount of slack cotton from the bobbin case. The farther this prong stands out, the more slack cotton it draws off the bobbin. The prong may be bent inward, as shown by the dotted lines, but care must be taken not to drive it in so far as to allow the needle when descending, to strike on it, or to deviate from its true vertical position. Points K and L fit between the nose and neck of the hook, while M comes against the heel. The hook is driven alternately by points K and M.

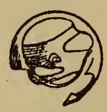


Fig. 84. Hook ring

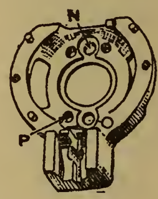


Fig. 85. Hook guide

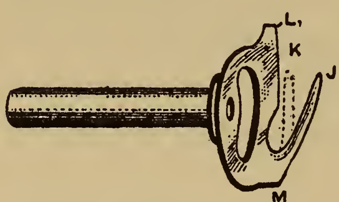


Fig. 86. Hook driver

When the hook is just entering the loop formed by the needle, it (the hook) is being driven by the driver wheel or M, and an opening is being made between point K and the hook nose for the free passage of the cotton. When the loop is being drawn off the hook by the takeup lever, the hook is driven by point K, and an opening is made between M and the heel of the hook for the exit of the cotton. There must always be sufficient clearance at points K, L, and M for the cotton or thread being used. As the heel of the driver M wears, the space at K will be reduced. Sometimes this can be remedied by bending the driver in at M, by giving it a blow with a hammer, placing a brass punch at M, but this should not be attempted if the driver is very hard. There is a means of adjustment provided in the hook guide (Fig. 85). This part is held in position by two set screws N and O. At the left of O is a small adjusting screw P. Supposing there is not sufficient space at point K (Fig. 86), for the cotton to pass, loosen the screw O (Fig. 85), and slightly tighten the screw P. This will tilt the hook guide and give more space. Should the screw P be turned in too far, the point L (Fig. 86), will be brought in contact with the narrow part of the hook near the neck, and this will impede its freedom, so that if allowed to run at much speed, the probable result will be the breaking of the hook off at the neck. This should be noticed in fitting a new hook, as the adjusting screw P (Fig. 85) will in all probability require loosening. The screws at N and O, however, must be kept quite tight. At each side of N is a small screw hole. The screws which fit here are for adjusting the hook closer to or farther from the needle. As an example, supposing a very fine needle has been used in the machine, and it is now required to take a very coarse one on account of the thick material to be stitched, the hook in all probability would strike the needle, indicating that the hook guide requires moving back a little. To do this, loosen the two small adjusting screws and tighten the set screw in N. Afterward try the set screw in O to ascertain if it is secure. In this way, the hook is thrown farther from the needle. Loosening the screw at N, and tightening the adjusting screws, will bring the hook forward. If the hook stands too far from the needle, it is likely to miss the loop. The hook nose must be well pointed and perfectly smooth, roughness or sharpness removed from any part of the hook over which the cotton passes during the formation of a stitch.

Hook rings are made in three sizes, numbers 1, 2, and 3. Number 1 is for a new hook, numbers 2 and 3 are for fitting as the hook wears. No matter what size of ring is used the hook must have perfect freedom. Sometimes the three pins in the guide draw the ring, and cause the hook to bind. It is best, therefore, to fix the ring to the guide, and then test the hook. If it is at all tight, grind it on the rim by means of an emery wheel or a grindstone. If neither is available, use number 1 or number 1½ emery cloth first, finishing with number 00 emery cloth. It is better to have the hook a little loose, even sluggish, than too tight. The timing of the hook will be dealt with later on.

The bobbin case (Fig. 87), fixes to a stud in the centre of the hook. It is held in position, that is, kept from revolving with the hook, by means of a stop pin, Q, fitting between a holder. The tension is obtained by a spring, R, which is regulated by turning a small screw, S, to the right to tighten and to the left to loosen. Fig. 88 shows the bobbin case in position, with the holder raised ready for taking it out of the machine. Fig. 89 shows the bobbin in position in the bobbin case and method

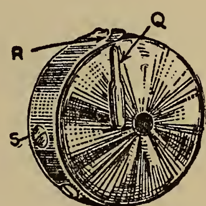


Fig. 87. Bobbin case

of threading, and Fig. 91, the direction the cotton should draw off the bobbin when it is in the machine.

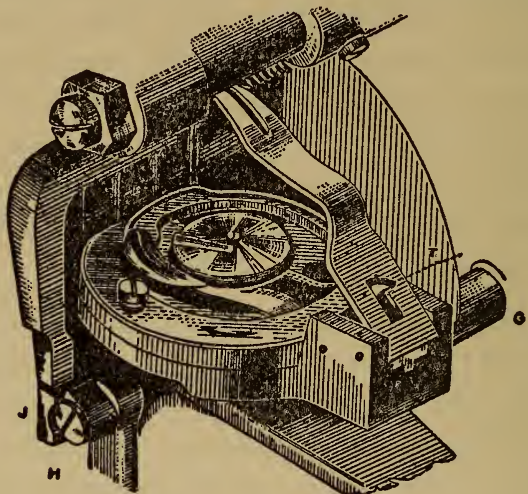


Fig. 88. Bobbin case in position

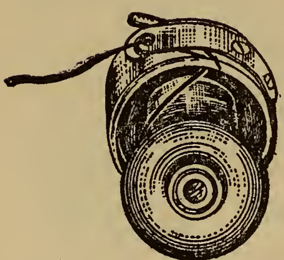


Fig. 89. Bobbin in position in bobbin case — Method of threading

It will be noticed that the cotton pulls in the opposite direction to which the hook travels, as shown by an arrow in Fig. 88. The bobbin case holder (Fig. 91), should prevent the bobbin case from revolving with the hook. As parts wear, the bobbin case is liable to slip past the holder, causing the cotton to be stranded and broken. When such is the case the holder should be bent as shown by (Fig. 92), but it must not fit so tightly against the bobbin case as to cause the cotton to become trapped. The holder is held rigid by means of a catch and spring T (Fig. 88). Should the catch or holder become worn, fit new parts by driving out the pins U and V. Any sharpness or roughness on the forked part of the holder should be removed. Should the stop pin Q (Fig. 87) become loose, it should be soldered and well cleaned with an emery cloth. The centre tube of the bobbin case should also be kept quite firm. Should it become loose, place it over some hard substance, rivet it until tight, and thoroughly smooth with very fine emery cloth.

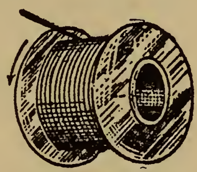
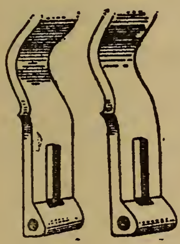


Fig. 90. Direction cotton should draw off



Figs. 91 and 92. Bobbin case holders

The take up spring (Fig. 93) is attached to the face plate, and is shown in position in Fig. 83. Replace a new one as follows: First take out the set screw W (Fig. 93), and remove the complete thread controller from the face plate. Then take out the screw and withdraw the old spring. Place the ring part of the new spring in the recess between plate Y and back plate Z, and replace the screw X, being careful not to get the spring fastened under the screw head. This done, fix the spring and other parts on the face plate. A small barrel with a slot in it receives the coiled portion of the spring. See that the part of the spring that is turned in enters the slot in the barrel, then replace the screw W, but before tightening this screw, see that the hooked part of the spring A′ rests on the regulator B′, which determines the amount of action given to the take-up spring. By raising it, less action is given. The amount of pressure on the spring

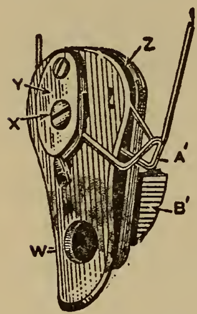
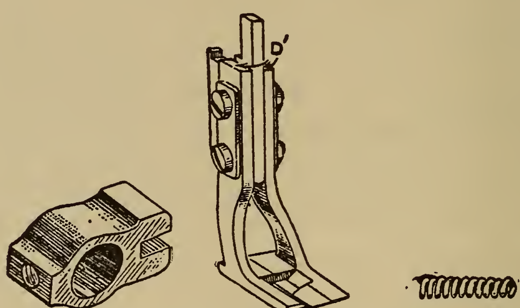


Fig. 93. Take-up spring



Figs. 94, 95, 96. Presser foot with details

is regulated by adjusting the barrel in the face plate. Take off the face plate, loosen the screw C

(Fig. 83), fix a screwdriver in the rear of the barrel (seen inside the face plate), turn it toward you for more pressure, and backward for less and tighten the set screw C.

Presser feet are made solid for ordinary purposes, although alternating feet can be fitted when desired. Figs. 94, 95, and 96 show a pressure foot, collar, and spring. To fix this foot, remove the ordinary presser foot, turn the foot bar round by loosening the set screw, so that the groove made for the reception of the presser foot is directly behind the needle. Put on the collar (Fig. 95), then turn the foot (Fig. 94), and screw it in position. Next place the spring each side at the points D1 (Fig. 94), press down the collar (Fig. 95), and secure it by its set screw. The springs will act on each half of the foot, and keep them firm, though the material be uneven. The foot is particularly useful when overseaming a hem or the top band of a lady's boot, etc. To time the hook and needle, raise the connection rod so as to produce no throw, and tighten the screw as in Fig. 81. Then take off the needle plate and remove the slide E1 (Fig. 81) under which will be seen a crank and screws.

Now turn the machine back as at Fig. 88, lift up the bobbin case holder by pressing the catch T, and remove the bobbin case. Take off the hook guide cap by removing the two screws. Turn the hand wheel F (Fig. 81), toward you, until the needle bar has descended to its lowest point of travel, and loosen the crank screw farthest from you. Having done this, continue turning the hand wheel until the needle bar has risen. With the lowest mark level with the rocking frame casting, at this point, examine the hook, the point of which should be just up to the needle. If otherwise, loosen the other screw in the crank under the plate E1 (Fig. 81). Be sure the needle bar mark is level with the rocking frame, place the hook with its point just up to the needle, and tighten the crank set screw, being careful to have no end play to the short shaft. Again examine the needle bar and hook and if in proper time finally secure crank set screws and replace the fittings previously removed. Thread the machine as indicated (Fig. 81). Set the needle as high in the bar as it will go, with the long groove facing the operator, and thread the needle from the long groove side. The stitch regulator will be found at F′ (Fig. 81). The raising of it will shorten and the lowering of it will lengthen the stitch. The feed should be set about one thirty-second of an inch above the needle plate when at its highest point. To raise the feed, turn the machine back as in Fig. 88. Near to the part G1 (Fig. 88) will be found a large set screw. Loosen it and press the lever H1 (Fig. 88) upward raising the feed bar J1 as high as required, and tighten the set screw at G1 firmly. To remove the feed for cleaning and sharpening, take off the needle plate, under which will be seen two feed set screws. By unscrewing these, the feed can be lifted out.

One of the modern machines on the market is the Wheeler and Wilson, known as the Number 61, which is of rotary hook principle. The hook forms part of the under shaft, somewhat similar to that known as the D9 W and W. This hook and shaft revolves in two long bearings, and is held in position by a fluted wheel, which forms a collar at the right-hand end; thus when set properly no end play is permitted. This is an advantage over the boat-shaped shuttle machine. In the latter, the shuttle rocks about, becomes worn on the surface, often blunt pointed by striking the needle. As it wears, it becomes loose in the carrier, thus giving it freedom to roll away from or toward the needle, as well as making its action with relation to the needle very uncertain; and on account of the number of little loosenesses in fittings that this uncontrolled shuttle produces, missed stitches are frequent, and difficult to remedy, unless a number of new fittings are obtained or old ones repaired.

If there is any alteration required in the time of the rotary hook referred to, it can be made to the smallest fractional part of an inch very quickly and easily, and the movement can be relied on. The shaft to which it is secured is positive in its action (no variable motion), and at every stitch will meet the needle at exactly the same spot. This is an improvement over the boat-shaped shuttle, which has to have a certain amount of play or slackness to allow the loop to extricate itself; and this slackness increases as the machine is worked, so that the shuttle action often becomes very erratic.

Sometimes a carrier becomes sprained at one end, thus allowing the shuttle too much freedom. If at the heel end, the carrier should be removed and placed in a vise (heel uppermost). The heel should be given a light blow with a hammer, thus bending it into correct position, but it must never be allowed to incline toward the shuttle; it should stand perfectly square, and have the upper corners rounded off. If inclined toward the shuttle, the loop may occasionally hang on the heel, and cause an irregular tension.

In some machines the bobbin case holder (Fig. 97) rests on the casting seen in Fig. 81. It is secured by a large set screw, D (Fig. 97). For general use, this screw should be adjusted to allow number 40 cotton to pass freely over the bobbin case. The holder should not be removed, except when adjustment or repair is needed. The vertical portion is hinged to the base, and is kept upright by a lock spring and stud. If the spring is pressed from the stud, the vertical or ring part can be drawn back for placing in or taking out the bobbin case. The face of this portion must be perfectly square with the bottom of the base, otherwise it may cause considerable trouble. A slight adjustment can be made by loosening the two screws and moving the lock spring. A set square, E, should be used for testing the accuracy of this part as shown (Fig. 98), F representing the bobbin case holder.

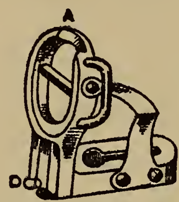


Fig. 97. Bobbin case holder

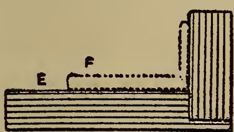


Fig. 98. Set square

The thread controller is similar in design to several others, but its movement is regulated by a small lever (Fig. 99) which receives its motion from a link attached to the foot bar bracket set screw, and this may be seen through a hole in the face plate. At G (Fig. 99), this lever engages with a stop washer located behind the thread controller plate. The washer is recessed to form a stop, at the same time to give sufficient clearance for the action of the spring; thus as the foot bar rises and falls, so does the thread controller spring. It is a common practice when cleaning a machine to remove the face plate, thus detaching the link referred to, and not connecting it again when replacing the face plate. From this, trouble arises. The tension pulley should be placed on its stud, the large boss being toward the face plate.

Fig. 99. Lever

Thread a machine as follows: From the reel pin to nipper F (Fig. 81), round tension pulley G as the arrow indicates, down and into thread controller H up to take up lever, threading over the roll and through the slot from the top of lever, then down the thread guide J, into guide K, and through the needle eye from right to left.

In the ordinary boat-shaped shuttle, the looping up of the thread is not difficult. The needle, as it descends, enters an opening or cavity in the carrier, one side of which forms a support for the needle and guards it from contact with the shuttle point. Now, it is important that there be clearance for the needle. If the carrier stands so prominent as to spring the needle out of its true vertical line it will carry it away from the shuttle, and give the latter a chance to miss the loop.

Then there are carriers and drivers of varying heights. Those of the raised kind are preferable, if properly fitted. By "raised" is meant that they are higher, so as to form a better guard for the needle, as previously referred to (Fig. 100 A, in which E indicates the portion of raised carrier, F the shuttle point, and G the needle). But sometimes they are too high, and permit the needle eye to be buried in the carrier, thus preventing the proper formation of the loop. This can be so bad as to cause very frequent missing; or it may be of such a slight character as to cause a miss-stitch only now and then. Occasionally, a needle bar has to be lowered, and that is sufficient to cause

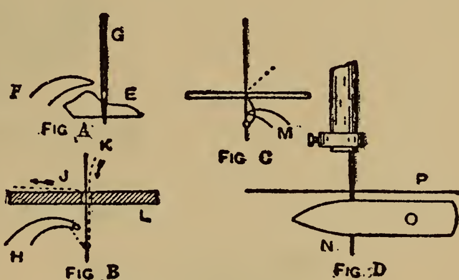


Fig. 100 A, B, C, D. Carriers and drivers

the same fault. The eye of the needle should always be about one thirty-second of an inch above the upper edge of the carrier, and the latter should be shaped so as to allow that amount of clearance the whole of the time the needle is rising to form the loop, until the shuttle point has well entered the same. Fig. 100 B shows how a carrier is hollowed to give the necessary clearance to the needle eye.

When a machine is reasonably tight in all parts, gauges and setting marks may be adhered to for

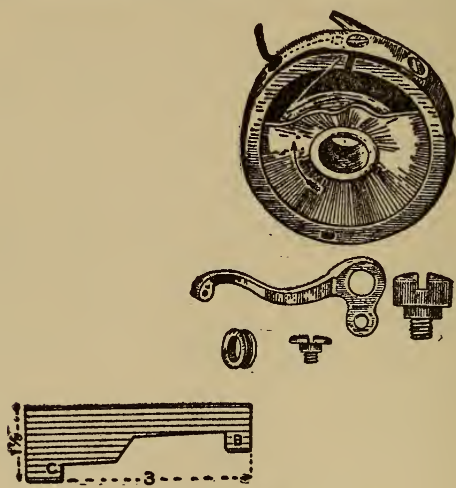


Fig. 101. Sewing machine items

the preliminary adjustments; and then if the machine works erratically, other adjustments must be made. Where no marks or gauges are furnished for the adjustment of the needle bar, it should be so set as to allow the shuttle or hook to enter the bold part of the loop formed from the needle. A good rule is to set the needle bar so that the needle-eye is about 1/32 inch below the point of the shuttle M (Fig. 100 C) when the latter is up to the centre of the needle groove. But this may have to be varied from 1/64-inch to 3/32-inch. In boat-shaped and similar shuttle machines, a good rule is to set the needle so that the eye N will pass just below the lower side of the shuttle O as the latter is passing through the loop as in Fig. 100D, P, indicating the level of the bed plate.

II

MECHANICAL MOVEMENTS

WHAT is meant by this term is that these devices are intended for the transmission of motion. Motion in mechanics may be simple or compound. Simple motions are those of straight translation, which if of indefinite duration must be reciprocating, or what is called oscillating or helical.

Compound motions consist of combinations of any of the simple motions. Perpetual motion is an incessant motion conceived to be attainable by a machine supplying its own motive forces independently of any action from without, or which has within itself the means, when once set in motion, of continuing its motion perpetually, or until worn out, without any new application of external force. The machine by means of which it has been attempted, or supposed possible to produce such motion, is an invention much sought after, but physically impossible.

The illustrations herewith exhibit a number of devices of various kinds, well known to the practical mechanician and professional engineer, and usually called mechanical movements. It is estimated there are no less than 1,500 of these movements doing service at the present day; but many of them are, of course, quite complex, and difficult to master. In this book, I show about one hundred of the simplest sort, or those in common use. Their usefulness will at once be appreciated if we refer to Fig. 102, which shows a machine for grinding or breaking up substances within its capacity. It contains within itself the true principle of the little mill used to grind coffee. The word "grind" in this connection is scarcely the right one, as the mill rather "crushes" or breaks up, than grinds. You will notice coffee, ready for use, is coarse and unlike flour in texture, the latter being "ground" fine and smooth. In grinding, the abrading surfaces are brought very much closer together than in the breaking or crushing processes. In a coffee mill, the berries or grains drop into a vacancy, left between the revolving cone and the walls of the mill. The vacancy between the walls and the cone is a little less at the bottom where the crushed coffee is discharged, and this enables the small and large grounds to fall into the drawer. The detailed plan in illustration (Fig. 102) shows a mill complete, as well as the various parts. It will be noticed that the cone (Fig. 5), is corrugated or grooved as shown (Fig. 4). Figs. 6 and 7 show sections of lining at B and C (Fig. 3). A shows the hopper into which the coffee berries are placed before grinding. Figure 9 shows the crank detached, and Figs. 8 and 10 show the remaining parts of

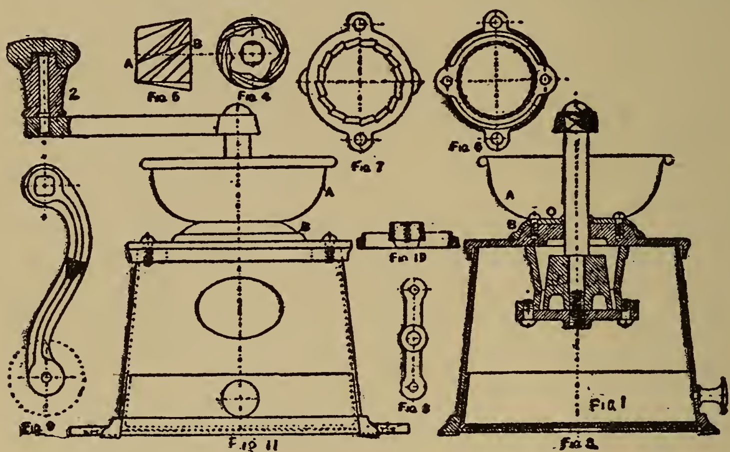


Fig. 102. Coffee mill and details

the machine, while Figs. 1 and 2 show the handle and drawer. The latter is to receive the ground or crushed coffee after it has gone through the mill. Further description is unnecessary if we take for example the movement represented at Fig. 150, which is a sort of ball-bearing motion, only instead of small balls wheels are used. Besides being made use of in bicycles in small balls, it is used as depicted for "hanging" grindstones, and for many other similar purposes.

The device also shown at Fig. 139, is one in common use. It is a modification of the sprocket wheel on the bicycle. Many of the devices shown herewith are rarely noticed because of our familiarity with them.

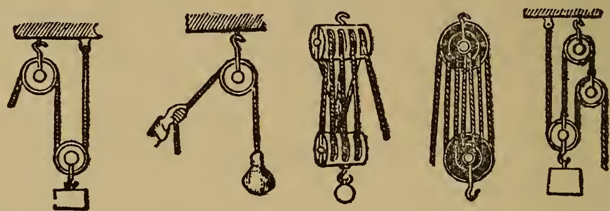
The action of pumps, the working of pistons, the changing of motion, and many other things are shown and explained in the little illustrations given in these descriptions, which do not pretend to be exhaustive, or even full.

Fig. 103. In this the lower pulley is movable. One end of the rope being fixed, the other has to move twice as fast as the weight, and a corresponding gain of power is consequently effected.

Fig. 104 is a simple pulley used for lifting weights. In this the power must be equal to the weight to obtain equilibrium.

Fig. 105. Blocks and tackle. The power obtained by this contrivance is calculated as follows: Divide the weight by double the number of pulleys in the lower block; the quotient is the power required to balance the weight.

Fig. 106 represents what are known as "White's pulley's, which can be made with separate loose pulley; or a series of grooves can be cut in a solid block, the diameters being made in proportion to the speed of the rope; that is, 1, 3, and 5 for one block, and 2, 4, and 6 for the other. Power as 1 to 7.



Figs. 103, 104, 105, 106, 107. Various phases of block and tackle

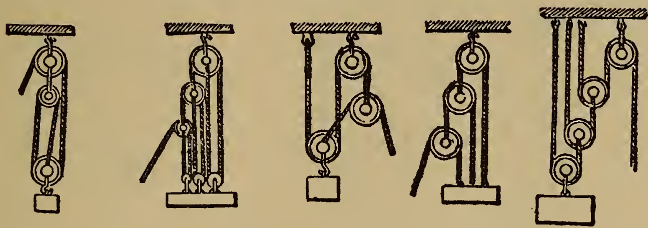
Figs. 107-108 are what are known as Spanish bartons.

Fig. 108 is a combination of two fixed and one movable pulley.

Figs. 111-113 are different arrangements of pulleys. The following rule applies to these: In a system of pulleys where each is embraced by a cord attached to one end of a fixed point, and at the other to the centre of the movable pulley, the effect of the whole will be the number 2 multiplied by itself as many times as there are movable pulleys in the system.

Fig. 114. Endless chain for maintaining power on going barrel, to keep a clock going while winding,

as during that operation the action of the weight or main-spring is taken off the barrel. The wheel



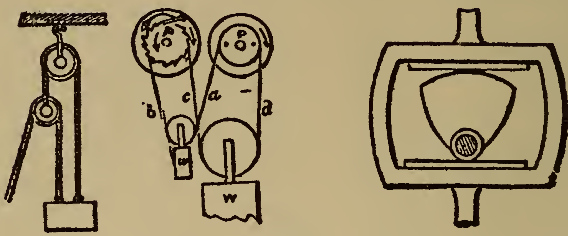
Figs. 108, 109, 110, 111, 112. Other combinations of blocks and pulleys

to the right is the going wheel, and that to the left the striking wheel. P is a pulley fixed to the great wheel of the going part, and roughened to prevent a rope or chain hung over it from slipping. A similar pulley rides on another arbour, *p*, which may be the arbour of the great wheel of the striking part, attached by a ratchet and click to that wheel, or to the clock frame if there is no striking part. The weights are hung as may be seen, the small one being only large enough to keep the rope or chain on the pulleys. If the part *b* of the rope or chain is pulled down, the ratchet-pulley runs under the click, and the great weight is pulled up by *c*, without taking its pressure off the going wheel at all.

Fig. 115. Triangular eccentric, giving an intermittent reciprocating rectilinear motion, often used for the valve motion of steam-engines.

Fig. 116. Ordinary crank-motion.

Fig. 117. In this, rotary motion is imparted to



Figs. 113, 114, 115. Blocks and rocker

the wheel by the rotation of the screw, or rectilinear motion of the slide by the rotation of the wheel. Used in screw cutting and slide lathes.

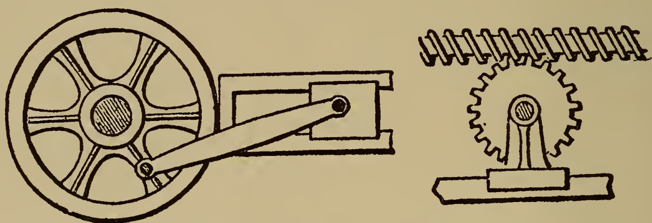
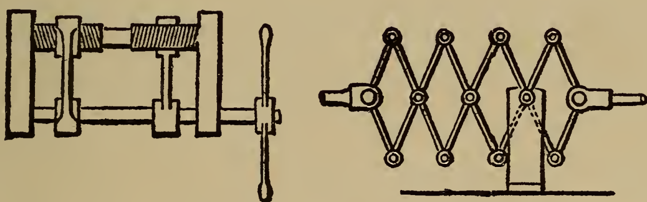

Figs. 116, 117. Crank and rotary motion

Fig. 118. Uniform circular into uniform rectilinear motion; used in spooling frames for leading or guiding the thread on to the spools. The roller is divided into two parts, each having a fine screw-thread cut upon it, one a right and the other a left-handed screw. The spindle, parallel with the roller, has arms which carry two half nuts, fitting to the

screw, one over the other under the roller. When one half nut is in, the other is out of gear. By pressing the lever to the right or left the rod is made to traverse in either direction.

Fig. 119. A system of crossed levers, termed "lazy tongs." A short, alternating rectilinear motion of rod at the right will give a similar, but much greater motion to the rod at the left. It is frequently used in children's toys. It has been applied to machines for raising sunken vessels; also applied to ship pumps three quarters of a century ago.



Figs. 118, 119. Rectilinear motion

Fig. 120. Centrifugal governor for steam engines. The central spindle and attached arms and balls are driven from the engine by the bevel gears at the top, and the balls fly out from the centre by centrifugal force. If the speed of the engine increases, the balls fly out from the centre, raise the slide at the bottom, and thereby reduce the open-

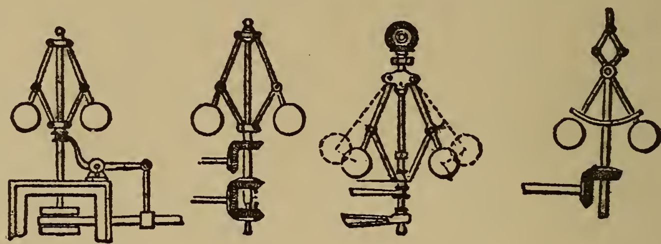
ing of the regulating valve, which is connected with the slide. A diminution of speed produces an opposite effect.

Fig. 121. Water-wheel governor acting on the same principle as Fig. 120, but by different means. The governor is driven by the top horizontal shaft and bevel gears, and the lower gears control the rise and fall of the shuttle or gate over or through which the water flows to the wheel. The action is as follows: The two bevel gears on the lower part of the centre spindle, which are furnished with studs, are fitted loosely to the spindle, and remain at rest so long as the governor has a proper velocity; but immediately the velocity increases, the balls flying farther out, draw up the pin, which is attached to a loose sleeve which slides up and down the spindle, and this pin, coming in contact with the stud on the upper bevel gear, causes that gear to rotate with the spindle, and to give motion to the lower horizontal shaft in such a direction as to make it raise the shuttle or gate, and so reduce the quantity of water passing to the wheel. On the contrary, if the speed of the governor decreases below that required, the pin falls and gives motion to the lower bevel gear, which drives the horizontal shaft in the opposite direction, and produces a contrary effect.

Fig. 122. Another arrangement for a water-wheel governor. In this the governor controls the shuttle or gate by means of the cranked lever, which acts on the strap or belt in the following manner: The belt runs on one of three pulleys, the middle one of which is loose on the governor spindle, and the upper and lower ones fast. When the governor is running at the proper speed the belt is on the loose pulley, as shown; but when the speed increases, the belt is thrown on the lower pulley, and thereby caused to act upon suitable gearing for raising the gate or shuttle and decreasing the supply of water. A reduction of the speed of the governor brings the belt on the upper pulley, which acts upon the gearing for producing an opposite effect on the shuttle or gate.

Fig. 123. Another form of steam-engine governor. Instead of the arms being connected with a slide working on a spindle, they cross each other, are elongated upward beyond the top, and connected with the valve-rod by two short links.

Figs. 124, 125. Diagonal catch and hand-gear used in large blowing and pumping engines. In Fig. 124 the lower steam valve and upper eduction valves are open, while the upper steam valve and lower eduction valve are shut; consequently the piston is ascending. In the ascent of the piston rod the lower handle will be struck by the projecting tappet, and being raised will become en-

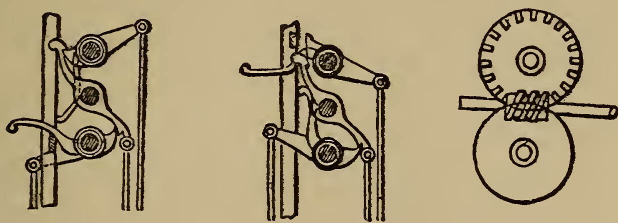


Figs. 120, 121, 122, 123. Governors for steam-engines

gaged by the catch, so as to shut the upper eduction and lower steam valves; at the same time the upper handle will be disengaged from the catch, the back weight will pull the handle up and open the upper steam and lower eduction valves, when the piston will consequently descend. Fig. 125 represents the position of the catches and handles when the piston is at the top of the cylinder. In going down, the tappet of the piston rod strikes the upper handle, and throws the catches and handles to the position shown in Fig. 124.

Fig. 126. A mode of driving a pair of feed rolls, the opposite surface of which require to move in the same direction. The two wheels are precisely similar, and both gear into the endless screw,

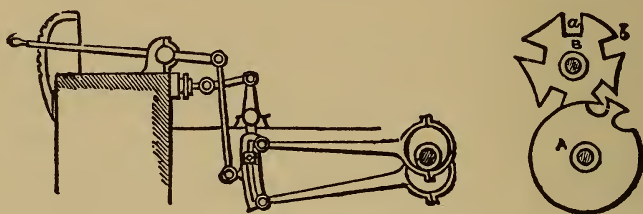
which is arranged between them. The teeth of one wheel only are visible, those of the other being on the back or side which is concealed from view.



Figs. 124, 125, 126. Valve Regulation and Feed Rolls

Fig. 127. Link-motion valve gear of a locomotive; two eccentrics are used for one valve, one for the forward and the other for the backward movement of the engine. The extremities of the eccentric rods are jointed to a curved slotted bar, or, as it is termed, a link, which can be raised or lowered by an arrangement of levers terminating in a handle, as shown. In the slot of the link is a slide and pin connected with an arrangement of levers terminating in the valve stem. The link, in moving with the action of the eccentrics, carries with it the slide, and thence motion is communicated to the valve. Suppose the link raised so that the slide is in the middle, then the link will oscillate on the pin of the slide, and consequently the valve will be at rest. If the link is moved so that the slide is at one of

the extremities, the whole throw of the eccentric connected with that extremity will be given to it, the valve and steam ports will be opened to the full, and it will only be toward the end of the stroke that they will be totally shut; consequently the steam will have been admitted to the cylinder during almost the entire length of each stroke. But if the slide is between the middle and the extremity of the slot, as shown in the figure, it receives only a



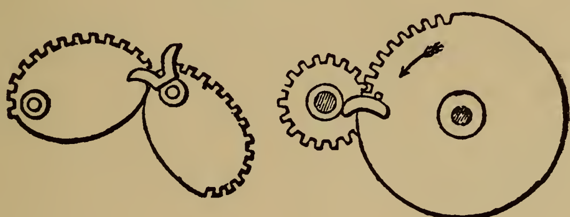
Figs. 127, 128. Link and other motions

part of the throw of the eccentric and the steam ports will only be partially opened, and quickly closed again, so that the admission of steam ceases some time before the termination of the stroke, and the steam is worked expansively. The nearer the slide is to the middle of the slot the greater will be the expansion, and vice versa.

Fig. 128 represents a mode of obtaining motion from rolling contact. The teeth are for making the motion continuous, or it would cease at the point of contact shown in the figure. The fork catch is to guide the teeth into proper contact.

Fig. 129. What is called the Geneva-stop, used in Swiss watches to limit the number of revolutions in winding-up; the convex curved part of the wheel serving as the stop.

Fig. 130. A continuous rotary motion of the large wheel gives an intermittent rotary motion to the pinion-shaft. The part of the pinion shown next the wheel is cut of the same curve as the plain portion of the circumference of the wheel, and therefore serves as a lock while the wheel makes a part of a revolution, and until the pin upon the wheel strikes the guide-piece upon the pinion, when the pinion-shaft commences another revolution.

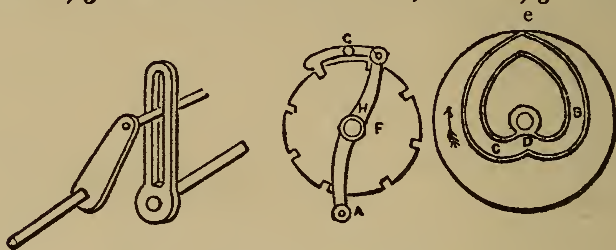


Figs. 129. 130. Stop and rotary motions

Fig. 131. The two crank-shafts are parallel in direction, but not in line with each other. The revolution of either will communicate motion to the other with a varying velocity, for the wrist of one

crank working in the slot of the other is continually changing its distance from the shaft of the latter.

Figs. 132 and 133. These are parts of the same movement, which has been used for giving the roller motion in wool-combing machines The roller to which the wheel F,(Fig. 132) is secured, is required to make ⅓ revolution backward, then ⅔ revolu-



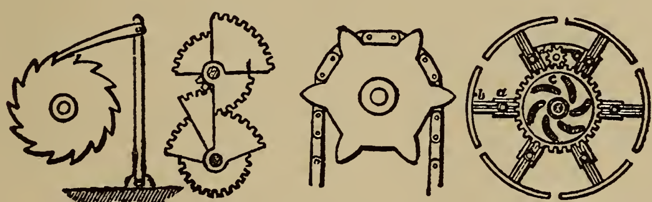
Figs. 131, 132, 133. Irregular Motions

tion forward, when it must stop until another length of combed fibre is ready for delivery. This is accomplished by the grooved heart-cam C, D, B, e, (Fig. 133) the stud working in the said groove; from C to D it moves the roller backward, and from D to e it moves it forward, the motion being transmitted through the catch G, to the notch wheel F, on the roller-shaft H. When the stud A arrives at the point e in the cam, a projection at the back of the wheel, which carries the cam, strikes the projecting piece on the catch G, and raises it out of the notch in the wheel F, so that while the stud is travelling in the cam from e to C, the catch is passing over the plain surface between the two notches in the wheel F, without imparting any motion; but when stud A arrives at the part C, the catch has dropped in another notch and is again ready to move wheel F and roller as required

Fig. 134. An arrangement for obtaining variable circular motion. The sectors are arranged on different planes, and the relative velocity changes according to the respective diameters of the sectors.

Fig. 135. Intermittent circular motion of the ratchet-wheel from vibratory motion of the arm carrying a pawl.

Figs. 136. This represents an expanding pulley. On turning pinion d to the right or left, a similar motion is imparted to wheel c, by means of curved slots cut therein, which thrust the studs



Figs. 135, 134, 137, 136. Movements of various kinds

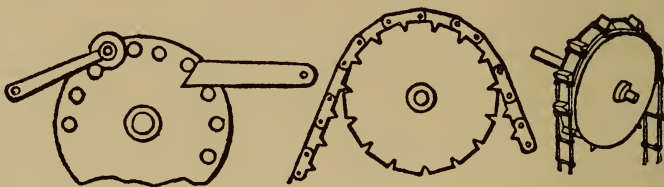
fastened to arms of pulley outward or inward, thus augmenting or diminishing the size of the pulley.

Fig. 137 represents a chain and chain pulley. The links being in different planes, spaces are left between them for the teeth of the pulley to enter.

Fig. 138. Another kind of chain and pulley.

Fig. 139. Another variety.

Fig. 140 shows two different kinds of stops for a lantern-wheel.

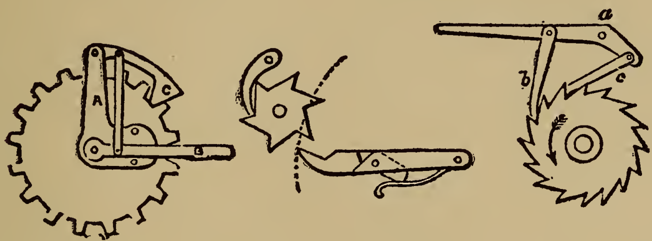


Figs. 140, 138, 139. Chain pulleys and lantern wheel

Fig. 141. Intermittent circular motion is imparted to the toothed wheel by vibrating the arm B. When the arm B is lifted, the pawl C is raised from between the teeth of the wheel, and travelling backward over the circumference again drops between two teeth on lowering the arm, and draws with it the wheel.

Fig. 142. The oscillating of the tappet-arm produces an intermittent rotary motion of the ratchet-wheel. The small spring at the bottom of the tappet arm keeps the tappet in the position shown in the drawing, as the arm rises, yet allows it to pass the teeth on the return motion.

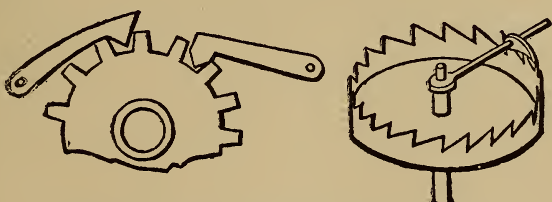
Fig. 143. A nearly continuous circular motion is imparted to the ratchet-wheel on vibrating the lever *a* to which the two pawls *b* and *c* are attached.



Figs. 141, 142, 143. Intermittent circular motion

Fig. 144. An arrangement of stops for a spur-gear.

Fig. 145. A reciprocating circular motion of the top arm makes its attached pawl produce an intermittent circular motion of the crown-ratchet, or ray-wheel.

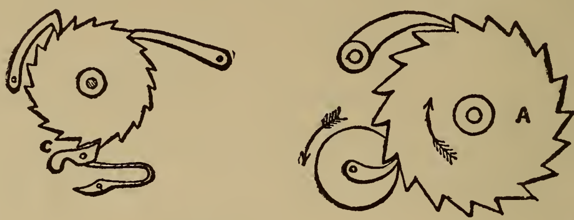


Figs. 144, 145. Intermittent circular motion

Fig. 146 represents varieties of stops for ratchet-wheel.

Fig. 147. Intermittent circular motion is im-

parted to the wheel A by the continuous circular motion of the smaller wheel with one tooth.

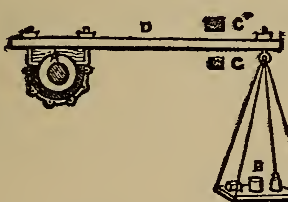


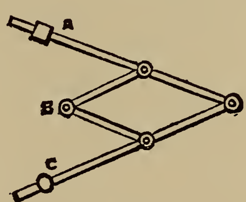
Figs. 146, 147. Ratchet motion

Fig. 148. A dynamometer, or instrument used for ascertaining the amount of useful effect given out by any motive power. It is used as follows: A is a smoothly turned pulley, secured on a shaft as near as possible to the motive power. Two blocks of wood are fitted to this pulley, or one block of wood and a series of straps fastened to a band or chain, as in the drawing, instead of a common block. The blocks, or block and straps, are so arranged that they may be made to bite or press upon the pulley by means of the screws and nuts on the top of the lever D. To estimate the amount of power transmitted through the shaft, it is only necessary to ascertain the amount of friction of the drum A when it is in motion, and the number of revolutions made. At the end of the lever D is hung a scale B, in which weights are placed. The

two stops C C are to maintain the lever as nearly as possible in a horizontal position. Now, suppose the shaft to be in motion, the screws are to be tightened and weights added in B, until the lever takes the position shown in the drawing, at the required number of revolutions. Therefore the useful effect would be equal to the product of the weights, multiplied by the velocity at which the point or suspension of the weights would revolve if the lever were attached to the shaft.

Fig. 149 represents a pantagraph for copying, enlarging and reducing plans. One arm is attached to and turns on the fixed point C. B is an ivory tracing point, and A the pencil. Arranged as shown, if we trace the lines of a plan with the point B, the pencil will produce it double the size.





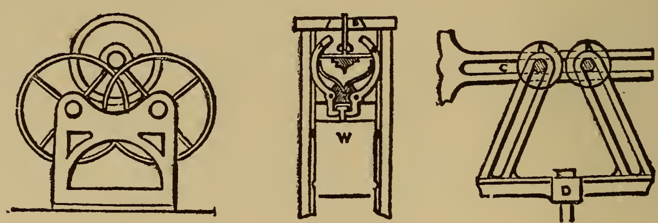
Figs. 148, 149. Dynamometer — Pantagraph

By shifting the slide attached to the fixed point C and the slide carrying the pencil along their respective arms, the proportions to which the plan is traced will be varied.

Fig. 150. Anti-friction bearing. Instead of a shaft revolving in an ordinary bearing, it is sometimes supported on the circumference of wheels. The friction is thus reduced to the least amount.

Fig. 151. Releasing hook used in pile-driving machines. When the weight W is sufficiently raised, the upper ends of the hooks A, by which it is suspended, are pressed inward by the side of the slot B, in the top of the frame; the weight is thus suddenly released, and falls with accumulating force on to the pile-head.

Fig. 152. A and B are two rollers which require to be equally moved to and fro in the slot C. This is accomplished by moving the piece D, with oblique slotted arms, up and down.



Figs. 150, 151, 152. Anti-friction — Drop hook — Regular motion

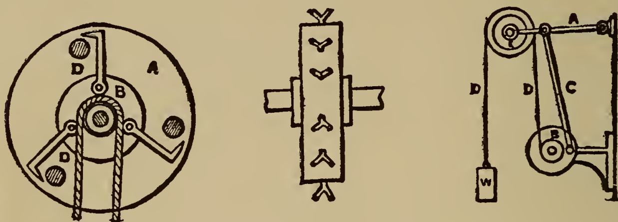
Fig. 153. Centrifugal check-hooks, for preventing accidents in case of the breakage of machinery which raises and lowers workmen, or ores, in mines. A is a framework fixed to the side of the shaft of

the mine, and having fixed studs D, attached. The drum on which the rope is wound is provided with a flange B, to which the check-hooks are attached. If the drum acquires a dangerously rapid motion, the hooks fly out by centrifugal force, and one or other, or all of them, catch hold of the studs D, arrest the drum, and stop the descent of whatever is attached to the rope. The drum ought besides this, to have a spring applied to it, otherwise the jerk arising from the sudden stoppage of the rope might produce a worse effect than its rapid motion.

Fig. 154. A sprocket-wheel to drive or to be driven by a chain.

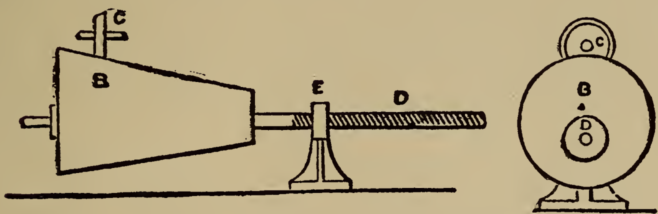
Fig. 155. A combination movement, in which the weight W moves with a reciprocating movement, the down-stroke being shorter than the up-stroke. B is a revolving disc, carrying a drum which winds around itself the cord D. An arm C is jointed to the disc and to the upper arm A, so that when the disc revolves, the arm A moves up and down, vibrating on the point G. This arm carries with it the pulley E. Suppose we detach the cord from the drum, tie it to the fixed point, and then move the arm A up and down. The weight W will move the same distance, and in

addition the movement given it by the cord, that is to say, the movement will be doubled. Now, let us attach the cord to the drum, and revolve the disc B, and the weight will move vertically with the reciprocating motion, in which the down stroke will be shorter than the up-stroke, because the drum is continually taking up the cord.



Figs. 153, 154, 155. Hooks — Sprocket — Combination movement

Figs. 156, 157. The first of these figures is an end view, and the second is a side view of an arrangement or mechanism for obtaining a series of changes in velocity and direction. D is a screw on which is placed eccentrically the cone B, and C is a friction roller, which is pressed against the cone by a spring or weight. Continuous rotary motion, at a uniform velocity of the screw D carrying the eccentric cone, gives a series of changes of velocity and direction to the roller C. It will be understood that during every revolution of the cone the roller would press against a different part of the cone, and that it would describe thereon a spiral motion, the movement in one direction being shorter than that in the other.



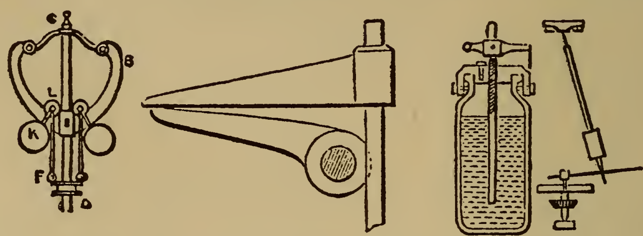
Figs. 156, 157. Change of speed

Fig. 158. An engine governor. The rise and fall of the balls K are guided by the parabolic curved arms B, on which the anti-friction wheels L run. The rods F, connecting the wheel L with the sleeve, move it up and down the spindle C D.

Fig. 159. Toe and lifter for working poppet-valves in steam engines. The curved toe on the rock-shaft operates on the lifter attached to the lifting rod to raise the valve.

Fig. 160. Mercurial compensation pendulum. A glass jar of mercury is used for the bob or weight. As the pendulum-rod is expanded lengthwise by increased temperature, the expansion of mercury in the jar carries it to a greater height therein, and so raises its centre of gravity relatively to the

rod sufficiently to compensate for downward expansion of the rod. As rod is contracted by a reduction of temperature, contraction of mercury lowers it relatively to rod. In this way the centre of oscillation is always kept in the same place, and the effective length of pendulum always the same.

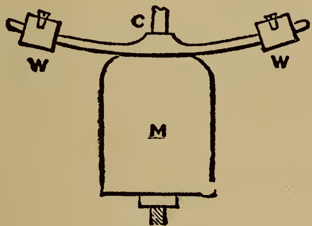


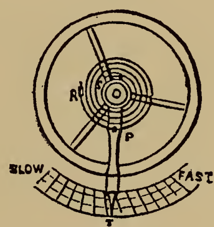
Figs. 158, 159, 160. Governor, lifter, and pendulum

Fig. 161. Compound bar compensation pendulum. C is a compound bar of brass and iron, or steel brazed together with brass downward. As brass expands more than iron, the bar will bend upward as it gets warmer, and will carry the weights W, W, up with it, raising the centre of the aggregate weight M, to raise the centre of oscillation as much as elongation of the pendulum-rod would let it down.

Fig. 162. Watch regulator. The balance-spring is attached at its outer end to a fixed stud R, and at its inner end to staff of balance. A neutral point is formed in the spring at P, by inserting it

between two curb-pins in the lever, which is fitted to turn on a fixed ring concentric with staff of balance, and the spring only vibrates between this neutral point and staff of balance. By moving lever to the right, the curb-pins are made faster, and by moving it to the left, an opposite effect is produced.



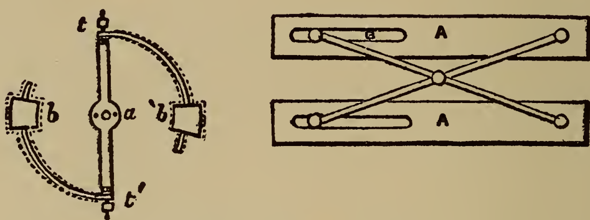


Figs. 161, 162. Compound bar — Hair spring

Fig. 163. Compensation balance. *t*, *a*, *t′* is the main bar of balance, with timing screws for regulation at the ends. *t* and *t′* are two compound bars, of which the outside is brass and the inside steel, carrying weights *b*, *b′*. As heat increases, these bars are bent inward, diminishing the inertia of the balance. As the heat diminishes, an opposite effect is produced. This balance compensates both for its own expansion and contraction, and that of the balance-spring.

Fig. 164. Parallel ruler, consisting of a simple

straight ruler B, with an attached axle C, and a pair of wheels *A A*. The wheels, which protrude but slightly through the under side of the ruler, have their edges nicked to take hold of the paper and keep the ruler always parallel with any lines drawn upon it.

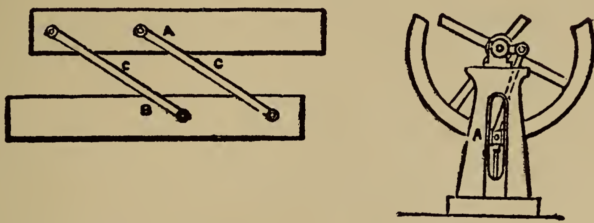


Figs. 163, 164. Balance — Ruler

Fig. 165. Compound parallel ruler, composed of two simple rulers A, A, connected by two crossed arms pivoted together at the middle of their length, each pivoted at one end to one of the rulers, and connected with the other one by a slot and sliding pin, as shown at B. In this the ends as well as the edges are kept parallel. The principle of construction of the several rulers represented is taken advantage of in the formation of some parts of machinery.

Fig. 166. A simple means of guiding or obtaining a parallel motion of the piston rod of an engine. The slide *a* moves in and is guided by the vertical

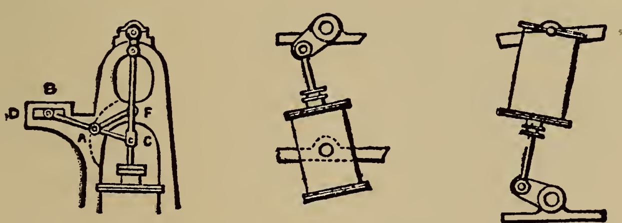
slot in the frame, which has been planed to a true surface.



Figs. 165, 166. Ruler — Parallel motion

Fig. 167. Parallel motion for direct-action engines. In this, the end of the bar *B C* is connected with the piston-rod, and the end *B* slides in a fixed slot D. The radius bar F A is connected at F with a fixed pivot, and at A midway between the ends of B C.

Fig. 168. Oscillating engine. The cylinder has trunnions at the middle of its length, working in



Figs. 167, 168, 169. Parallel motion methods

fixed bearings, and the piston rod is connected directly with the crank, and no guides are used.

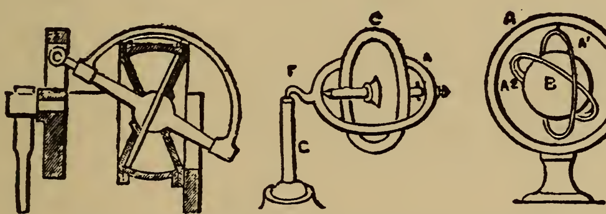
Fig. 169. Inverted oscillating or pendulum engine. The cylinder has trunnions at its upper end, and swings like a pendulum. The crank shaft is below, and the piston rod connected directly with crank.

Fig. 170. Section of disc-engine. Disc-piston, seen edgewise, has a motion substantially like a coin when it first falls after being spun in the air. The cylinder heads are cones. The piston rod is made with a ball to which the disc is attached, said ball working in concentric seats in cylinder-heads, and the left-hand end is attached to the crank arm or fly-wheel on end of shaft at left. Steam is admitted alternately on either side of piston.

Fig. 171. The gyroscope, or rotascope, an instrument illustrating the tendency of rotating bodies to preserve their plane of rotation. The spindle of the metallic disc C is fitted to return easily in bearings in the ring A. If the disc is set in rapid rotary motion on its axis, and the pintle F at one side of the ring A is placed on the bearing in the top of the pillar G, the disc and ring seem indifferent to gravity, and instead of dropping begin to revolve about the vertical axis.

Fig. 172. Bohnenberger's machine, illustrating

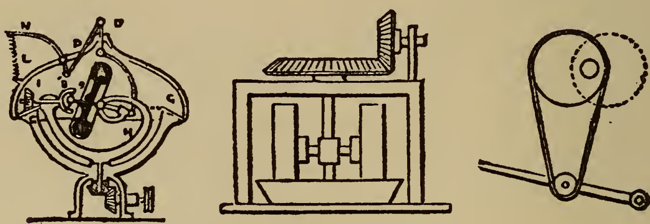
the same tendency of rotating bodies. This consists of 3 rings, *A*, *A′*, *A2*, placed one within the other, and connected by pivots at right angles to each other. The smallest ring, *A2*, contains the bearings for the axis of a heavy ball B. The ball being set in rapid rotation, its axis will continue in the same direction, no matter how the position of the rings may be altered; and the ring A2, which supports it, will resist a considerable pressure tending to displace it.



Figs. 170, 171, 172. Disc-engine and gyroscopes

Fig. 173. What is called the gyroscope governor, for steam-engines, introduced by Alban Anderson in 1858. A is a heavy wheel, the axle *B B′* of which is made in two pieces connected together by a universal joint. The wheel A is on one piece B, and a pinion 1 on the other piece *B′*. The piece B is connected at its middle by a hinge-joint with the revolving frame *H*, so that variations in the inclination of the wheel A will cause the outer

end of the piece *B* to rise and fall. The frame *H* is driven by bevel gearing from the engine, and by that means the pinion 1 is carried round the stationary toothed circle *G*, and the wheel *A* is thus made to receive a rapid rotary motion on its axis. When the frame H and wheel A are in motion, the tendency of the wheel A is to assume a vertical position, but this tendency is opposed by a spring L. The greater velocity of the governor, the stronger the tendency, above mentioned, and the more it overcomes the force of the spring, and the reverse. The piece B is connected with the valve rods by rods C, D, and the spring L is connected with the said rods by levers N and rod P.



Figs. 173, 174, 175. Governor — Reverse motions

Fig. 174. Pair of edge runners or chasers for crushing or grinding. The axles are connected with vertical shaft, and the wheel or chasers run in an annular pan or trough.

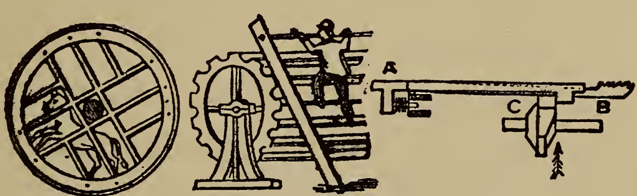
Fig. 175. Rotary motion of shaft from treadle

by means of an endless band running from a roller on the treadle to an eccentric on the shaft.

Fig. 176. Tread-wheel horse-power turned by the weight of an animal attempting to walk up one side of its interior; has been used for driving the paddle-wheels of ferry-boats and many other purposes. The turn-spit dog used also to be employed in such a wheel in ancient times for turning meat while roasting on a spit.

Fig. 177. The treadmill, employed in jails in some countries for exercising criminals condemned to labour, and employed in grinding grain; turns by weight of person stepping on tread-boards on periphery. This is supposed to be a Chinese invention, and it is still used in China for raising water for irrigation.

Fig. 178. A. B. Wilson's four-motion feed, used in Wheeler and Wilson's, Sloat's, and other sewing



Figs. 176, 177, 178. By different sources of power

machines. The bar A is forked, and has a second bar B, carrying the spur or feeder, pivoted in the said fork. The bar B is lifted by a radial projection on the cam C, at the same time the two bars are carried forward. A spring produces the return stroke, and the bar B drops of its own gravity.

Fig. 179. Mechanical means of describing parabolas, the base, altitude, focus, and directrix being given. Lay straight edge with near side coinciding with directrix, and square with stock against the same, so that the blade is parallel with the axis, and proceed with pencil in bight of thread, as in the preceding.

Fig. 180. Mechanical means of describing hyperbolas, their foci and vertices being given. Suppose the curves two opposite hyperbolas, the points in vertical dotted centre line their foci. One end of

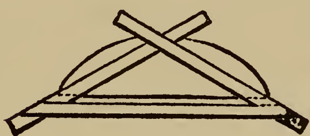
Figs. 179, 180. To describe conic sections

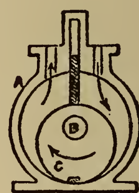
thread being looped on pin inserted at the other focus, and other end held to other end of rule, with just enough slack between to permit height to reach vertex when rule coincides with centre line. A pencil held in bight, and kept close to the rule, while latter is moved from centre line, describes one-half of parabola; the rule is then reversed for the other half.

Fig. 181. Cyclograph for describing circular arcs in drawings where the centre is inaccessible. This is composed of three straight rules. The cord and versed sine being laid down, draw straight, sloping line from ends of former to top of latter; and to these lines lay two of the rules crossing at the apex. Fasten these rules together, and another rule across them to serve as a brace, and insert a pin or point at each end of chord to guide the apparatus, which, on being moved against these points, will describe the arc by means of pencil in the angle of the crossing edges of the sloping rules.

Fig. 182. Proportional compasses used in copying drawings on a given larger or smaller scale. The pivot of compasses is secured in a slide which is adjustable in the longitudinal slots of legs, and capable of being secured by a set screw; the dimensions are taken between one pair of points and transferred with the other pair, and thus enlarged or diminished in proportion to the relative distances of the points from the pivot. A scale is provided on one or both legs to indicate the proportions.

Fig. 183. One of the many forms of rotary engine. A is a cylinder having the shaft B pass centrally through it. The piston C is simply an eccentric fast on the shaft, and working in contact with the cylinder at one point. The induction and eduction of steam take place as indicated by arrows, and the pressure of the steam on one side of the piston produces its rotation and that of the shaft. The sliding abutment D, between the induction and eduction ports, moves out of the way of the piston to let it pass.



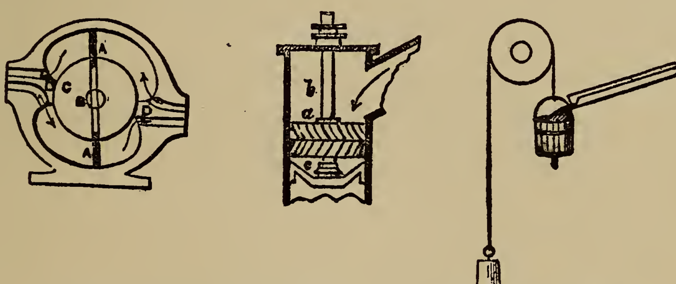


Figs. 181, 182, 183. For drawing curves. Rotary engine

Fig. 184. Another form of rotary engine, in which there are two stationary abutments D, D, within the cylinder; and the two pistons A, A, in order to enable them to pass the abutments, are made to slide radially in grooves in the hub C of the main shaft B. The steam acts on both pistons at once, to produce the rotation of the hub and shaft. The induction and eduction are indicated by arrows.

Fig. 185. Jonval turbine. The shutes are arranged on the outside of a drum, radial to a common centre, and stationary within the trunk or casing *b*. The wheel *c* is made in nearly the same way; the buckets exceed in number those of the shutes, and are set at a slight tangent instead of radially, and the curve generally used is that of the cycloid or parabola.

Fig. 186. A method of obtaining a reciprocating motion from a continuous fall of water, by means of a valve in the bottom of the bucket which opens by striking the ground, and thereby emptying the bucket, which is caused to rise again by the action of a counterweight on the other side of the pulley over which it is suspended.



Figs. 184, 185, 186. Different forms of water movements

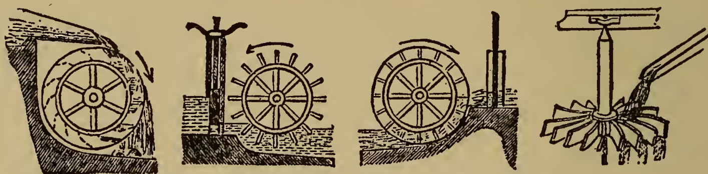
Fig. 187. Overshot water-wheel.

Fig. 188. Undershot water-wheel.

Fig. 189. Breast-wheel. This holds intermediate

place between overshot and undershot wheels; has float-boards like the former, but the cavities between are converted into buckets by moving in a channel adapted to circumference and width, into which water enters nearly at the level of axle.

Fig. 190. Horizontal overshot water-wheel.



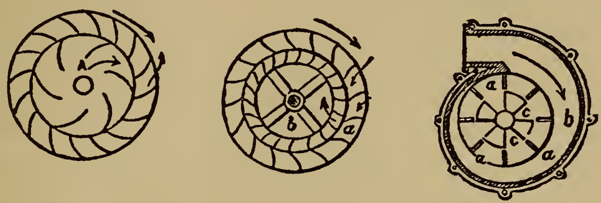
Figs. 187, 188, 189, 190. Water-wheels

Fig. 191. A plan view of the Fourneyron turbine water-wheel. In the centre are a number of fixed curved chutes, or guides, A, which direct the water against the buckets of the outer wheel B, which revolves, and the water discharges at the circumference.

Fig. 192. Warren's central discharge turbine, plan view. The guides *A* are outside, and the wheel *B* revolves within them, discharging the water at the centre.

Fig. 193. Volate wheel, having radial vanes *A*, against which the water impinges and carries the wheel around. The scroll or volute casing *B* confines the water in such a manner that it acts against the vanes all around the wheel. By the

addition of the inclined buckets *c*, *c*, at the bottom, the water is made to act with additional force as it escapes through the openings of said buckets.



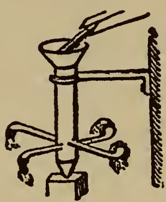
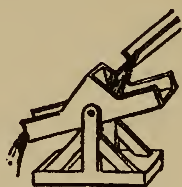
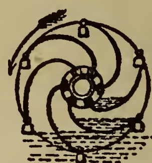
Figs. 191, 192, 193. Central discharge and turbine wheels

Fig. 194. Barker, or reaction mill. Rotary motion of central hollow shaft is obtained by the reaction of the water escaping at the ends of its arms, the rotation being in a direction the reverse of the escape.

Fig. 195 represents a trough divided transversely into equal parts, and supported on an axis by a frame beneath. The fall of water filling one side of the division, the trough is vibrated on its axis, and at the same time that it delivers the water the opposite side is brought under the stream and filled, which in like manner produces the vibration of the trough back again. This has been used as a water-meter.

Fig. 196. Persian wheel, used in Eastern countries for irrigation. It has a hollow shaft and

curved floats, at the extremities of which are suspended buckets or tubs. The wheel is partly immersed in a stream acting on the convex surface of its floats; and as it is thus caused to revolve, a quantity of water will be elevated by each float at each revolution, and conducted to the hollow shaft at the same time that one of the buckets carries it full of water to a higher level, where it is emptied by coming in contact with a stationary pin placed in a convenient position for tilting it.

Figs. 194, 195, 196. Water motors

Fig. 197. Machine of ancient origin, still employed on the river Eisach, in the Tyrol, for raising water. A current keeping the wheel in motion, the pots on its periphery are successively immersed, filled, and emptied into a trough above the stream.

Fig. 198. Application of Archimedes screw for raising water, the supply stream being the motive power. The oblique shaft of the wheel has extending through it a spiral passage, the lower end

of which is immersed in water, and the stream acting upon the wheel at its lower end produces its revolution by which the water is conveyed upward continuously through the spiral passage and discharged at the top.

Fig. 199. Common lift pump. In the upper-stroke of piston or bucket the lower valve opens and the valve in piston shuts; air is exhausted out of suction pipe, and water rushes up to fill the vacuum. In down stroke lower valve is shut and valve in piston opens, and the water simply passes through the piston. The water above piston is lifted up, and runs over out of spout at each up stroke. This pump cannot raise water over thirty feet high.

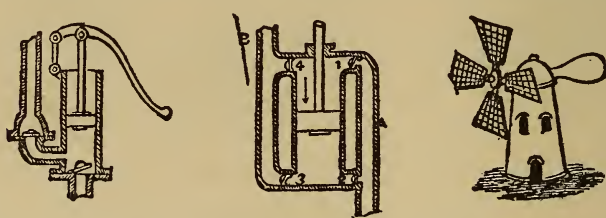
Figs. 197, 198, 199. Water-wheels and pumps

Fig. 200. Ordinary force pump, with two valves. The cylinder is above water, and is fitted with solid piston; one valve closes outlet pipe, and other closes suction pipe. When piston is rising suction-valve is open, and water rushes into cylinder, out-

let valve being closed. On descent of piston suction valve closes, and water is forced up through outlet valve to any distance or elevation.

Fig. 201. Double-acting pump. Cylinder closed at each end, and piston-rod passes through stuffing-box on one end, and the cylinder has four openings covered by valves, two for admitting water and like number for discharge. A is suction pipe, and B discharge pipe. When piston moves down, water rushes in at suction valve 1, on upper end of cylinder, and that below piston is forced through valve 3 and discharge pipe B; on the piston ascending again, water is forced through discharge valve 4, on upper end of cylinder, and water enters lower suction valve 2.

Fig. 202. Common windmill, illustrating the pro-



Figs 200, 201, 202. Pumps and windmill

duction of circular motion by the direct action of the wind upon the oblique sails.

Fig. 203. Ordinary steering apparatus. Plan

view. On the shaft of the hand wheel, there is a barrel on which is wound a rope, which passes round the guide-pulleys, and has its opposite ends attached to the tiller, or lever, on top of the rudder; by turning the wheel, one end of the rope is wound on and the other left off, and the tiller is moved in one or the other direction, according to the direction in which the wheel is turned.

Fig. 204. Capstan. The cable or rope wound on the barrel of the capstan is hauled in by turning the capstan on its axis by means of handspikes or bars inserted into holes in the head. The capstan is prevented from turning back by a pawl attached to its lower part and working in a circular ratchet on the base.

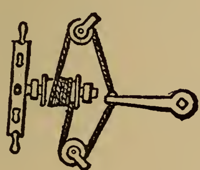


Fig. 203. Cable.

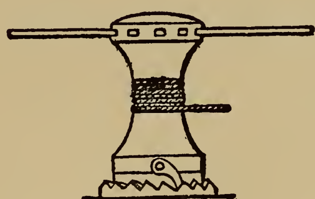
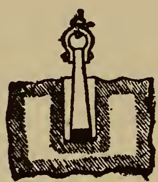


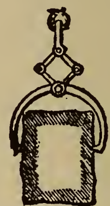
Fig. 204. Capstan

Fig. 205. Lewis bolt for lifting stone in building. It is composed of a central taper-pin or wedge, with two wedge-like packing pieces arranged one on each side of it. The three pieces are inserted

together in a hole drilled into the stone, and when the central wedge is hoisted upon it, it wedges the packing pieces out so tightly against the sides of the hole as to enable the stone to be lifted.

Fig. 206. Tongs for lifting stones. The pull on the shackle which connects the two links causes the latter so to act on the upper arms of the tongs





Figs. 205, 206. Lewis bolts, for lifting stones

as to make their points press themselves against or into the stone. The greater the weight, the harder the tongs bite.

III

THE WEATHER AND INDOOR WORK

THE measure of rainfall varies considerably within comparatively small areas, and this renders it no easy matter to get correct figures, so that the nearest records are those taken from a number of gauges within a limited district, and generalized. The more this is done, the less will be the inaccuracy in referring to the rainfall of any particular district or country.

If numerous rain-gauges were established throughout the country, and all their records sent to one central station, what valuable information might be collected for a particular district or country in the course of years. Means might be found for using the superabundant water, which falls in one part over another part, where the rainfall is less. Information such as this might be of special value in the West and South. It is collected now to a certain extent; but not done so generally as it ought to be.

As the fall of rain is always measured in inches gauges are made to indicate the equivalent of a cubic inch of rain on the surface of the earth. The simplest form of rain-gauge is a square or circular box or jar with a perfectly flat bottom and perpendicular sides (see Fig. 207). If the depth of water in such a gauge be measured after a fall of rain, one can ascertain in inches, or parts of an inch, the amount of rain that has fallen on the surface of the earth. Care must be taken to have the edge of the gauge thin and free from dents, the sides perpendicular and the bottom of the jar perfectly flat, for though in one measurement these irregularities may not make much difference, they would lead to a very decided error in a large number of measurements. Evaporation is also liable in such a gauge to give rise to errors, and extraneous matters are easily introduced. The better rain-gauges are constructed to avoid these contingencies, as far as possible and to depend only on the area of entry for the accuracy of the measurements. This area may be a square, but is usually circular for convenience. The circle must be

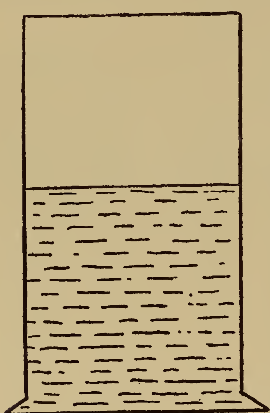


Fig. 207. Rain gauge

accurate, and its area is then easily calculated, so that one can estimate the amount of rainfall, however large the receiving vessel may be. The edge of the circle, which may be made of copper, more durable than iron, must be sharp, with an overlapping rim to prevent raindrops from being whirled out of the receiver, and connected by a shoulder to a funnel, which directs the water into the receiver. This may be a glass bottle fitted with a cork to hold the funnel firmly, and prevent leakage between the outside of the funnel and the neck of the bottle (see Fig. 208). A more convenient receiver, and one less likely to be broken, is a round tin case of convenient size, with a top fitting accurately under the overlapping edge of the funnel-shaped cover. In this large receiver may be placed a small tin mug, with a lip just under the funnel, for conveniently measuring small quantities of rain, and prevent-

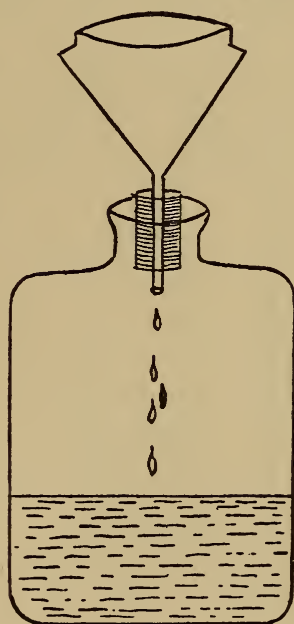


Fig. 208. A made rain-guage

ing waste by evaporation. Any overflow from the mug will be caught in the large receiver (see Fig. 209). The circle of entry may, of course, be of any size; but one whose diameter is between 4 or 8 inches will be most convenient. Make the circle determine its area by careful measurement, using the following formula: $D^2 \times .7854$ = area, each square inch will give cubic inches for area. Take this amount of water and pour it into a glass, marked at the top of the water, and then divide the intervening space between this mark and the bottom into 100 equal parts. This graduated glass will give the rainfall in inches and 100ths of an inch. As an inch glass is somewhat cumbersome, a half-inch glass is usually sent out with a rain-gauge. It may, however, be sometimes convenient to use an ordinary ounce measure, as

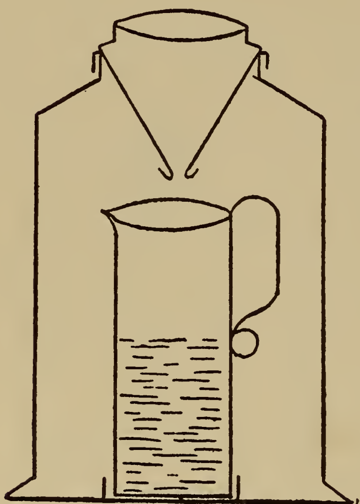


Fig. 209. A more complete rain-gauge

graduated glass measures, when broken, are not always easily replaced; so that it may be necessary to find the corresponding relation between the cubic inches of receiving area and ounces and drachms. To do this, we will suppose the diameter of the circular top of gauge to be 4.7 inch; this squared = 22.09, multiplied by .7854 = 17.349486, divided by 1:733 (an ounce avoir. = 1.733 c. in.) = 10.011 oz. avoir.

Now if the rainfall is collected daily at a certain time in an ounce measure, the amount may easily be recorded in inches by reference to the accompanying table:

		inch			inch
10 oz.	=	1.0000	1 oz.	=	.1000
9 "	=	.9000	7 dr.	=	.0875
8 "	=	.8000	6 "	=	.0750
7 "	=	.7000	5 "	=	.0625
6 "	=	.6000	4 "	=	.0500
5 "	=	.5000	3 "	=	.0375
4 "	=	.4000	2 "	=	.0250
3 "	=	.3000	1 "	=	.0125
2 "	=	.2000			

A similar calculation can be made and table prepared for any larger circle of entry by the same method.

The amount of rainfall in any country is a matter of great importance to that country, and, like the rise of the Nile in Egypt, it indicates the coming state of the crops. If we have too small a rainfall, drought and withered crops follow, and if we get too great a fall of rain, drowned out crops, and disastrous floods occur, so you see how necessary it is that those people who are elected to look after the welfare of a nation, should keep posted on matters of rainfall in all its phases. In India, China and some other parts of the world the question of rainfall is one of life and death to the people, and most of the great famines of the past have been due to the small rainfall. Hundreds of thousands of people used to perish by famine and disease year after year. Much of this danger from shortage of rain has happily been avoided in India by the efforts of the British government, which has inaugurated and carried out great schemes of irrigation and artificial waterways to prevent the recurrence of famine from drought. Our own government also is expending large sums of money on irrigation plans now being executed in Arizona, Texas, Colorado and other states, which will render immense territories fit for cultivation, which would otherwise have remained barren and of no use. The matter of rainfall is of the highest importance to a nation and to the men and beasts inhabiting it.

"Will it rain to-day?" is a question frequently asked, as regards the weather, showing how important the subject is, and while I am talking on it, it may not be amiss to make a few remarks regarding the formation and distribution of rain, as formulated by learned meteorologists. We are told that the two great causes of rain are the sun and the ocean — the latter, of course, includes the great lakes and rivers — and since these two factors may be taken as constant, it follows that the rainfall over the earth as a whole will always be constant, while the local variations will be due to local conditions. The rain which falls on this continent is drawn up by the sun from the various sources, but the conditions which cause its precipitation may be said to be local. To your imagination may be left the tracing of the journey of the rain drops back to the ocean again. The starting points in considering the causes of rain are, therefore, heat and moisture. From the surface of land and water moisture is continually evaporating into the atmosphere, and the higher the temperature of the air the more watery particles it can hold. If any reduction in the temperature of this saturated air should take place, the vapour becomes visible as fog, mist, or cloud, and it is from this vapour that the rain drops are formed. Recent research says that these watery particles require minute dust atoms as nuclei before they can form, and it has been estimated, by experiment, that there are one thousand millions of them in a cubic foot of saturated air, though their total weight amounts to only 3 grains. Accepting these figures, the mathematically inclined may be told that it would require a cloud three miles thick to produce one inch of rainfall. But before these watery particles can fall to the earth as rain, they must first form into rain drops, and the question arises, how are rain drops formed?

These watery particles pass into the air by evaporation, and there are several ways by which the reduction in temperature necessary to render them visible can be brought about. It may take place through contact with a colder body of air, by expansion, or by a reduction of pressure owing to a rise in altitude. Clouds are said to be formed by this last method, for a volume of hot air rises higher and higher until it presently reaches a point when its contained vapour condenses, and becomes visible as a cloud. Meteorologists repeat one of these processes in the laboratory, by releasing from pressure damp air placed in a convenient glass globe, and are able to see something of the methods of cloud formation. It has been customary to speak of a cloud as being composed of watery particles floating motionless in the upper air; but although it may appear unchanged in form, it is all movement. So soon as ever a cloud is formed, its particles of moisture commence to fall slowly, the rate of fall being in proportion to the diameter of the particles, and this is due to the slight resistance the air makes to such very small atoms. In passing, it may be said that one observer estimates the diameter of these particles as from .00033 inch to .00025 inch. The component parts of a cloud are always in motion and recognizing this fact it becomes possible to take the first step in considering the formation of a rain drop.

An easy way out of the difficulty of explaining the formation of a raindrop, is to say that, since clouds are so often of two opposite electric potentials, there is always a continuous bombardment of watery particles taking place, and some of these must unite and fall as rain. The meteorologist is always tempted to call in electricity as an agency whenever he is anxious to discover a cause for some particular phenomenon. This often explains one mystery by another. The production of rain, snow, and hail has for many years been explained by vaguely ascribing them to the action of electricity, without any information being forthcoming as to the precise way in which this action takes place. Meteorologists are at present attempting to find a more satisfactory explanation. Another theory is that the particles of moisture in a cloud, like all other objects, radiate heat, and, growing cold, condense moisture upon their surfaces, thereby increasing in weight until they assume the proportions of a drop. This seemed a reasonable explanation of the formation of a rain drop until modern research decided that whenever moisture is condensed, latent heat is set free, so that all moisture deposited on a watery particle only serves to raise its temperature, and cause evaporation of the moisture thus acquired. The particles of water could not by this means grow to the full estate of a rain drop, and the theory is being gradually abandoned.

A rain drop is, according to modern meteorologists, explained in a very simple way. It has been seen how the hot, damp air is formed into a cloud, and also how the minute particles of water at once commence to fall slightly earthwards. Now these little particles as they pass into a warm layer of air would soon be evaporated, and would never reach the earth at all. Their downward journey, however, is often through a cloud many miles thick, and the most modern and simple theory is that in this journey they overtake some of their fellows, and the joined particles increase their rate of travel, overtake more and more particles until they presently become heavy enough to take the final plunge to earth. Were it possible to be just beneath a cloud, an observer would see rain drops coming from it of all sizes. The same process goes on in drops, which trickle down a window pane, or in the effervescing globules in a bottle of seltzer water. In the latter instance, the process is reversed, for the globules are seen overtaking one another in an upward direction. There are many points in favour of this theory of the formation of rain drops, and at least it gets rid of those elaborate complications, electricity and condensation. With respect to the formation of rain by the impinging of clouds upon the tops of cold mountains in the northwest, one authority argues that moisture is in these circumstances not condensed solely because of the contact with the cold hills; that rain there is due to a mechanical cause, the watery particles being squeezed together by the grinding effect of the clouds on the sides of the mountains in such a way that they coalesce, and fall as drops.

A rain drop's roundness is due to the action of capillarity. Just as a circle made by dropping a stone into water owes its shape to the fact that the force is able to act equally in all directions, so a rain drop is spherical, owing to similar untrammelled action on the part of capillarity. These are some of the explanations of the formation of a rain drop, but meteorologists still have the subject under consideration.

The periods of rainfall are divided broadly into times of drought and times of flood, and it is in these matters that meteorology is seen in its practical aspect. Some people ask, "Where does all the rain come from?" Others are surprised that rainfall totals up to such large quantities.

A fall of rain to a depth of one inch over a very limited area, represents millions of gallons, but in spite of this vast quantity of falling water, many times multiplied if the annual rainfall be taken into account, there still are water famines. The question has often been debated whether man can modify climate or effectively tamper with the processes which produce rain. Rain making has not, so far, been a success, though the firing off of heavy guns has been tried, along with the legitimate avocations of the meteorologist. The afforesting or deforesting of a district has, however, a marked effect upon rainfall. Three notable instances are Ascension Island, Malta, and the neighbourhood of the Suez Canal, where the planting of trees seems to have had the result of increasing the rainfall. The effect of trees is felt more in the storage of rain water, while leaves and roots serve to retain moisture that would otherwise quickly drain away. A hill may be converted into a sponge by the judicious planting of trees. The question of the storage of rain water becomes more pressing each year, and the longer the settlement is put off, the more difficult will decision become. Engineers called upon to prevent floods and to conserve rain water reply, "Save our forests, cover the land with trees."

The fact that such problems arise, serve to show how great is the amount of water formed by the continual falling of the tiny rain drops. As long as this beneficent downpouring is allowed to drain away unused or uncontrolled, so long will droughts annoy and water famines bring distress.

In recording weather conditions, symbols are sometimes used in order to shorten reports and, while not universal, most nations adopt these: The symbol for rain is o, a small circle filled in; for lightning ↯; for thunder T, while the two latter combined make T↯, the symbol for a thunder-storm. Nearly every weather component has a distinctive symbol, and since a great part of the meteorologist's work consists in going over records of observations to search for the number of times the different phenomena occur during each week or month, the task is much simplified when observers employ the symbols, as it is easier to pick out a symbol from a printed or written page than it is to recognize a word. These symbols, moreover, have been agreed upon as a sort of international notation, and make it easier for the meteorologists of different countries to understand the records of foreign meteorological services.

Everybody does not know the Russian word for snow, or the Dutch for hail, or the Bosnian for rain, but all who run, may read when "snow" is universally written, and hail represented by a wedge-shaped figure with lines drawn across. Time and space being limited, nearly all published records of weather merely set forth the number of days throughout the year on which the different phenomena occurred, and should snow, hail or thunder happen two or three times in one day, it would still be counted only as one day. The yearly totals, therefore, show the number of days on which these conditions have been observed. It is now an almost universal custom to count .01 inches or more during the twenty-four hours as a day of rain. Accordingly, where observers read their rain-gauge to three places of decimals, that on which less than .005 inch fell would not be counted as a rainy day. Smaller amounts would, however, be included in the total. Dew may sometimes fall to the amount of .01 in. or more; and that is counted as a rainy day, the rule being to consider the amount of precipitation, irrespective of the manner in which it has fallen. If you wish to make these observations comparable with published records you would do well to conform to these rules.

HAIL

Hail, the next weather component to be considered, presents many difficulties when the attempt is made to explain its origin and formation. Those who have anything to do with scientific matters are well acquainted with the hypothesis, which explains a given fact, and in considering the subject of hail, the meteorologist hears of many hypotheses which are put forward as complete explanations of this phenomenon. Caution is, therefore, to be exercised and every reported statement severely questioned. Remembering the aphorism: "The man or boy who never makes a mistake will never make anything," meteorologists have attacked the question of hail formation, and, although many mistakes have probably been made, the subject has lost a good deal of its mystery. For many years, it was customary to be content with a recognition of the fact that hail and lightning very often occur together, and the conclusion was drawn that the one was in some way responsible for the other. Sufficient corroboration of this hypothesis was to some meteorologists, found in the fact that thunder and lightning are said to be almost unknown in the Arctic regions, and this supposed companion, hail, almost unknown. Roughly speaking, the assumption was that lightning, as it flashed through a cloud laden with watery particles, caused hail to form. Such an explanation only tended to make the subject more mysterious, and the question, How is hail formed? practically remained unanswered. Many simpler explanations of hail have been propounded as the result of modern research, and, like rain and lightning, it has been demonstrated that hail owes its origin to the movement of the minute watery particles found everywhere in the atmosphere.

The clouds from which hail fall are ordinarily of great height above the earth, 40,000 feet or even higher. These are the well-known cirrus. The first condition necessary to the formation of hail is a powerful ascending current of hot, moist air, which may condense its moisture in the shape of the large woolly cloud, known as cumulus. Such a cloud may be 100 cubic miles in volume, and as long as it retains its shape nothing is likely to fall from it to the earth beneath. Before the formation of a thunder-shower, cirriform fibres in some instances break away from the upper portion of this cloud, the electrical tension is lowered, and rain falls. The coalescing of the particles of moisture has a great deal to do with the changes which take place in a cloud. All these changes take place in the higher clouds in a marked degree, and the varying strata through which the watery particles pass in ascending to and decending from this great height bring about the violent change essential to the formation of hail. The necessary conditions for hail are, therefore, a powerful, hot, ascending current of air and great variation in the strata of the atmosphere as regards moisture and temperature. Mountains assist in forcing currents of air upwards, and one mass of air impinging on another is also thrown upwards, so that condensation of moisture rapidly takes place. A hail cloud may be described as a tower of hot air, from the top of which, vapor is ejected into a frosty region. Hot plains are accordingly the most favourable spots for the formation of hail, and in mountainous districts, more hail falls at a distance from the mountains than among them. Snow is observed in all latitudes and at all heights, but hail is confined to middle latitudes, and is rare in high latitudes. The places most affected by hail are those in which, the temperature and humidity of the air are high, while above, at a great height, there is a cold area below the temperature of freezing point; but, as in the case of the rain drop, before anything can be definitely stated, it must be shown how the particles of moisture coalesce to form hail.

SNOW

Snow is frozen water which falls instead of rain when the temperature is below the freezing point. The ultimate constituents of snow are tiny, six-pointed crystals of ice. They assume in combination a thousand different figures (Fig. 210), all exceedingly beautiful. Professor Tyndall has shown, further, that the ultimate particles of ice are also these six-pointed stars. The white colour of snow is caused by the commingling of rays of all the prismatic colours from the minute snow crystals. Separately the crystals exhibit different colours.

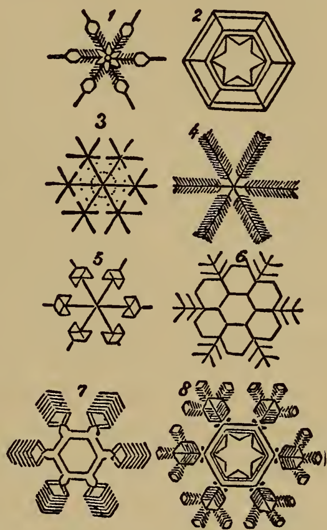


Fig. 210. Snow crystals

Snow is usually from ten to twelve times as light as water, bulk for bulk; so that where the snow falls pretty evenly, the corresponding rainfall is readily determined by merely measuring the depth of snow and taking one tenth of the result. The more accurate plan, however, is to thrust the open end of a cylindrical vessel into the snow, invert the cylinder, and then melt the snow in it.

Snow plays an important part in the economy of nature. In the first place, the mere transformation of the water particles into ice is a process during which a large amount of heat is given out; so that we may regard the formation of snow renders the air currents warmer than they would otherwise be.

Fallen snow serves to protect the ground, for, owing to its loose texture, it is a bad conductor of heat; so that, while checking the radiation of heat from the earth into space, it does not draw off the earth's heat by conduction. The ground is thus often 23 degrees to 30 degrees warmer than the surface of the snow above, and sometimes the difference of temperature has been more than 40 degrees.

Red snow and green snow have been met with, more commonly in Arctic regions, but also in other parts of the world. These colours are caused by the presence of minute organisms — a species of alga called *Protococcus nivalis.*

The snow line of mountains is on the slopes below which, all the snow which falls in the year, melts during the summer. Above the snow line, therefore, lies the region of perpetual snow. The altitude of the snow line depends on a variety of conditions. The latitude of a snow range is, of course, important in determining the position of the snow line, but many other circumstances have to be considered, as the shape and slope of the mountain, the aspect of either side of the range, the character of the surrounding country, the prevalent winds, and so on.

The following table shows the observed height of the snow line in feet above the sea level in different places:

Place	Latitude	Height	Place	Latitude	Height
Spitzbergen . .	78 N	0.	South Himalaya .	28 N	15.500
Sulitelma, Sweden	67 5′	3.835.	Abyssinian Mts. .	13	14.065
Kamtchatka .	59 30	5.240	Purace	2 2′	15.381
Unalaschta . .	56 30	3.510	Nevades of Quito .	0	15.820
Altai . . .	50	7.934	Arequipa, Bolivia .	16 S	17.717
Alps	46	8.885	Paachata, Bolivia	18	12.079
Caucasus . .	43	11.063	Portillo, Chili . .	33	14.713
Pyrenees . .	42 45	8.950	Cordilleras, Chili .	42 30	6.010
Rocky Mountains	43	12.467	Magellan Strait .	53 30	3.707
North Himalaya	29	19.560			

DESIGNING, MAKING, AND INFLATING PAPER BALLOONS

Draw a rough figure of the balloon, as shown at A, (Fig. 211.)

Divide this into any number of parts (the more the better) by horizontal lines. Take a radius of balloon on each line, and describe circles, B.

Divide this into twelve parts by radius lines, then make pattern as follows: Draw a perpendicular, C, with horizontal lines at distance of horizontal lines on A, but measured on circumference as *c d*. Then set off on each line from perpendicular one half the distance between the radius lines, B, on the corresponding circle as *e f;* draw line through points thus found, and result will be shape of each section. Allow a little on one side when cutting out for pasting. This will be best made with strong tissue paper of any colour desired.

Another method, giving a shape somewhat different, is shown in Fig. 212. First draw an elevation of the balloon it is intended to make, either full size, on the floor, or to scale. The shape here illustrated differs slightly from that of balloons usually sold ready made, being wider at the mouth. This shape, however, is not so liable to catch fire when swayed about by the wind. Divide the elevation into any number of parts (the more the better) by horizontal lines as shown (No. 1). Take the radius of the balloon on each line, as A B, describe circles (No. 2,) and divide these into twelve parts by radial lines. Then to make a pattern, draw a perpendicular (No. 3), with horizontal lines at the distance of the horizontal lines (No. 1,) but measured on the circum-

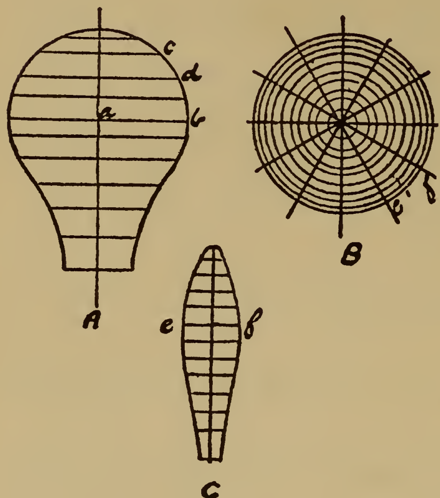


Fig. 211. Paper balloon

ference as C D. Then set off on each line from the perpendicular half the distance between the radius lines (No. 2), on the corresponding circle as E F, and

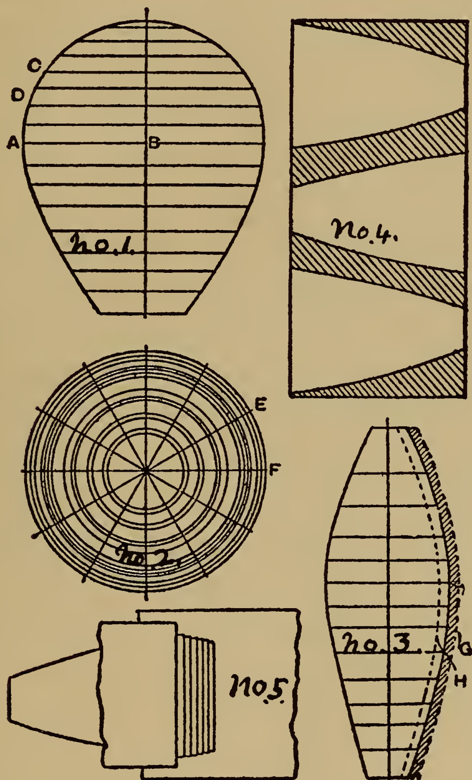


Fig. 212. An improved balloon

draw a line through the points thus found, and the result will be the shape of each section. Allow a little (say ¼ inch), on one side when cutting out for pasting. Each section will be made up of one, two, or three pieces, according to the size of the balloon to be made. If the pieces are cut as shown (No. 4,) a great saving of paper results. To paste these pieces together, place them in a pile on the table or bench with the edges flush and a piece of waste paper under the pile. Now rub the top sheet with the thumb nail until each piece is moved back from the one immediately under it about one-fourth inch. Place a piece of waste paper about the same distance from the edge of the top sheet, and pass the paste brush over the whole of the exposed edges. No. 5 will explain what is meant. Now place two of the completed sections together so as to look like No. 3, with a small part projecting as shown by the dotted line G. Paste the edge of the under section — that is, the part hatched — and turn it over on to the dotted line H. When each two of the sections have been joined in this way, proceed in the same manner to join these together till the whole is completed. A circular piece of paper is cut out to join the sections at the top, and a loop of string should be pasted to the top to suspend the balloon while inflating. A ring of wire with two cross pieces is fitted to the bottom of the balloon, and the inflammable material,

— tow soaked in methylated spirits — is fastened to the junction of the cross pieces.

MAGNETIZED WATCHES

The owner of a good American watch was a little troubled concerning it, because it had been running irregularly for some time past. It came out that he had visited the electric power house and had stayed for some time examining the works and machinery, so that parts of his watch had evidently become magnetized by the influence of the dynamos. The watch had been made some time ago, and had not the power to resist, or neutralize electric influences, that most watches have now.

To demagnetize the watch would bring it back to its original condition, but a second visit to the lighting plant would again spoil its time-keeping qualities. The watchmakers now have a way of making watches so that they are not affected by magnetism, but comparatively few of the time pieces in use are non-magnetic, and the average watch is subject to these seasons of fickleness.

The exceedingly fine and exact construction of the watch is not realized by the average possessor of the article. An examination of the works of a watch shows the mechanism as now constructed, although very small in size, to be accurately planned and executed. Changes of temperature are provided for, so that the movement is automatically adjusted. The mainspring and train of gears are usually concealed, while the balance and hair springs are in full view when the case is open. Upon the regularity of the movement of the balance depends the time keeping quality of the watch. On looking closely at the balance, you will observe that it is not a complete ring, but two halves supported at one end. These rings bear a number of large-headed screws, placed at irregular distances, which give it the exact weight and balance required. These half rings will also be found, on looking closely, to be composed of two metals so closely joined that a difference in colour alone gives evidence of the quality. This arrangement of iron and brass, on account of their different coefficients of expansion and contraction with changes of temperature, has been so carefully constructed that, with changes of temperature, the balance assumes such forms as to give it a uniform rate of motion.

The parts affected by magnetism are the balance and springs. The balance in an ordinary watch moves five times a second, 18,000 times an hour, and 432,000 times each day; but a slight change in the forces that move it is necessary to make a difference of several minutes each day. As the balance moves back and forth, the magnetism of the mainspring is pulling or pushing it. If this force were constant, and always in the same direction, the watch would run uniformly. Such, however, is not the case. When the mainspring is tightly wound, its magnetic poles are in a certain direction, and in unwinding they are constantly changing, so that the direction of this force is also constantly changed. The effect on the balance is to cause the watch to run too fast sometimes, and too slow at other times.

Non-magnetic watches are made with these parts of a non-magnetic metal, so that they are not influenced by electric machinery. For testing watches a small compass is used. When placed over the balance, the needle will vibrate with the motion of the balance in proportion to its magnetism.

A BOY'S WHEEL-BARROW

The bottom, sides, and ends were about three-quarters of an inch thick. Good white and red pine were used for the purpose. The stiles and rails of the bottom framework were mortised and tenoned together as shown at Fig. 213; these may be just stubbed together, or the tenons of the rails can go right through the stiles. The most satisfactory job is to groove the sides and ends together, and put all together with oil paint in the joints. If the joints are painted before the framework of the barrow is put together, it will last for years; otherwise, being a

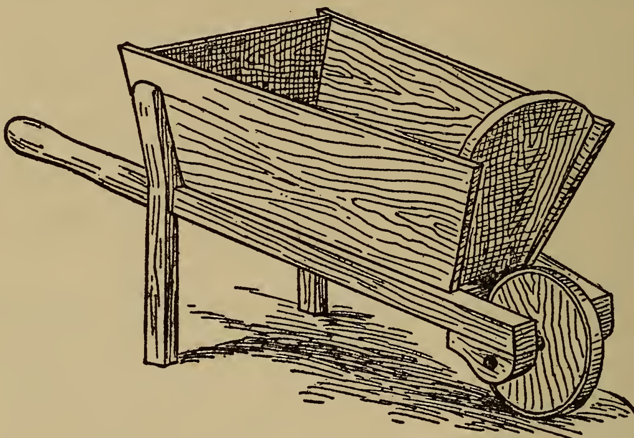
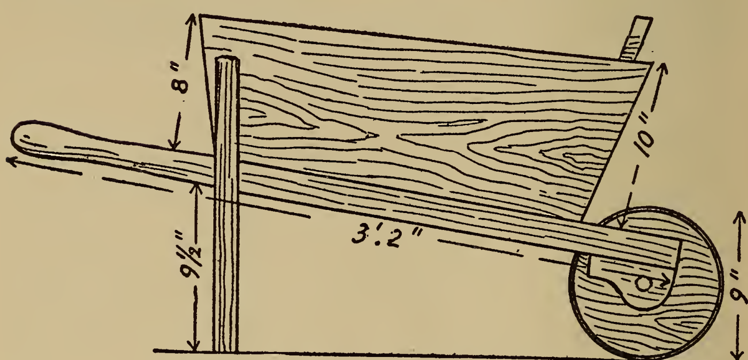
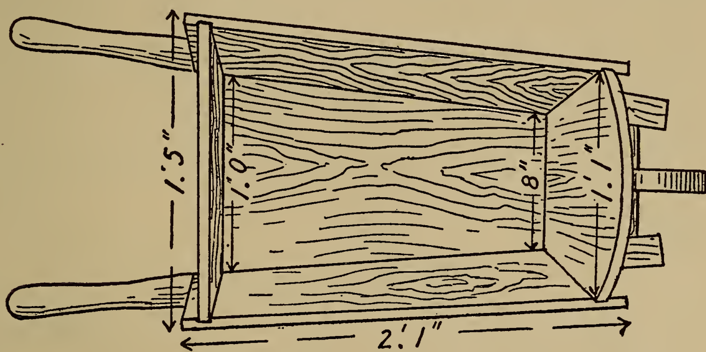


Fig. 213. A boy's wheel-barrow. Perspective view

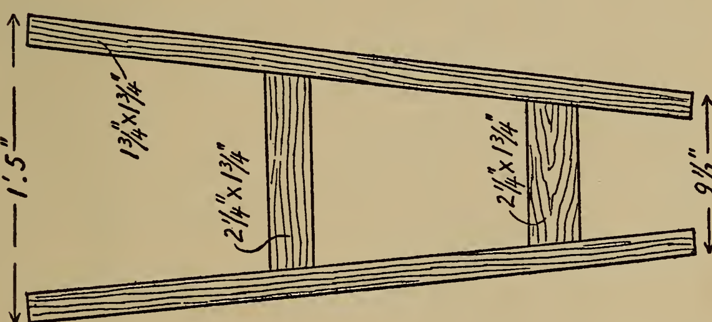


213 A. Boy's wheel-barrow. Side elevation

boy's wheel-barrow, it would likely often be forgotten and left out in the rain, and the joints getting wet would hasten decay. Two coats of good oil paint,



213 B. Finished plan



213 C. Plan of frame

Indian red, will give it a very nice appearance. This barrow, while not intended for heavy work, is capable of carrying quite a load. The wheel was cut out of a piece of plank about 1½ inches thick, hooped up with an iron tire made from heavy hoop iron. The axle was made of wood with a ¾-inch round iron rod running lengthwise through it and projecting about three inches through on each end. The arbours or boxing, in which ran the ends of the round rod, were formed on the ends of the handle stiles, as may be seen in the illustration. The cost of all the materials for this really useful article was less than $1.50, all told.

VACUUM CLEANERS

A single hand vacuum cleaner can be made from a powerful suction pump, as indicated in the sketch Fig. 214. This should be connected with a metallic box by means of a flexible armoured rubber hose, covered at the end with a piece of fine wire gauze to prevent large particles of dust, etc., being drawn into the pump. To another opening of the box should be fastened another flexible rubber tube, with a bell-shaped metal attachment at the end. The bell-shaped arrangement should be held closely to the carpet while the pump is in action. Within the box, the pipe to which the pump is attached should be bent upward, so that the rush of air shall not bring the dust with it; the object being to collect the dust in the box. A lid covers the box so that it can be emptied from time to time. The success of this arrangement depends on the strength of the pump; if it be a weak one, the inrush of air through the funnel will be so slight that the dust will not be raised.

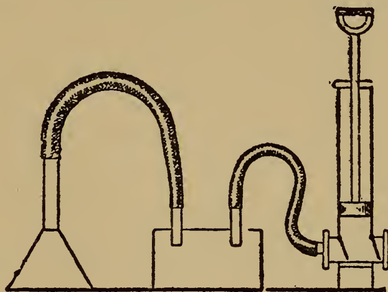


Fig. 214. Home-made vacuum cleaner

Rotary pumps are not satisfactory for vacuum cleaners. The best type for this work is a plunger, having a large displacement, with a comparatively short stroke in proportion to the diameter. A suitable pump is shown in the accompanying illustrations. Fig. 214, shows the section of a single barrel, but should a greater supply be required, two barrels may be worked and connected as shown in Fig. 216. The pump is easily made, and of light construction. In Fig. 215, is a brass cylinder with a flange at the bottom; this may be made out

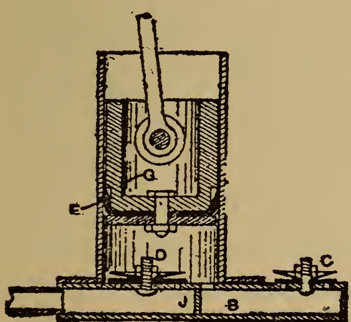


Fig. 215. Metallic vacuum cleaner

of a length of 3-inch brass tube with a flange cut from ⅛-inch sheet brass. The barrel is 8 inches long. G is the plunger, which may be constructed as a piston; but in the drawing, it is adapted to the arrangement that is shown in Fig. 216. With a piston will be required a guide for the rod at the top of the cylinder. E is a hydraulic cup, its leather kept soft and pliable by oiling. B is the base, which is hollow, and may be built up in sheet metal. At the centre at J, the base is divided into two compartments, one side being the inlet to the pump from the dust box, and the other in communication with the outlet valve C. C and D are two valves with guards. The valves are discs of very soft and pliable leather, well saturated with grease, D being the inlet from the dust box, and C the outlet to the atmosphere. The drawing clearly shows the construction of the other parts. Fig. 216 shows two pumps fitted to one base and worked by a rocking lever; both pumps are in communication with the one inlet N. This arrangement of pumps is easy to work, portable,

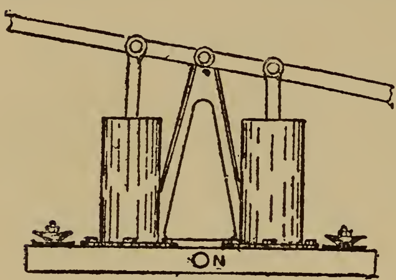


Fig. 216. Simple vacuum cleaner

and well adapted to domestic purposes in cleaning carpets.

Fig. 217, which is reproduced from *The Scientific American*, exhibits an ingenious form of vacuum cleaner. It has recently been patented, and consists of a suction-fan operated by a water-motor that may be attached to the ordinary kitchen faucet. A tube is connected with the chamber of the suction-fan, and this terminates in a suitable nozzle, or foot plate, which may be moved over a carpet or rug to draw out the dust and dirt. One of the advantages of this system is that dirt drawn up by the suction fan can be carried away with the water down the kitchen drain.

Fig. 217. A motor vacuum cleaner

A good power-driven cleaner may be made at home, says *Popular Mechanics*, by following these directions: First take a good pine board, 1 inch thick, 1 foot wide, and 3 feet long, and nail to each end a 1-foot length of 2-inch by 2-inch pine, as shown at A, Fig. 218. Next a $\frac{3}{4}$-inch board, 1 foot wide and about 1 foot, 3 inches long, should be fastened near the centre, and at right angles to the first board, as shown at B. Procure a tin pan measuring about 10 inches in diameter and 3 inches deep.

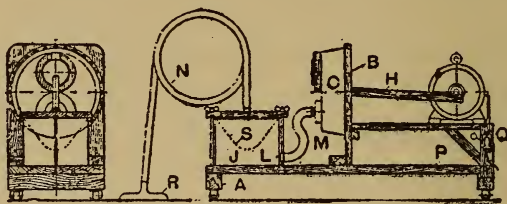


Fig. 218. Home-made power-driven vacuum cleaner

This pan shown at C, must be fitted with two valves, which are the most important and difficult part of the work. Cut, from a smooth piece of pine, 1 inch thick, two discs, 5 inches in diameter, with a 3-inch hole in the centre of each. Obtain a sheet of packing rubber, 1/8 of an inch thick, and cut from it two discs, each 5 inches in diameter, and two 3½ inches in diameter. One of the discs of wood should be fastened to the back of the pan at the top, as shown at D, Fig. 219, with one of the 5-inch diameter rubber discs placed between the tin and the wood, and both secured to the tin by a row of small bolts around the outside edge of the wood. A hole, 3 inches in diameter, can now be cut through the tin and rubber, using the hole in the wood as a guide. Two discs with a diameter of 3¼ inches should be cut from cigar box wood and fastened centrally on the 3½-inch rubber disc. One of the latter pieces should be fastened by its top edge to the top edge of the 5-inch disc of wood, as shown in E. This

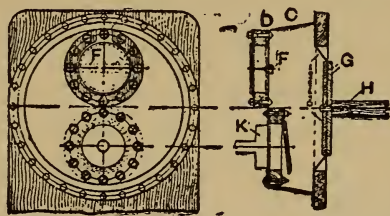


Fig. 219. Home-made, power-driven vacuum cleaner

forms a flap valve, and great care should be taken to see that the rubber disc covers the opening all the way around when the valve is closed, so that it will be air-tight. A spring will be necessary to quicken the action of this valve. This is best made by fastening a narrow strip of wood across the valve opening on the inside of the pan, as shown at F, and attaching a rubber band to the centre of the valve and to this stick. This completes the outlet or exhaust valve. Another valve must now be made in the same manner, and fastened to the bottom of the pan on the inside, as shown. This is the inlet valve, and works in the opposite direction to the outlet valve just described.

Next procure a piece of leatherette about twelve inches in diameter, or large enough to cover the opening of the pan. This is to be used for the diaphragm. Cut a round hole about 8 inches in diameter in the upright piece B (Fig. 218), its centre about 7 inches from the top. From a piece of ½-inch pine, cut two discs 6 inches in diameter. Also secure a piece of hardwood H 1 inch by 1 foot 2 inches. The discs G should now be placed, one on each side of the leather diaphragm, exactly in the centre, and fastened to one end of the 1-foot 2-inch piece by means of a long screw. This piece H should exactly be in the centre of the diaphragm.

The pan can now be put in place. Set the diaphragm over the hole in the board B, the stick projecting through the hole. The pan is now placed over the diaphragm, and held by means of small bolts around the edge. The diaphragm between the wood and the tin acts as a gasket, and makes an air-tight joint.

Secure an air-tight tin about 8 inches in diameter and 12 inches high, and fasten it to the base board, as shown at J, Fig. 218. The cover of a coffee tin should now be soldered over the inlet valve, as shown at K, Fig. 219. Solder a hose connection in the centre of this cover, also one in the side of the tin, as shown at L, Fig. 218. Couple a short piece of hose M to these connections. The strainer S should be made of very strong and closely woven unbleached drill. Make it in the form of bag with a 1-inch hem at the top, and place it in the tin, as shown by the dotted line, the hem fitting closely over the inside edge of the tin. The cover of the tin is made from a flat pine board about one inch thick, and is held in place by two ¼-inch rods fastened in the base board. These rods have thumb nuts on the top, which allow the cover to be readily removed or tightened down. It is best to place a rubber or leather gasket between the cover and the edge of the tin so as to make an air-tight joint.

An air-tight piece of garden hose can be used for the suction hose N, one end being fastened in the centre of the cover and the other to the brush or nozzle R, Fig. 218. It is best to buy this nozzle, as it would be rather expensive and unsatisfactory if home-made.

This machine may be driven by an electric motor of about 1¼ horse-power, which should be placed in the position shown in Fig. 218. The end of the connecting rod H is fastened to a crank on the motor shaft, and allowed to have about a one and one half inch stroke. The motor is wired up with a switch, P, and it would be best to connect to a rheostat, to allow the regulation of speed best suited to the machine. This can readily be determined after the machine is started. If an electric motor is not available, a small water motor will do equally well; or it may even be run by hand, by means of a long lever, fulcrumed at P.

The machine is now ready for using. First, however, test it all over for leakage, as its success depends on its being perfectly air-tight. As the motor revolves, the rod H is drawn forward, bringing with it the diaphragm. This creates a partial vacuum in the pan C, which opens the inlet valve, sucking the air through the suction hose and strainer, the air carrying with it the dust and dirt. The refuse is left in the strainer bag while the air goes on through the connecting hose and pan and outlet valve into the atmosphere. After the article being cleaned has been gone over thoroughly, care being taken to hold the nozzle against the material, the cover may be removed and the bag emptied.

IV

MOTORS AND TYPE-WRITERS

MOTORS, GASOLENE AND STEAM—AUTOMOBILE FRAMES —THE MODERN TYPE-WRITER—DIRECTIONS FOR SECURING COPYRIGHTS.

THERE are two classes of heat engines in use; in one class the combustion takes place on the inside of the cylinder or generator, just as fire is applied to a tea-kettle, and the heat is transmitted by conduction through the metal walls to the part of machine doing the work. Motors and machines of this kind, are generally called "external combustion" engines, of which the steam engine is a prominent example.

Engines where the combustion takes place inside the machine itself, and acts directly on it, are engines of the second class, termed "internal combustion engines." The gasolene engine is of this type, and so are all gas and oil engines.

The principle of the motor-cycle engine, in its action, is similar to the regular automobile engine and the gas engine. All these are internal combustion or explosion engines; that is, their motive power is derived from the force exerted by the explosion of a gas while under compression, the compressed gas generally ignited by means of an electric spark. In the case of gasolene motors, the gas is obtained from the liquid gasolene, either by allowing air to be drawn through it or by spraying the spirit through a small hole, the latter being the method most generally used. A great quantity of air has to be mixed with the vapour before it will ignite. The amount that is required varies considerably, atmospheric conditions and the height above sea level causing variations in the demand. The action of the common gasolene engine is known as the "four-stroke-cycle," that is, there are four strokes of the piston for every impulse, one being a "power" stroke and the other three "duty" strokes, as it were. Each performs a certain operation that is necessary for the correct working of the engine. Some engines are worked on the "two-stroke-cycle" principle; in this case, there are only two strokes for each impulse. This type of engine has many disadvantages, and there are very few two-stroke engines in use for driving motor cycles.

The principle of the "four-stroke-cycle" is shown in Figs. 220 to 223. In Fig. 220 the piston A is just beginning the downward stroke, and the valve B is opened by the pressure of the atmosphere, or by mechanical means. The piston in descending causes a partial vacuum in the cylinder head or top C, which allows the atmospheric pressure on the sur-

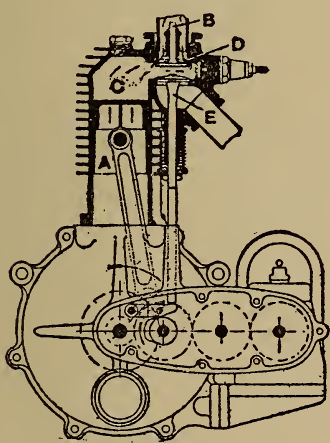


Fig. 220. Suction stroke begun

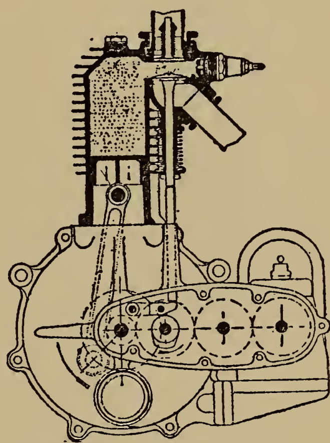


Fig. 221. Compression stroke begun

face of the gasolene in the carburetor to force some of the liquid through the spray hole, thence through the inlet-valve opening D, into the compression space of the engine cylinder. The suction of the piston does not bring in the explosive mixture of gas and air; it is the pressure of the atmosphere that causes the mixture of gas and air to rush into the cylinder. Just before the piston is at the extreme end of the downward or outward stroke, the inlet valve B is closed by the spring shown, and the piston begins the first upward or "compression" stroke

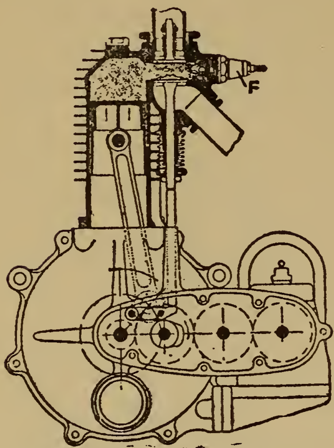


Fig. 222. Power stroke begun

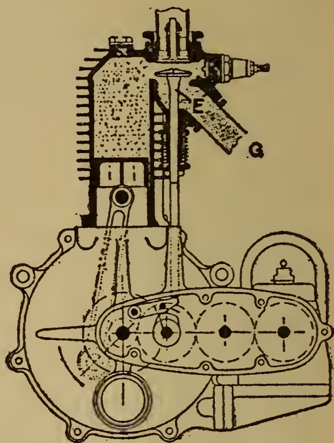


Fig. 223. Exhaust stroke begun

with both the inlet valve B and the exhaust valve E closed. The charge is being compressed when the piston is on its upward stroke, as shown in Fig. 221. Speaking generally, soon after the piston is over what is known as the "dead centre," and is about the position shown in Fig. 222, an electric spark is made to jump across two points of the sparking plug F; this ignites the mixture of gas and air (which is at a pressure of about 80 lb. per sq. in.), and the explosion causes the piston to descend on the power stroke. Just before the piston reaches the bottom of the power stroke, the exhaust valve E, Fig. 223, opens, and remains open during the upward stroke. The momentum of the fly-wheels, etc., carries the piston upward, and thus forces out the burnt gases through the exhaust opening G, and from there to the silencer. Immediately the piston begins its next downward stroke, the inlet valve opens, fresh air is drawn in, and the cycle of operations is repeated as before. The illustrations show a magneto gear driven by the engine.

These engines when properly arranged are made to do service as marine motors, and are then installed either horizontally or vertically. A vertical engine has been shown on previous pages, but perhaps a little further explanation may not be amiss. Engines for boats are made with one cylinder or with more, and there are many considerations which make an engine of two or more cylinders particularly desirable. It is a self-evident fact that when the limit of size of a single-cylinder is reached, it is necessary to add other cylinders if greater power is desired. Even for moderate or small powers, there are many advantages. Among these may be noted the fact that with the proper arrangement of cylinders the impulses may be made to occur at shorter intervals than with a single-cylinder engine.

Thus with a two-cylinder engine, the cylinder may be so arranged that the impulses will occur twice for every revolution instead of once, as in a single-cylinder. This gives a more even turning effect to the shaft, and consequently steadier running, and it also requires a less heavy fly-wheel. The vibration is much less, as one set of working parts may be made to travel upward while the other is travelling downward, thus neutralizing the throw of each and lessening the vibration.

In case of the disablement of one cylinder, there is the chance of getting home on the remaining ones. The weight, power for power, of the multiple-cylinder engine is less than that of the single-cylinder engine, as the weight of the fly-wheel and other working parts is less.

While for marine work, single-cylinder engines have been built as large as eight or ten horse-power, they are so large as to be rather cumbersome and the practice now is to build engines of more than six horse-power with two or more cylinders. There are several firms who are making double-cylinder engines as small as four horse-power, which both as to weight and reliability are much superior to those of a single-cylinder.

The original method of constructing a multiple engine, and one which is still used by some builders, is simply to use two or more single-cylinder engines coupled together. This is a cumbersome method and takes up a great amount of space. The simplest method which can be recommended is that shown in Fig. 224. It consists of two single-cylinders mounted on a common base of special design, bringing the cylinders much nearer together than when a coupling is fitted to connect two separate engines — as the shaft can be made in one piece. This particular engine is of the two port type, two vaporizers V-V being used. The gasolene enters at G and branches to each vaporizer. The pump is shown at P with the discharge at W, piped with a branch to each cylinder. The cooling water outlet is at O. The exhausts are connected to a common pipe with the outlet at E. The igniting gear for each cylinder is independent and on opposite ends. By means of the lever L,

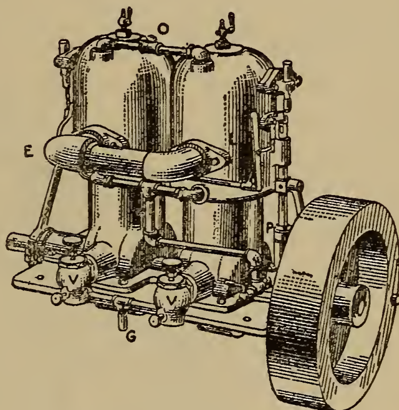


Fig. 224. Two-cylinder engine

which is connected to both igniting gears, the time of ignition is regulated and kept the same on both cylinders. This allows multiple-cylinder engines to be built with very few extra parts, as the cylinders, ignition gear, etc., are the same as in the single-cylinder engine.

A view of a representative single-cylinder engine is shown at Fig. 225. The cam shaft is located at *a* and is driven by the gears which are shown just in the rear of the fly-wheel. At *c* are the cam and the

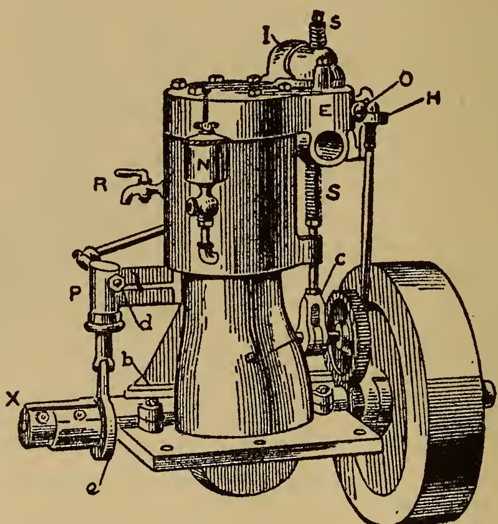


Fig. 225. Single-cylinder engine

roller, which actuates the exhaust valve. The cam consists of a collar with a flat projection or toe upon its surface; the roller rests just above the surface of the collar, and is forced upward when struck by the projection. The roller is inserted to lessen the friction by rolling instead of rubbing. The valve stem extends upward into the valve chamber, and is encircled by the coiled spring *e;* the stem is guided by the guide at *g.* The exhaust is at E; I is the pipe leading from the vaporizer V to the inlet port in the valve chest. The inlet valve is directly below the spring S and is inverted, being held in place by the spring. The dome-shaped cap containing the inlet valve is removable for access to both valves. The complete cover is also removable. It will be observed that this engine has an open frame very similar to that of a steam engine, giving free access to the crank-pin and main bearings; the latter are shown fitted with oil boxes *b* instead of the grease cups, as there is no pressure tending to force the oil out along the shaft as in the two-cycle type. This open base not only makes the bearings more accessible, but renders it easier to lubricate them and keep them cool. At H is the ignition gear. P is the cooling water pump, run by the eccentric *e.* The suction is piped to *d* and the pump discharges through the pipe *k* into the cylinder. The outlet for the cooling water is at O; N is the cylinder oil cup for oiling the bore of the cylinder. The compression cock R is for relieving the compression at starting. The coupling at X is for attaching the propeller shaft.

In this engine, the cylinder, base and bolting flange are one casting, the upper half of the main bearing being removable for the insertion of the shaft. The cover is bolted on separately.

AUTOMOBILE FRAMES

The chassis for the single-cylinder, eight horse-power motor machine shown herewith is built on the principle of most frames, of any make and is typical of the majority of light motor car chassis at present in use.

A diagrammatic plan of the eight horse-power, single-cylinder chassis is shown in the accompanying illustration (Fig. 226) in which, A indicates parts enclosed, taking the mixture of gasolene and air from the float-feed spray carburetor B, which has an automatic air regulator. The purpose of this last device is to dilute the mixture when the engine has a light load and is inclined to race; generally speaking, this regulator serves to proportion the ingredients of the explosive mixture to the requirements of the engine. Current O for the ignition of the

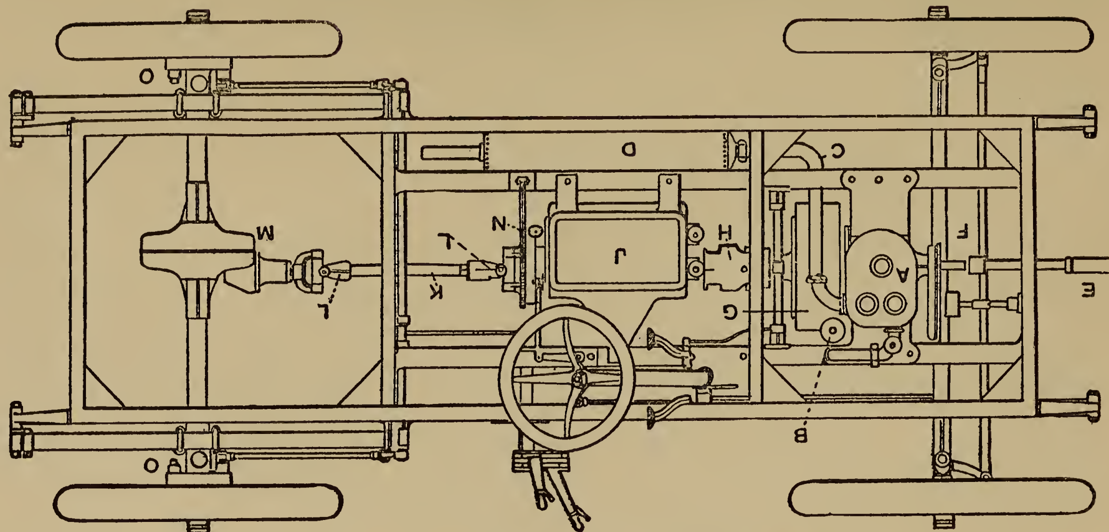


Fig. 226. Eight horse-power single cylinder chassis

explosive mixture (ignition occurs once for every two revolutions of the fly-wheel), is supplied by an accumulator and intensified by a high-tension coil. The products of combustion pass through the exhaust pipe C to the muffler D, from which they pass to the atmosphere through a series of fine holes. The starting handle E makes a simple connection with the end of the motor shaft F when required. G is the fly-wheel. The drive from the engine is through a universal joint H to the change-speed gear J, the latter consisting of two trains of toothed wheels, a big wheel on the primary shaft gearing with a small one on the secondary shaft to give a high speed, and vice versa. From the change-speed gear, the drive is through a shaft K, having a universal joint L at each end, to the bevel gearing above the differential gear of the live rear axle. Bevel gears and the differential gear are all contained in the casings M. Three brakes are fitted, one operated by pedal, working on a drum N secured to the propeller shaft, the others operated by the side lever and working on drums O O, secured to the rear wheels. The change-speed gear gives three speeds forward and a reverse; the frame is of pressed steel; the rod and wheels are of the artillery type and carry 700 mm. by 85 mm. pneumatic tires. The gasolene

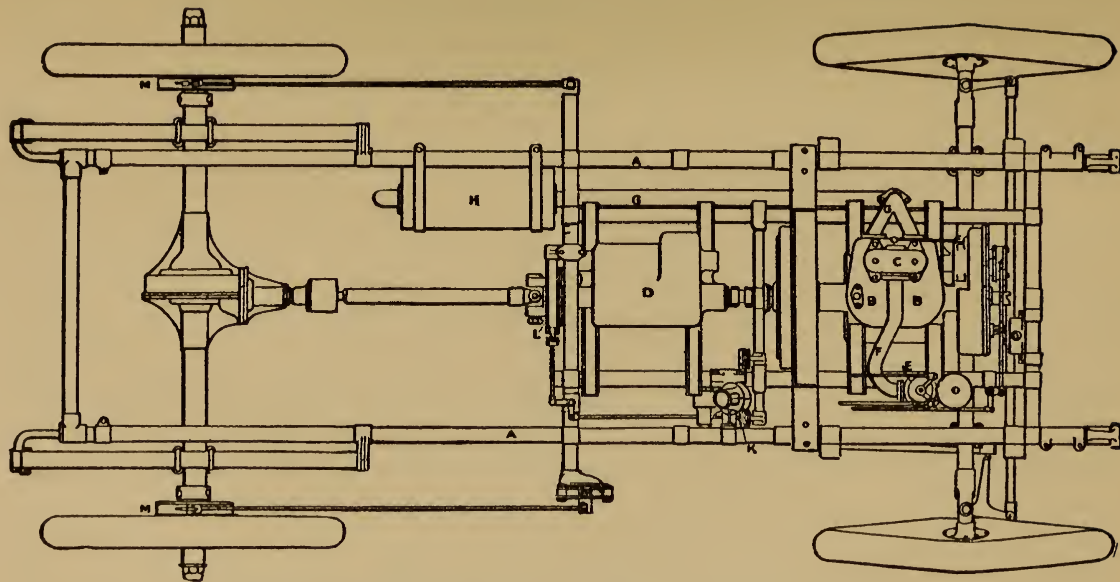


Fig. 227. Plan of chassis of light racing car—two-cylinder motor

tank holds 4½ gallons, sufficient for 200 miles, and the lubricating oil tank holds 1 gallon, sufficient for 350 miles. Any beginner in motoring matters, who studies the diagram, will obtain a fair idea of the mechanism of the customary type of light car chassis.

A chassis, suitable for a 7½ horse-power quick-speed, two-cylinder motor, is shown in Fig. 227.

It is not necessary to enter fully into the details of construction after describing such a typical gear-driven car as that at Fig. 226.

The frame A is of tubular steel, there are four semi-elliptic springs, and the artillery wheels have 28-inch by 3-inch tires. The two-cylinder engine B is one casting, with a large waterway covered by an inspection plate C. The bore is 3.5 inches stroke 4-inches, cylinder capacity 76.9 cubic inches, and the piston displacement is 92.300 cubic inches per minute. A governor automatically throttles the inlet when the motor attempts to race, but by means of a lever the governor can be cut out and the motor accelerated from its normal speed of 1,200 revolutions per minute. The balanced crank has but a single throw; the water circulation is assured by a motor-driven pump, and there is a belt-driven fan behind the radiator. The commutator is easily accessible, being mounted on a bevel shaft lying in a sloping position and passing through the side of the crank chamber. Ignition is high tension with wide contact, the wiring being enclosed in a neat wooden casing. The change-speed gear D gives three speeds and a reverse, and its main bearings are fitted with ring lubricators. A pressure sight feed lubricator on the dash-board has three outlets, one to the engine, another to the main clutch, and a third to the driving pinion on the end of the propeller shaft. The brakes are of the usual kind. In Fig. 2, E is the carburetor, F the inlet and G the exhaust pipes, H the exhaust muffler, J the brake pedal, K the clutch pedal, L the band-brake on the propeller shaft, and M the internal expanding brakes on the wheel hubs. A shield is arranged under the front of the car to protect the mechanism from mud and dust. The weight of the car unladen is about 1,414 pounds, the wheel base is 73½ inches, the track 46 inches, and the over-all dimensions are 111 inches by 60 inches. During a 600-mile trial this engine consumed 36 gallons, 6 pints of gasolene, this being at the rate of 1 gallon for every 16.9 car miles; .077 gallon was consumed every ten miles.

THE MODERN TYPE-WRITER

Every home of importance contains a writing machine of some kind, and these often require some little adjustment or "fixing." It is within the capacity of any bright boy to make these adjustments, or to do the little fixings, if he tries it earnestly.

The first marketable type-writer was introduced in the year 1875. No sooner had the type-writer acquired a commercial value, than the fire of inventive talent was awakened in Europe and America, and type-writer after type-writer appeared on the market — a few came to stay, but the many disappeared, either during the chrysalis or experimental stage, or shortly after it had been passed. Inventors and investors have learned that hasty innovations and untried experiments spell "failure" in the type-writer field, and only patient and careful study, backed by experience, tireless effort, and abundant resource, have a chance of success.

By the year 1888, there were six different kinds of machines in the market, to-day there are at least twenty, but the favourites seem to be, "The Remington," "Smith Premier," "The Underwood" and "The Oliver."

Modern type-writers may be defined as being tabulating, book recording, card indexing, and document writing machines. They are speedier and produce finer and more varied work than their predecessors.

The manner in which the type-writer performs its work is of the simplest. The type-writer may be considered as composed of three general parts, as follows:

The keyboard, by which the operation of the machine is directed.

The type mechanism, by which the desired letters are, one after the other, in any desired sequence, imprinted on the paper.

The carriage, which holds the paper in proper position for writing, and which, by its regular movements, provides for the spacing of letters and lines.

The Remington may be considered the pioneer of writing machines. In appearance the Remington No. 5 (introduced in 1888) is square, and strikes a novice as being somewhat complicated. It is only the multiplicity of parts, however, which creates this impression. The machine is not complex, the same parts being repeated over and over again. The action is simplicity itself. The machine is quite open on every side, so that its entire construction can easily be seen. There is a japanned iron frame enclosing and holding the working parts, consisting of a base, four upright posts, and a top plate. In front is a series of keys arranged in four banks, like the keys of an organ, each key representing the two characters, termed "upper" and "lower" case letters. These are connected with long light wooden levers, which, being depressed, communicate motion by means of a rod fastened to the lever of a type bar. At the end of each type bar is fixed the hard metal type representing the two characters. The type bars are arranged in a circle, therefore the point of percussion of the type on the paper is at a common centre. The inking is done by a ribbon, which travels automatically across the machine, winding and rewinding on and from spools.

The paper is inserted between two rollers; one of rubber, called the "paper cylinder," and the other of wood, called the "feed roll." The rollers are held together by two elastic india-rubber bands. As one revolves so does the other. The portion which holds these rollers is designated the "carriage." By a clever, yet simple piece of mechanism, this carriage is caused to travel, simultaneously with the return of the type or spacing bar, from right to left, the width of a letter at each movement across the machine. The carriage works on a sliding frame, and this sliding mechanism is controlled by two keys, which do not impress letters on the paper. These change the character of the printing keys, causing them to print capitals or small letters, numerals or other marks at will. Depress the key marked "upper case" and all the keys will print capitals; remove the finger and they all print small letters again. Moreover, the machine can be arranged to print capitals continuously by the mere raising of a lever, and quite independently of the "upper case" shift key.

To obtain an impression, the required key is struck lightly, and the type bar causes the type to strike against the ribbon, thus leaving an imprint on the paper held round the cylinder; the carriage moves automatically the width of the letter, and the operation is repeated until a word is completed. Then the "spacing bar" at the front of the machine is depressed at any point, thereby securing the requisite space between the words.

When the end of a line is reached, warning is given by the ringing of a bell, and then, by pulling out the lever at the right-hand side of the carriage and gently pressing to the right, the paper carriage is advanced into position to receive the next line. The distance between the lines and the width of the writing can be regulated. The paper carriage being hinged at the back allows of its being raised from the front by the hand, so that the line that has just been written can be inspected.

The motive power is imparted by an adjustable coiled spring, a thin leather strap being fastened to it and the carriage, and the uniform space is governed by two clutches working on a rack. This rack is fixed on a rocking shaft, and derives a swinging motion from a universal bar fixed beneath the light wooden key levers.

A small lever attached to the left of the carriage holds its movements under the control of the operator. Two scales are fixed on the machine, and these in conjunction with the pointer, permit of headlines being centred, corrections made, etc.

In some machines, a special key and its accompanying mechanism is provided for each character or sign used — such are termed "complete" keyboard machines. In others, each key is made to represent the letters or signs — such are designated "single-shift" machines. Others, again, have two shift-keys, and each key represents not only a lower case (small) and an upper case (capital) letter, but a figure or other sign as well — such are known as "double-shift" machines.

The two classes of modern type-writers may be arranged into three groups, namely:

"Blind" writers, in which the writing remains hidden until exposed by manipulative effort of the operator. "Semi-visible" writers, which show only the last lines, or only expose the centre of the paper, hiding the writing at both ends of the line. "Visible" writers, which expose a character directly in front of the operator the instant it is imprinted; the character subsequently does not pass out of sight, by feeding behind a scale or bar, or other obstruction. This classification and grouping is for

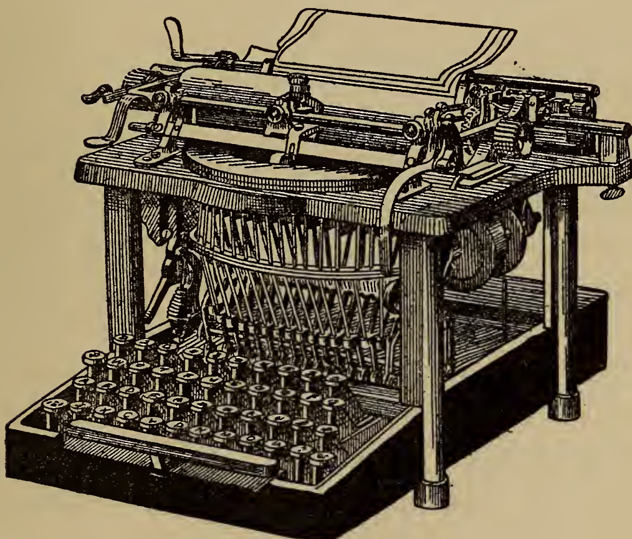


Fig. 228. Remington type-writer No. 7

convenience only, and is in no way intended to denote superiority.

With regard to the Remington, many changes of the details of construction, tending toward strength, durability, and a greater ease and convenience of operations, have been introduced into the machine, which have survived the severe test of time. This is especially the case with Remington No. 7 (see Fig. 228). The most important of these valuable improvements are: An entirely new form of escapement, giving increased speed and an easy touch. The carriage is stronger and lighter, and steadier in all respects. The annoying rubber bands, which guide the paper around the platen have been discarded for a new form of paper guide, which may be adjusted to any desired point. The paper feed has been so arranged as to render it possible to write on wide or narrow paper, and this can be fed into the machine by a simple movement of the hand without lifting the carriage, and can be turned forward or backward at will. The ribbon movement is improved and works entirely automatically, reversing and giving a lateral movement. The marginal stops also are improved, and simple means provided for writing outside the margin whenever desired. There is a keyboard lock, locking the types at the end of the line, and thus preventing one letter being printed over another. A new variable line spacer is embodied, which makes it easier to write at any point on the paper, and prolongs the life of the platen for the reason that the type no longer strikes in unchanging grooves. An adjustable side guide for arranging the paper to any desired marginal indentation is a recent addition. A new two colour ribbon lever bearing a disc, which signals the color which the machine is adjusted to write is another recent addition.

The Smith-Premier type (Fig. 229) has six models

Fig. 229. Smith Premier No. 4

in the market and all nearly alike in their mechanism, differing only in the carriage arrangements, or the number of the characters. The machine is particularly simple in construction, and claims, by means of a very long and strong adjustable bearing, to have secured a perfect and permanent alignment. The type bars work on hardened steel bearings, $1\frac{5}{8}$ inches apart, and the type bars are the shortest of any on a "complete" keyboard machine. But the original and exclusive feature of the machine is the rocking shaft, which replaces the usual wooden or metal key lever. This consists of a circular rod, passing from the front to the rear of the machine — one rod for each key. Projecting from each shaft is a small bar, which is attached at the front end to the lower portion of the key stem. A similar projection is attached to the rod communicating with the type bar, and the result is that on the depression of the key the rocking shaft is made to revolve slightly, and so raise the free end of the type bar to the printing point. The type bar hangers are solidly riveted to the type ring. It will be seen that matters are so arranged that the amount of force to imprint the character is precisely the same in every case —a uniform, light and elastic touch. A very noticeable feature is its quietness in operation, due to the rigidity of its parts, and the fact that the ball-bearing principle is adopted wherever it can be used to advantage. It is also equipped with a circular brush, built into the machine, into which, a handle can be immediately inserted, when, with a turn or two, the whole of the type can be cleaned.

The most striking recent development is the adoption of a three-coloured ribbon device. A simple movement of the lever in front of the machine brings the required colour into place ready for use. A two-colour or single colour ribbon may be employed. If desired. The ribbon can be instantly shifted from the printing point for duplicating purposes. The ribbon reverses automatically, and it is at-

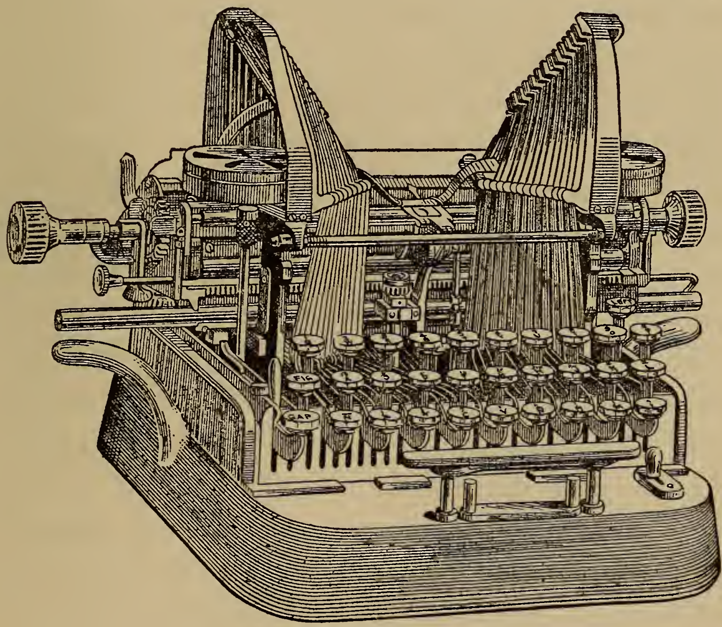


Fig. 230. The Oliver No. 3

tached to the spools with clamps — one on each spool, dispensing entirely with pins and tapes.

The Oliver, Fig. 230, differs in mechanical principle from other machines. It has a wide U–shaped steel type bar, provided with a tool-steel axle as broad as the bar is long, and braced joints insuring the alignment without guides. The connection between the type bars and the key levers is direct and perpendicular. The type bars strike down on the platen in a line perpendicular to its plane, thus transmitting the maximum power with the minimum resistance, and further, maintaining the alignment with several sheets as with one. The type are of steel, and lie face upward — very convenient for cleaning. The keyboard is the "Universal," having twenty-eight keys with a "double" shift, giving eighty-four characters and the special model thirty-two keys, giving ninety-six characters.

The tension and depression of the keys are light and uniform. It may also be noted that the type blocks decrease in weight with the increase of length of type bar — necessary to secure a uniform stroke. The escapement mechanism is exceedingly simple and positive, and although very rapid is almost frictionless. The writing is semi-visible. The carriage is provided with three paper-feed rolls, thus ensuring a perfect feed of the paper down to the bottom edge of the sheet. It runs on anti-friction travellers on guide rails, ensuring an easy and steady motion. It is equipped with all the necessary devices. The line space mechanism operates automatically as the carriage is returned from the left to the right for a new line. The machine is compact and portable — weight about twenty pounds.

The parts of any of the machines now in the market, may readily be disconnected, but care must be taken by the novice in laying aside the parts so that they may be easily and correctly assembled. Repairs on the various parts may be made while out, and when made may be placed *in situ*. Any or all of the parts may be cleaned when the carriage is taken off. A little study of the machine when sitting before a person, will enable him to understand its mechanism, and when this is accomplished, cleaning and repairing can be done intelligently.

The tendency of the times is to employ the typewriter whenever possible. Special devices are from time to time invented to meet extended uses. The most important of recent applications is to office work for billing and book-keeping; this work alone has necessitated important modifications. In this direction, the tabulator calls for review. The lack of a practical method enabling tabular matter to be typed with a rapidity equal to that of the ordinary typing has long been felt to be a deficiency in type-writers. The invention of the tabulator has enormously increased the scope of the machine in this direction.

The tabulator is a device by means of which, figures or words can be written in columns, with out employment of the space bar or carriage release lever, or any adjustment whatever of the carriage by hand. By its use, the carriage may be set automatically at any point that may be required. At present this device is an accessory to most machines, but in the near future, it must form an integral part of all machines, and further, enable the carriage to be automatically placed in a proper position to write numbers in correct relation to each other in columns; that is, units under units, tens under tens, and so on. The built-in tabulators of to-day, with but two exceptions, are deficient in this respect. The tabulator in either form does not interfere with the use of the machine for other work, such as correspondence, etc.

The tabulator was followed by the introduction of a bi-chrome (two-coloured ribbon), and quite recently the Smith Premier Typewriter Company has advanced still further in this direction by introducing a tri-chrome (three-colour) ribbon. By a simple movement it is possible to vary the colour of the impression instantaneously, so that credits, marginal notes, footnotes, and underscoring may be indicated in red or other colour preferred. One-colour ribbons can be used if desired.

The machine embodying the parti-coloured ribbons and tabulator devices are generally known as "invoicing" machines, and by simple arrangements, every phase — not only of correspondence, but also of office and statistical work — can be accomplished, with an enormous saving of time. Items can be made on sheets, which may be taken from the machine with absolute certainty that when re-inserted, the subsequent entries will fall into their proper places.

Card Indexing.—For greater convenience in card indexing, special platens are obtainable, or the ordinary platens can be temporarily fitted with a metal clip. Both can be fitted to or removed from the machine in a few seconds, and the cards can be adjusted in an instant. The increasing use of the card file system for a wide variety of purposes lends special importance to the value of the type-writer for this class of work.

Interchangeable Carriages.—For years the thousand and one wide forms, statements, and blanks common in every business office, have been filled by the pen, the reason being that there was no machine practicable for both wide and ordinary work. The manufacturers of most of the modern type-writers now have models embodying inter-

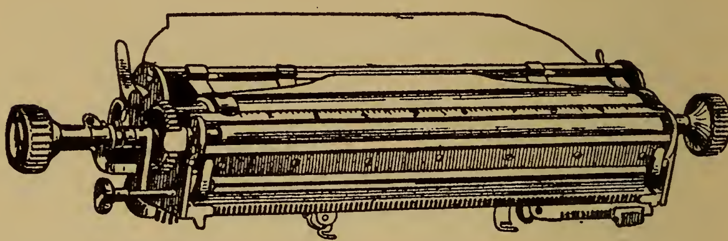


Fig. 231. Interchangeable carriage

changeable carriages, which enable any one possessing a machine with this improvement to have at the same time a set of carriages from the largest to the smallest, all of which can be used upon one machine. In one or two makes this is additional to interchangeable platens.

Duplicators. — The value of a mechanical contrivance for the rapid and effective multiplication of copies of documents is fully recognized at the present time.

Duplicating machines have been on the market for several years. They will produce from one typescript original up to 3,000 copies, of any size, from a post card to a sheet of brief, every copy having the exact appearance of an original. While there are various makes and styles of duplicators, the main principle is the same throughout. The original is prepared by the now well-known stencil process; that is, writing the matter required with a type-writer on a sheet of waxed paper. The pressure of the type expels the wax out of the paper and leaves openings through which the ink can penetrate. In the Roneo rotary duplicator, a metal frame supports a cylinder of thin, perforated steel. On the outer surface of the cylinder is stretched a linen ink-pad, and over this is placed the stencil. The pad is inked by a rubber roller resting in an ink receptacle suspended between the two sides of the framework. By means of a simple lever this roller can be brought into contact with the cylinder, and ink is thus supplied as required. The cylinder is rotated by a handle. Paper fed into the machine is gripped by a rubber impression roller, which presses it against the stencil as the cylinder revolves, and the sheet perfectly printed, is then automatically discharged on the other side. The rotary can be fitted with three devices, namely, a simple contrivance, which automatically feeds the sheet into the machine, reducing hand labour to a minimum; an interlever, which automatically drops an interleaving sheet as each copy is printed — thus permitting of the use of highly glazed or very hard paper; a cyclometer for registering the number of copies. The rotary system is far superior to the hand duplicators in the matter of speed; such a machine will print ten copies while the hand device prints one. There is no lost motion, a copy being printed and discharged at every revolution.

Press Copying.—At the present time, there are four methods of letter copying in vogue, namely: (1) The letter-book method, damping sheets and screw press. (2) Roller process, water bath and drying drum. (3) Carbon paper. (4) The chemical letter copier.

The roller copies employ a water bath, and give but little if any improvement in the regulation of the degree of moisture. The copies are wound on a drying drum to prevent off-setting, and subsequently have to be cut apart for filing purposes.

The carbon process enables the answers to be filed with the original letter.

The modern chemical letter copier offers distinct advantages over other methods. It consists of a simple machine designed to carry a roll of specially prepared paper. The letter to be copied is laid on the feed board, the handle is turned, the sheet is fed automatically into the machine.

It will be noticed that a water bath and brush or damping sheets, are completely dispensed with; there is no "off-sheeting" and no drying drum. The copy may be either filed with the letter to which it relates, or placed, day by day, in a cover having the appearance of an ordinary letter-book; or two copies can be made of each letter — one for filing and the other for the book.

(1). A type-writer should be durable. Every part should be simple and strong and adapted to serve its purpose with the smallest degree of wear. Every mechanical movement must be definite, and incapable of incomplete performance. All wearing parts should be adjustable and interchangeable.

(2). It should possess absolutely "visible" writing. The common-sense way to write easily and speedily is to see what you are writing while you are writing it.

The writing should be performed in such a part of the machine as to be most readily seen during progress.

(3). The keyboard — on type bar machines in particular — should be that known as the "Universal," or "Standard" arrangement.

The keys on any style of keyboard should have a light and uniform depression, so that the machine may be operated with the minimum of fatigue.

(4). The types should present an even and regular appearance, termed "alignment." A type bar made of suitable material in the right way is the keystone of typewriter construction. In all machinery, there is some part on which falls the greatest strain and wear; consequently on the durability of that part rests the life of the machine. The devices used to secure alignment are numerous and ingenious. One machine depends on a wide pivoted bearing and a rigid type bar; another has a bearing composed of a continuous steel rod, with a type bar flexible while in motion, and made rigid at the printing point by means of guides; a third employs a wide pivotal bearing, a flexible type bar and an indispensable guide plate at the printing point; a fourth employs a compound type bar and an indispensable guide at the printing centre, and so on. Some have wide and adjustable bearings, to enable the wear to be taken up. These devices, however, are not the only essentials; The type bar hangers in machines embodying the pivotal principle need to be rigid and solidly fixed, while the paper carriage should be perfectly rigid and present a level and even platen surface for the type to strike against.

(5). The type should be capable of being easily and quickly cleaned, and in such a way as not to injure the type or soil the hands. A device should be embodied for rendering it impossible to batter the face of the type when the type bars are accidentally struck one against the other, and for preventing the type perforating or puncturing the platen.

(6). The mechanism controlling the movement of the carriage should act rapidly and uniformly, and its tension should be adjustable. The carriage should have a sure and regular paper feed and be capable of accommodating any smaller width of paper; also the margin regulators and bell trip should be easily and readily altered.

(7). The platen roll should be instantly interchangeable, thereby allowing of a soft substance platen being used for a single copy work and a hard one for manifolding. If the hard platen is of reduced diameter, more perfect alignment is secured on machines employing a complete circle of rigid type bars and a central top carriage.

(8). The line-spacing mechanism should be variable, and effected by one movement at all times; that is, the same movement that accomplishes the line feed should be utilized to return the carriage for a new line.

(9). The ribbon movement should consist of a reliable feeding mechanism, and allow of the fabric being quickly withdrawn, replaced, or adjusted. It should bring the whole surface in contact with the type, and also automatically reverse the endwise travel.

(10). The machine should be as noiseless in operation as possible. Machines differ very much in this particular. The employment of the guides to force the alignment introduces metallic contact, and consequent friction and noise.

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