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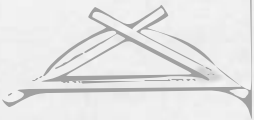

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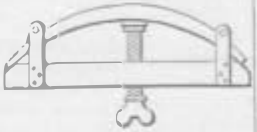

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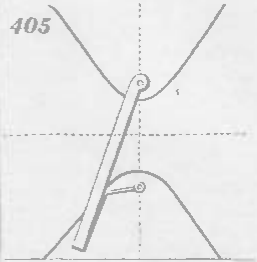

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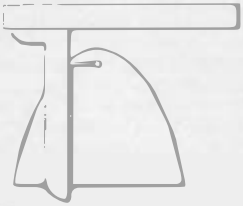

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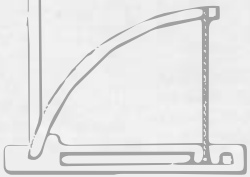

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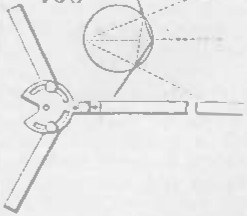

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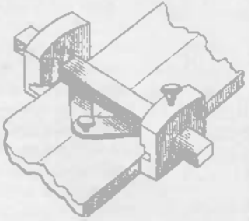

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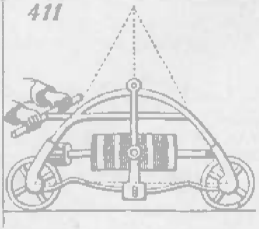

403. Cyclograph for describing circular arcs in drawings where the center is inaccessible. This is composed of three straight rules. The chord and versed sine being laid down, draw straight sloping lines from ends of former to top of latter, and to these lines lay two of the rules crossing at the apex. 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.

404. Another cyclograph. The elastic arched bar is made half the depth at the ends that it is at the middle, and is formed so that its outer edge coincides with a true circular arc when bent to its greatest extent. Three points in the required arc being given, the bar is bent to them by means of the screw, each end being confined to the straight bar by means of a small roller.

405. Mechanical means of describing hyperbolas, their foci and vertices being given. Suppose the curves two opposite hyperbolas, the points in vertical dotted center line their foci. One end of rule turns on one focus as a center through which one edge ranges. One end of 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 center line. A pencil held in bight, and kept close to rule while latter is moved from center line, describes one-half of parabola; the rule is then reversed for the other half.

406. 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.

407. Instrument for describing pointed arches. Horizontal bar is slotted and fitted with a slide having pin for loop of cord. Arch bar of elastic wood is fixed in horizontal at right angles. Horizontal bar is placed with upper edge on springing line, and back of arch bar ranging with jamb of opening, and the latter bar is bent till the upper side meets apex of arch, fulcrum-piece at its base insuring its retaining tangential relation to jamb; the pencil is secured to arched bar at its connection with cord.

408. Centrolinead for drawing lines toward an inaccessible or inconveniently distant point: chiefly used in perspective. Upper or drawing edge of blade and back of movable legs should intersect center of joint. Geometrical diagram indicates mode of setting instrument, legs forming it may form unequal angles with blade. At either end of dotted line crossing central, a pin is inserted vertically for instrument to work against. Supposing it to be inconvenient to produce the convergent lines until they intersect, even temporarily, for the purpose of setting the instrument as shown, a corresponding convergence may be found between them by drawing a line parallel to and inward from each.

409. 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 proportion.

410. Bisecting gauge. Of two parallel cheeks on the cross-bar one is fixed and the other adjustable, and held by thumb-screw. In either cheek is centered one of two short bars of equal length, united by a pivot, having a sharp point for marking. This point is always in a central position between the cheeks, whatever their distance apart: so that any parallel sided solid to which the cheeks are adjusted may be bisected from end to end by drawing the gauge along it. Solids not parallel sided may be bisected in like manner, by leaving one cheek loose, but keeping it in contact with solid.

411. Self-recording level for surveyors. Consists of a carriage, the shape of which is governed by an isosceles triangle having horizontal base. The circumference of each wheel equals the base of the triangle. A pendulum, when the instrument is on level ground, bisects the base, and when on an inclination gravitates to right or left from center accordingly. A drum, rotated by gearing from one of the carriage wheels, carries sectionally ruled paper, upon which pencil on pendulum traces profile corresponding with that of ground traveled over. The drum can be shifted vertically to accord with any given scale, and horizontally, to avoid removal of filled paper.

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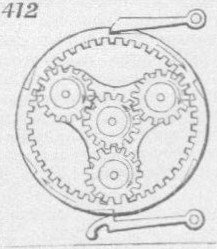

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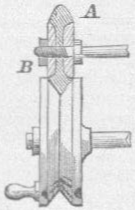

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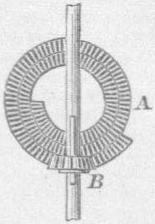

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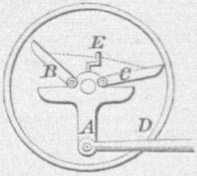

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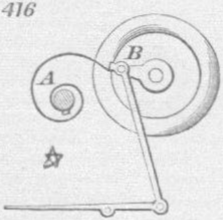

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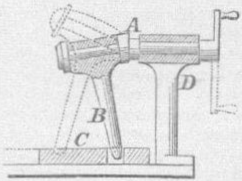

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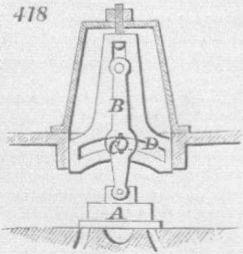

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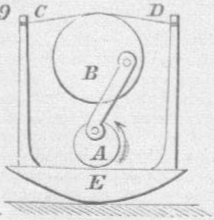

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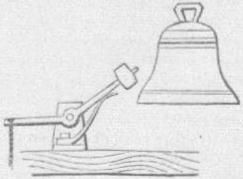

412. Wheel-work in the base of capstan. Thus provided, the capstan can be used as a simple or compound machine, single or triple purchase. The drumhead and barrel rotate independently; the former, being fixed on spindle, turns it round, and when locked to barrel turns it also, forming single purchase; but when unlocked, wheel-work acts, and drumhead and barrel rotate in opposite directions, with velocities as three to one.

413. J. W. Howlett's patent adjustable frictional gearing. This is an improvement on that shown in 45 of this table. The upper wheel, A, shown in section, is composed of a rubber disk with V-edge, clamped between two metal plates. By screwing up the nut, B, which holds the parts together, the rubber disk is made to expand radially, and greater tractive power may be produced between the two wheels.

414. Scroll gear and sliding pinion, to produce an increasing velocity of scroll-plate, A, in one direction, and a decreasing velocity when the motion is reversed. Pinion, B, moves on a feather on the shaft.

415. P. Dickson's patent device for converting an oscillating motion into intermittent circular, in either direction. Oscillating motion communicated to lever, A, which is provided with two pawls, B and C, hinged to its upper side, near shaft of wheel, D. Small crank, E, on upper side of lever, A, is attached by cord to each of pawls, so that when pawl, C, is let into contact with interior of rim of wheel, D, it moves in one direction, and pawl, B, is out of gear. Motion of wheel, D, may be reversed by lifting pawl, C, which was in gear, and letting opposite one into gear by crank, E.

416. A device for assisting the crank of a treadle motion over the dead-centers. The helical spring, A, has a tendency to move the crank, B, in direction at right-angles to dead-centers.

417. Continuous circular motion into a rectilinear reciprocating. The shaft, A, working in a fixed bearing, D, is bent on one end, and fitted to turn in a socket at the upper end of a rod, B, the lower end of which works in a socket in the slide, C. Dotted lines show the position of the rod, B, and slide, when the shaft has made half a revolution from the position shown in bold lines.

418. Buchanan & Righter's patent slide-valve motion. Valve, A, is attached to lower end of rod, B, and free to slide horizontally on valve-seat. Upper end of rod, B, is attached to a pin which slides in vertical slots, and a roller, C, attached to the said rod, slides in two suspended and vertically adjustable arcs, D. This arrangement is intended to prevent the valve from being pressed with too great force against its seat by the pressure of steam, and to relieve it of friction.

419. Continuous circular motion converted into a rocking motion. Used in self-rocking cradles. Wheel, A, revolves, and is connected to a wheel, B, of greater radius, which receives an oscillating motion, and wheel, B, is provided with two flexible bands, C, D, which connect each to a standard or post attached to the rocker, E, of the cradle.

420. Arrangement of hammer for striking bells. Spring below the hammer raises it out of contact with the bell after striking, and so prevents it from interfering with the vibration of the metal in the bell.

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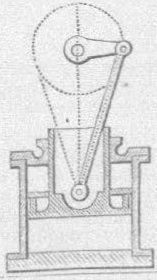

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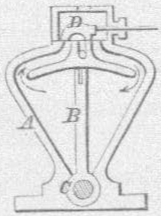

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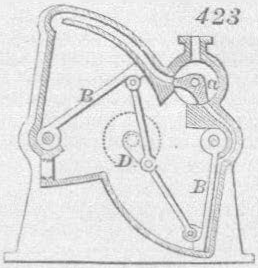

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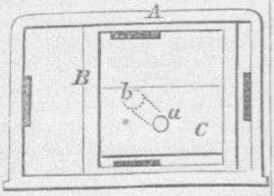

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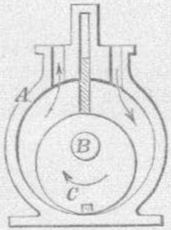

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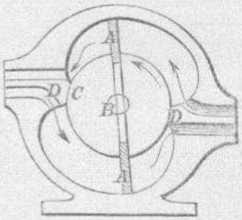

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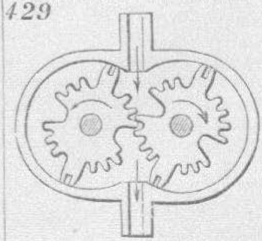


421. Trunk engine used for marine purposes. The piston has attached to it a trunk at the lower end of which the pitman is connected directly with the piston. The trunk works through a stuffing-box in cylinder-head. The effective area of the upper side of the piston is greatly reduced by the trunk. To equalize the power on both sides of piston, high-pressure steam has been first used on the upper side and afterward exhausted into and used expansively in the part of cylinder below.

422. Oscillating piston engine. The profilet of the cylinder A, is of the form of a sector. The piston, B, is attached to a rock-shaft, C, and steam is admitted to the cylinder to operate on one and the other side of piston alternately, by means of a slide-valve, D, substantially like thatt of an ordinary reciprocating engine. The rock-shaft is connected with a crank to produce rotary motion.

423. Root's patent double-quadrant engine. This is on the same principle as 422t; but two single-acting pistons, B, B, are used, and both connected with one crank, D. The steam is admitted to act on the outer sides of the two pistons alternately by means of one induction valve, *a*, and is exhausted through the space between the pistons. The piston and crank connections are such that the steam acts on each piston during about two-thirds of the revolution of the crank, and hence there are no dead points.

424. Roots double-reciprocating or square piston engine. The "cylinder," A, of this engine is of oblong square form and contains two pistons, B and C, the former working horizontally, and the latter working vertically within it; the piston, C, is connected with the wrist, *a*, of the crank on the main shaft, *b*. The ports for the admission of steam are shown black. The two pistons produce the rotation of the crank without dead points.

425. One of the many forms of rotary engine. A is the 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.

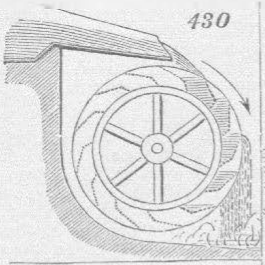
426. Another form of rotary engine, in which there are two stationary abutments, D, D, within the cylinder, and the two pistons, A, A, in order to enable them to pass the abutments, are made to slide radially in grooves in the hub, C, of the main shaft, B. The steam acts on both pistons at once, to produce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

427. Another rotary engine, in which the shaft, B, works in fixed bearings eccentric to the cylinder. The pistons, A, A, are fitted to slide in and out from grooves in the hub, C, which is concentric with the shaft, but they are always radial to the cylinder, being kept so by rings (shown dotted) fitting to hubs on the cylinder-heads. The pistons slide through rolling packings, *a*, *a*, in the hub, C.

428. The india-rubber rotary engine in which the cylinder has a flexible lining, E, of india-rubber, and rollers, A, A, are substituted for pistons, said rollers being attached to arms radiating from the main shaft, B. The steam acting between the india-rubber and the surrounding rigid portion of the cylinder presses the india-rubber against the rollers, and causes them to revolve around the cylinder and turn the shaft.

429. Holly's patent double-elliptical rotary engine. The two elliptical pistons geared together are operated upon by the steam entering between them, in such manner as to produce their rotary motion in opposite directions.

These rotary engines can all be converted into pumps.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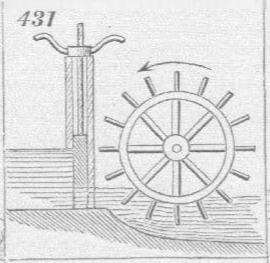
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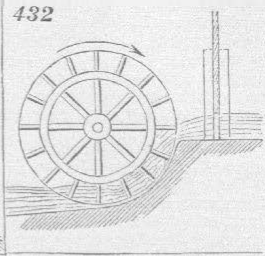
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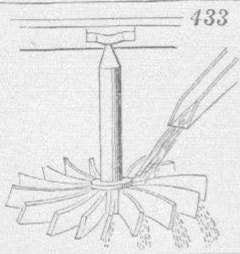
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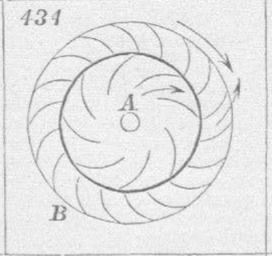
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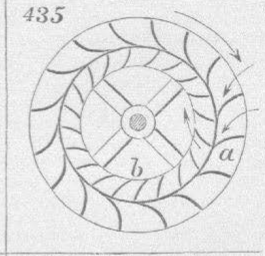
A
B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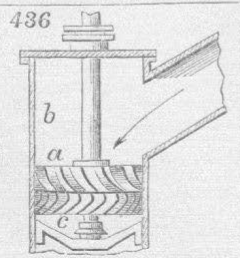
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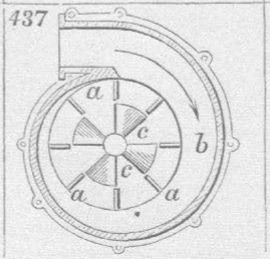
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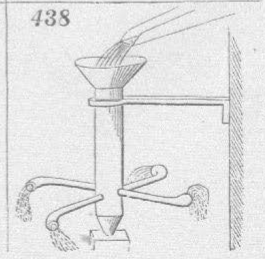
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430. Overshot water-wheel.

431. Undershot water-wheel.

432. 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, and into which water enters nearly at the level of axle.

433. Horizontal overshot water-wheel.

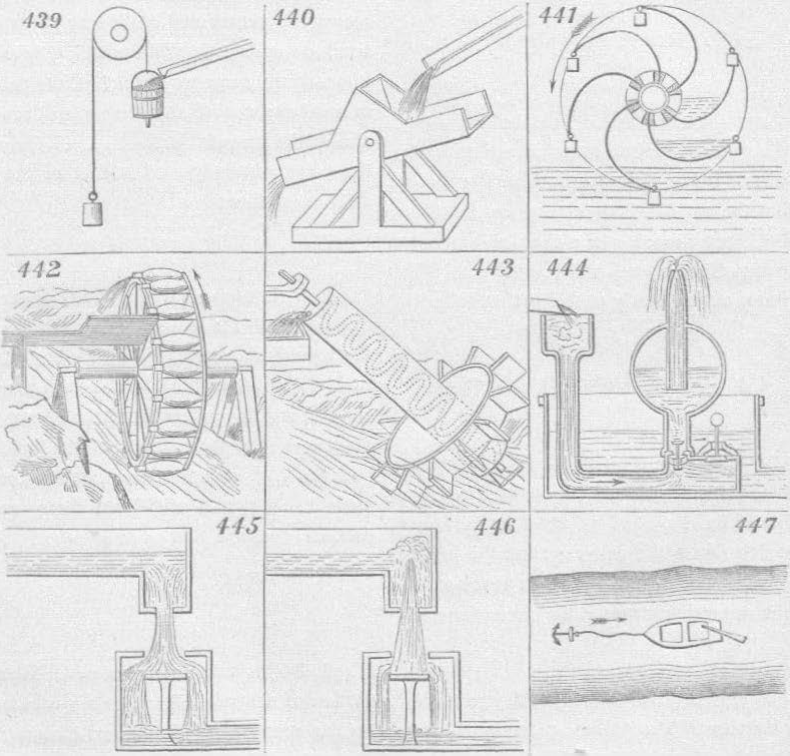
434. A plan view of the Fourneyron turbine water-wheel. In the center are a number of fixed curved "shutes" or guides, A, which direct the water against the buckets of the outer wheel, B, which revolves, and the water discharges at the circumference.

435. Warren's central discharge turbine, plan view. The guides, *a*, are outside, and the wheel, *b*, revolves within them, discharging the water at the center.

436. Jonval turbine. The "shutes" are arranged on the outside of a drum, radial to a common center 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.

437. Volute wheel, havingradial 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.

438. Barker's 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.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439. 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 counter-weight on the other side of the pulley over which it is suspended.

440. 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.

441. 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 floate at each revolution, and conducted to the hollow shaft at the same time that one of the buckets carries its fill 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.

442. 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.

443. Application of Archimedes's screw to raising water, the supply stream being the motive power. The oblique shaft of the wheel has extending through it a spiral passage, the lowere 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.

444. Montgolfier's hydraulic ram. Small fall of water made to throw a jet to a great height or furnish a supply at high level. The right-hand valve being kept open by a weight or spring, the current flowing through the pipe in the direction of the arrow escapes thereby till its pressure, overcoming the resistance of weight or spring, closes it. On the closing of this valve the momentum of the current overcomes the pressure on the other valve, opens it, and throws a quantity of water into the globular air-chamber by the expansive force of the air in which the upward stream from the nozzle is maintained. On equilibrium taking place, the right-hand valve opens and left-hand one shuts. Thus, by the alternate action of the valves, a quantity of water is raised into the air-chamber at every stroke, and the elasticity of the air gives uniformity to the efflux.

445 and 446. D'Ectol's oscillating column, for elevating a portion of a given fall of water above the level of the reservoir or head, by means of a machine all the parts of which are absolutely fixed. It consists of an upper and smaller tube, which is constantly supplied with water, and a lower and larger tube, provided with a circular plate below concentric with the orifice which receives the stream from the tube above. Upon allowing the water to descend as shown in 445, it forms itself gradually into a cone on the circular plate, as shown in 446, which cone protrudes into the smaller tube so as to check the flow of water downward; and the regular supply continuing from above, the column in the upper tube rises until the cone on the circular plate gives way. This action is renewed periodically and is regulated by the supply of water.

447. This method of passing a boat from one shore of a river to the other is common on the Rhine and elsewhere, and is effected by the action of the stream on the rudder, which carries the boat across the stream in the arc of a circle, the center of which is the anchor which holds the boat from floating down the stream.

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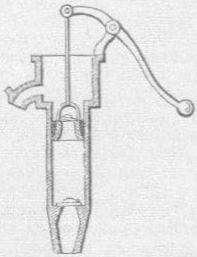

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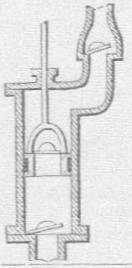

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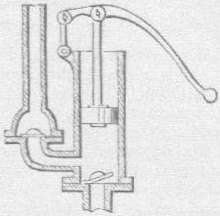

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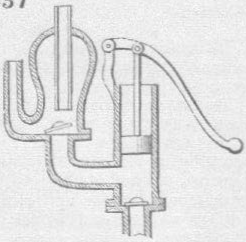

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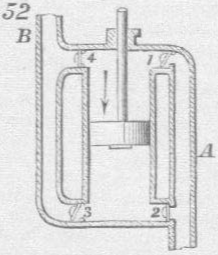

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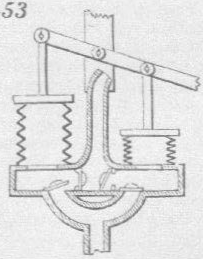

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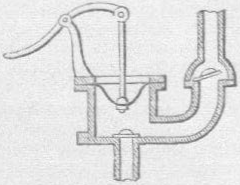

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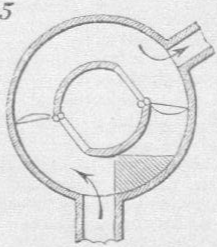

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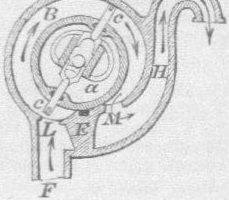

448. Common lift pump. In the up-stroke of piston or bucket the lower valve opens and the valve in piston shuts; air is exhausted out of suction-pipe, and water rushes up to fill the vacuum. In down-stroke, lower valve is shut and valve in piston opens, and the water simply passes through the piston. 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.

449. Modern lifting pump. This pump operates in same manner as one in previous figure, except that piston-rod passes through stuffing-box, and outlet is closed by a flap-valve opening upward. Water can be lifted to any height above this pump.

450. 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, outlet-valve being closed. On descent of piston suction-valve closes, and water is forced up through outlet-valve to any distance or elevation.

451. Force pump, same as above, with addition of air-chamber to the outlet, to produce a constant flow. The outlet from air-chamber is shown at two places, from either of which water may be taken. The air is compressed by the water during the downward stroke of the piston, and expands and presses out the water from the chamber during the up-stroke.

452. 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 a 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.

453. Double lantern-bellows pump. As one bellows is distended by lever, air is rarefied within it, and water passes up suction-pipe to fill space; at same time other bellows is compressed, and expels its contents through discharge-pipe; valves working the same as in the ordinary force pump.

454. Diaphragm forcing pump. A flexible diaphragm is employed instead of bellows, and valves are arranged same as in preceding.

455. Old rotary pump. Lower aperture entrance for water, and upper for exit. Central part revolves with its valves, which fit accurately to inner surface of outer cylinder. The projection shown in lower side of cylinder is an abutment to close the valves when they reach that point.

456. Cary's rotary pump. Within the fixed cylinder there is placed a revolving drum, B, attached to an axle, A. Heart-shaped cam, *a*, surrounding axle, is also fixed. Revolution of drum causes sliding-pistons, *c*, *c*, to move in and out in obedience to form of cam. Water enters and is removed from the chamber through ports, L and M; the directions are indicated by arrows. Cam is so placed that each piston is, in succession, forced back to its seat when opposite E, and at same time other piston is forced fully against inner side of chamber, thus driving before it water already there into exit-pipe, H, and drawing after it through suction-pipe, F, the stream of supply.

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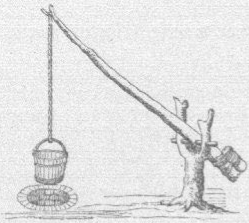

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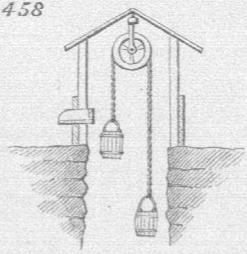

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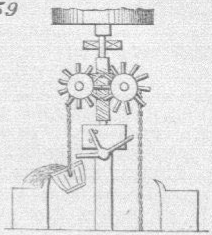

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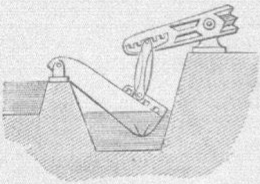

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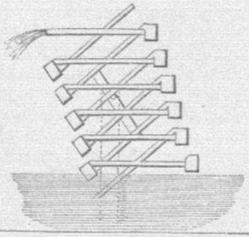

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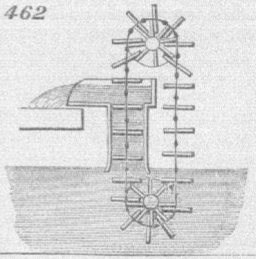

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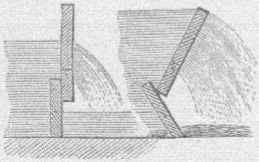

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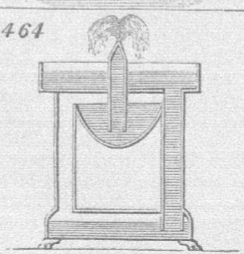

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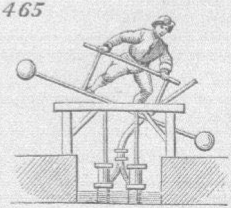


457. Common mode of raising water from wells of inconsiderable depth. Counterbalance equals about one-half of weight to be raised, so that the bucket has to be pulled down when empty, and is assisted in elevating it when full by counterbalance.

458. The common pulley and buckets for raising water; the empty bucket is pulled down to raise the full one.

459. Reciprocating lift for wells. Top part represents horizontal wind-wheel on a shaft which carries spiral thread. Coupling of latter allows small vibration, that it may act on one worm-wheel at a time. Behind worm-wheels are pulleys over which passes rope which carries bucket at each extremity. In center is vibrating tappet, against which bucket strikes in its ascent, and which, by means of arm in step wherein spiral and shaft are supported, traverses spiral from one wheel to other so that the bucket which has delivered water is lowered and other one raised.

460. Fairbairn's bailing-scoop, for elevating water short distances. The scoop is connected by pitman to end of a lever or of a beam of single-acting engine Distance of lift may be altered by placing end of rod in notches shown in figure.

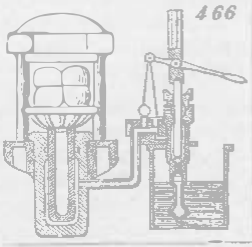
461. Pendulums or swinging gutters for raising water by their pendulous motions. Terminations at bottom are scoops, and at top open pipes; intermediate angles are formed with boxes (and flap valve), each connected with two branches of pipe.

462. Chain pump; lifting water by continuous circular motion. Wood or metal disks, carried by endless chain, are adapted to water-tight cylinder, and form with it a succession of buckets filled with water. Power is applied at upper wheel.

463. Self-acting weir and scouring sluice. Two leaves turn on pivots below centerst; upper leaf much larger than lower, and turns in direction of stream, while lower turns against it. Top edge of lower leaf overlaps bottom edge of upper one and is forced against it by pressure of water. In ordinary states of stream, counteracting pressures keep weir vertical and closed, as in the left-hand figure, and water flows through notch in upper leaf; but on water rising above ordinary level, pressure above from greater surface and leverage overcomes resistance below, upper leaf turns over, pushing back lower, reducing obstructions and opening at bed a passage to deposit.

464. Hiero's fountain. Water being poured into upper vessel descends tube on right into lower; intermediate vessel being also filled and more water poured into upper, confined air in cavities over water in lower and intermediate vessels and in communication tube on left, being compressed, drives by its elastic force a jet up central tube.

465. Balance pumps. Pair worked reciprocally by a person pressing alternately on opposite ends of lever or beam.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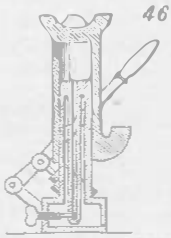
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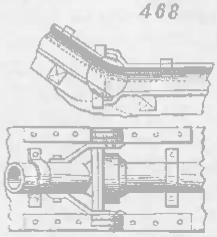
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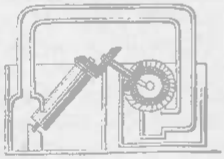
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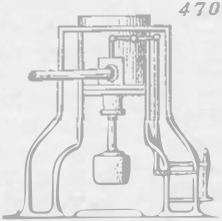
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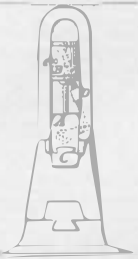
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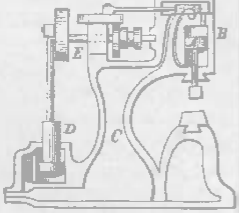

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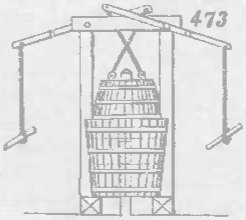
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466. Hydrostatic press. Water forced by the pump through the small pipe into the ram cylinder and under the solid ram, presses up the ram. The amount of force obtained is in proportion to the relative areas or squares of diameters of the pump-plunger and ram. Suppose, for instance, the pump-plunger to be one inch diameter and the ram thirty inches, the upward pressure received by the ram would be 900 times the downward pressure of the plunger.

467. Robertson's hydrostatic jack. In this the ram is stationary upon a hollow base and the cylinder with claw attached slides upon it. The pump takes the water from the hollow base and forces it through a pipe in the ram into the cylinder, and so raises the latter. At the bottom of pipe there is a valve operated by a thumb-screw to let back the water and lower the load as gradually as may be desired.

468. Flexible water main, plan and section. Two pipes of 15 and 18 inches interior diameter, having some of their joints thus formed, conduct water across the Clyde to Glasgow Water-works. Pipes are secured to strong log frames, having hinges with horizontal pivots. Frames and pipes were put together on south side of the river, and, the north end of pipe being plugged, they were hauled across by machinery on north side, their flexible structure enabling them to follow the bed.

469. French invention for obtaining rotary motion from different temperatures in two bodies of water. Two cisterns contain water: that in left at natural temperature and that in right higher. In right is a water-wheel geared with Archimedean screw in left. From spiral screw of the latter a pipe extends over and passes to the under side of wheel. Machine is started by turning screw in opposite direction to that for raising water, thus forcing down air, which ascends in tube, crosses and descends, and imparts motion to wheel; and its volume increasing with change of temperature, it is said, keeps the machine in motion. We are not informed how the difference of temperature is to be maintained.

470. Steam hammer. Cylinder fixed above and hammer attached to lower end of piston-rod. Steam being alternately admitted below piston and allowed to escape, raises and lets fall the hammer.

471. Hotchkiss's atmospheric hammer; derives the force of its blow from compressed air. Hammer head, C, is attached to a piston fitted to a cylinder, B, which is connected by a rod, D, with a crank, A, on the rotary driving-shaft. As the cylinder ascends, air entering hole, *c*, is compressed below piston and lifts hammer. As cylinder descends, air entering hole, *e*, is compressed above and is stored up to produce the blow by its instant expansion after the crank and connecting-rod turn bottom center.

472. Grimshaw's compressed air hammer. The head of this hammer is attached to a piston, A, which works in a cylinder, B, into which air is admitted—like steam to a steam engine—above and below the piston by a slide-valve on top. The air is received from a reservoir, C, in the framing, supplied by an air pump, D, driven by a crank on the rotary driving-shaft, E.

473. Air-pump of simple construction. Smaller tub inverted in larger one. The latter contains water to upper dotted line, and the pipe from shaft or space to be exhausted passes through it to a few inches above water, terminating with valve opening upward. Upper tub has short pipe and upwardly-opening valve at top, and is suspended by ropes from levers. When upper tub descends, great part of air within is expelled through upper valve, so that, when afterward raised, rarefaction within causes gas or air to ascend through the lower valve. This pump was successfully used for drawing off carbonic acid from a large and deep shaft.

474. Æolipile or Hero's steam toy, described by Hero, of Alexandria, 130 years B.C., and now regarded as the first steam engine, the rotary form of which it may be considered to represent. From the lower vessel, or boiler, rise two pipes conducting steam to globular vessel above, and forming pivots on which the said vessel is caused to revolve in the direction of arrows, by the escape of steam through a number of bent arms. This works on the same principle as Barker's mill, 438 in this table.

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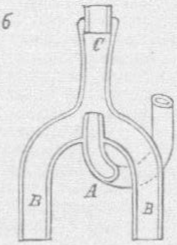

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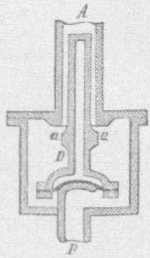

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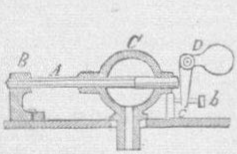

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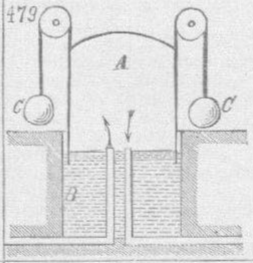

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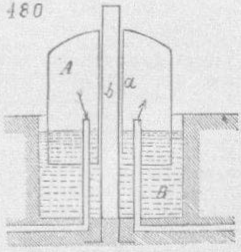

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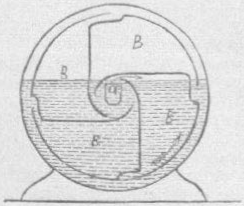

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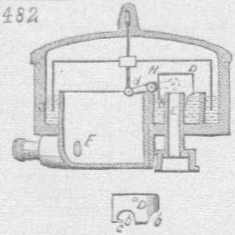

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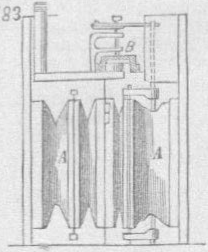

475. Bilge ejector (Brear's patent) for discharging bilge-water from vessels, or for raising and forcing water under various circumstances. D is a chamber having attached a suction-pipe, B, and discharge-pipe, C, and having a steam-pipe entering at one side, with a nozzle directed toward the discharge-pipe. A jet of steam entering through A expels the air from D and C, produces a vacuum in B, and causes water to rise through B, and pass through D and C, in a regular and constant stream. Compressed air may be used as a substitute for steam.

476. Another apparatus operating on the same principle as the foregoing. It is termed a steam siphon pump (Lansdell's patent). A is the jet-pipe; B, B, are two suction-pipes, having a forked connection with the discharge-pipe, C. The steam jet-pipe entering at the fork offers no obstacle to the upward passage of the water, which moves upward in an unbroken current.

477. Steam trap for shutting in steam, but providing for the escape of water from steam coils and radiators (Hoard & Wiggin's patent). It consists of a box, connected at A with the end of the coil or the waste-pipe, having an outlet at B, and furnished with a hollow valve, D, the bottom of which is composed of a flexible diaphragm. Valve is filled with liquid, and hermetically sealed, and its diaphragm rests upon a bridge over the outlet-pipe. The presence of steam in the outer box so heats the water in valve that the diaphragm expands and raises valve up to the seat, *a*, *a*. Water of condensation accumulating reduces the temperature of valve; and as the liquid in valve contracts, diaphragm allows valve to descend and let water off.

478. Another steam trap (Ray's patent). Valve, *a*, closes and opens by longitudinal expansion and contraction of waste-pipe, A, which terminates in the middle of an attached hollow sphere, C. A portion of the pipe is firmly secured to a fixed support, B. Valve consists of a plunger which works in a stuffing-box in the sphere, opposite the end of the pipe, and it is pressed toward the end of the pipe by a loaded elbow lever, D, as far as permitted by a stop-screw, *b*, and stop, *c*. When pipe is filled with water, its length is so reduced that valve remains open; but when filled with steam, it is expanded so that valve closes it. Screw, *b*, serves to adjust the action of valve.

479. Gasometer. The open-bottomed vessel, A, is arranged in the tank, B, of water, and partly counterbalanced by weights, C, C. Gas enters the gasometer by one and leaves it by the other of the two pipes inserted through the bottom of the tank. As gas enters, vessel, A, rises, and *vice versa*. The pressure is regulated by adding to or reducing the weights, C, C.

480. Another kind of gasometer. The vessel, A, has permanently secured within it a central tube, *a*, which slides on a fixed tube, *b*, in the center of the tank.

481. Wet gas meter. The stationary case, A, is filled with water up to above the center. The inner revolving drum is divided into four compartments, B, B, with inlets around the central pipe, *a*, which introduces the gas through one of the hollow journals of the drum. This pipe is turned up to admit the gas above the water, as indicated by the arrow near the center of the figure. As gas enters the compartments, B, B, one after another, it turns the drum in the direction of the arrow shown near its periphery, displacing the water from them. As the chambers pass over they fill with water again. The cubic contents of the compartments being known, and the number of the revolutions of the drum being registered by dial-work, the quantity of gas passing through the meter is registered.

482. Gas regulator (Powers's patent) for equalizing the supply of gas to all the burners of a building or apartment, notwithstanding variations in the pressure on the main, or variations produced by turning gas on or off, to or from any number of the burners. The regulator-valve, D, of which a separate outside view is given, is arranged over inlet-pipe, E, and connected by a lever, *d*, with an inverted cup, H, the lower edges of which, as well as those of valve, dip into channels containing quicksilver. There is no escape of gas around the cup, H, but there are notches, *b*, in the valve to permit the gas to pass over the surface of the quicksilver. As the pressure of gas increases, it acts upon the inner surface of cup, H, which is larger than valve, and the cup is thereby raised, causing a depression of the valve into the quicksilver, and contracting the opening notches, *b*, and diminishing the quantity of gas passing through. As the pressure diminishes, an opposite result is produced. The outlet to burners is at F.

483. Dry gas meter. Consists of two bellows-like chambers, A, A′, which are alternately filled with gas, and discharged through a valve, B, something like the slide-valve of a steam engine, worked by the chambers, A, A′. The capacity of the chambers being known, and the number of times they are filled being registered by dial-work, the quantity of gas passing through the meter is indicated on the dials.

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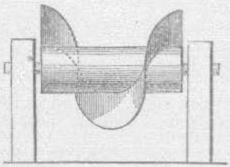

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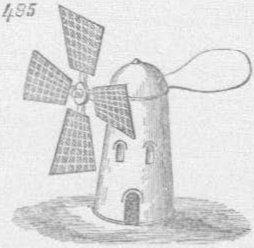

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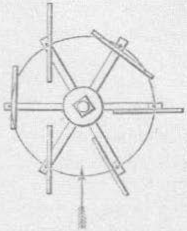

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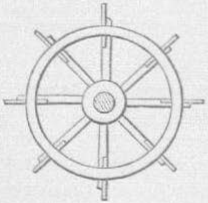

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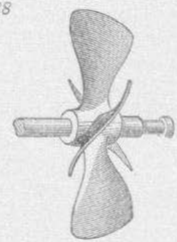

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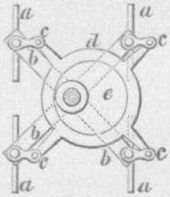

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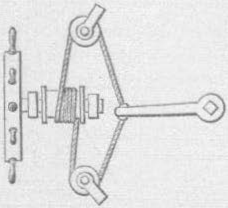

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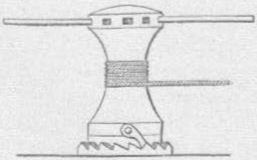

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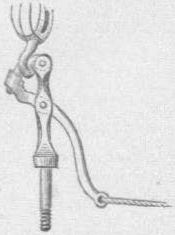

484. A spiral wound round a cylinder to convert the motion of the wind or a stream of water into rotary motion.

485. Common wind-mill, illustrating the production of circular motion by the direct action of the wind upon the oblique sails.

486. Plan of a vertical wind-mill. The sails are so pivoted as to present their edges in returning toward the wind, but to present their faces to the action of the wind, the direction of which is supposed to be as indicated by the arrow.

487. Common paddle-wheel for propelling vessels; the revolution of the wheel causes the buckets to press backward against the water and so produce the forward movement of the vessel.

488. Screw propeller. The blades are sections of a screw-thread, and their revolution in the water has the same effect as the working of a screw in a nut, producing motion in the direction of the axis and so propelling the vessel.

489. Vertical bucket paddle-wheel. The buckets, *a*, *a*, are pivoted into the arms, *b*, *b*, at equal distances from the shaft. To the pivots are attached cranks, *c*, *c*, which are pivoted at their ends to the arms of a ring, *d*, which is fitted loosely to a stationary eccentric, *e*. The revolution of the arms and buckets with the shaft causes the ring, *d*, also to rotate upon the eccentric, and the action of this ring on the cranks keeps the buckets always upright, so that they enter the water and leave it edgewise without resistance or lift, and while in the water are in the most effective position for propulsion.

490. 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 the top of the rudder; by turning the wheel, one end of the rope is wound on and the other let off, and the tiller is moved in one or the other direction, according to the direction in which the wheel is turned.

491. 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 hand-spikes 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.

492. Boat-detaching hook (Brown & Levell's). The upright standard is secured to the boat, and the tongue hinged to its upper end enters an eye in the level which works on a fulcrum at the middle of the standard. A similar apparatus is applied at each end of the boat. The hooks of the tackles hook into the tongues, which are secure until it is desired to detach the boat, when a rope attached to the lower end of each lever is pulled in such a direction as to slip the eye at the upper end of the lever from off the tongue, which being then liberated slips out of the hook of the tackle and detaches the boat.

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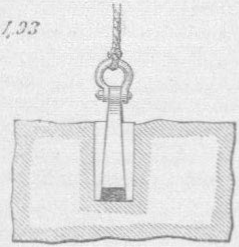

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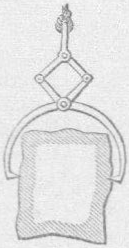

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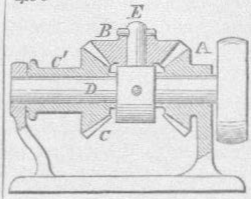

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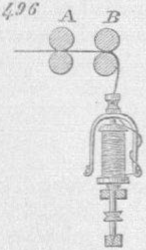

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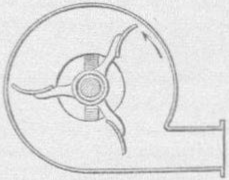

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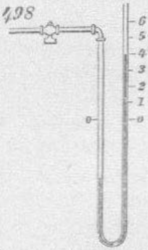

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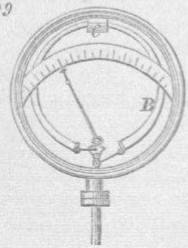

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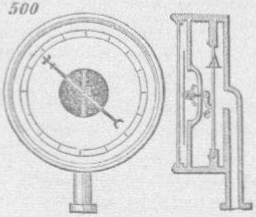

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493. "Lewis," for lifting stone in building. It is composed of a central taper pin or wedge, with two wedge-like packing-pieces arranged one on each side of it. The three pieces are inserted together in a hole drilled into the stone, and when the central wedge is hoisted upon it wedges the packing-pieces out so tightly against the sides of the hole as to enable the stone to be lifted.

494. Tongs for lifting stones, etc. The pull on the shackle which connects the two links causes the latter so to act on the upper arms of the tongs as to make their points press themselves against or into the stone. The greater the weight the harder the tongs bite.

495. Entwistle's patent gearing. Bevel-gear, A, is fixed. B, gearing with A, is fitted to rotate on stud, E, secured to shaft, D, and it also gears with bevel-gear, C, loose, on the shaft, D. On rotary motion being given to shaft, D, thee gear, E, revolves around A, and also rotates upon its own axis, and so acts upon C in two ways, namely, by its rotation on its own axis and by its revolution around A. With three gears of equal size, the gear, C, makes two revolutions for every one of the shaft, D. This velocity of revolution may, however, be varied by changing the relative sizes of the gears. C is representedle with an attached drum, C'. This gearing may be used for steering apparatus, driving screw-propellers, etc. By applying power to C, action may be reversed, and a slow motion of D obtained.

496. Drawing and twisting in spinning cotton, wool, etc. The front drawing-rolls, B, rotate faster than the back ones, A, and so produce a draught, and draw out the fibers of the sliver ore roving passing between them. Roving passes from the front drawing-rolls to throstle, which, by its rotation around the bobbin, twists and winds the yarn on the bobbin.

497. Fan-blower. The casing has circular openings in its sides through which, by the revolution of the shaft and attached fan-blades, air is drawn in at the center of the casing, to be forced out under pressure through the spout.

498. Siphon pressure gauge. Lower part of bent tube contains mercury. The leg of the tube, against which the scale is marked, is open at top, the other leg connected with the steam-boiler or other apparatus on which the pressure is to be indicated. The pressure on the mercury in the one leg causes it to be depressed in that and raised in the other until there is an equilibrium established between the weight of mercury and pressure of steam in one leg, and the weight of mercury and pressure of atmosphere in the other. This is the most accurate gauge known; but as high pressure requires so long a tube, it has given place to those which are practically accurate enough, and of more convenient form.

499. Aneroid gauge, known as the "Bourdon gauge," from the name of its inventor, a Frenchman. B is a bent tube closed at its ends, secured at C, the middle of its length, and having its ends free. Pressure of steam or other fluid admitted to tube tends to straighten it more or less, according to its intensity. The ends of tube are connected with a toothed sector-piece gearing, with a pinion on the spindle of a pointer which indicates the pressure on a dial.

500. Pressure gauge now most commonly used. Sometimes known as the "Magdeburg gauge," from the name of the place where first manufactured. Face view and section. The fluid whose pressure is to be measured acts upon a circular metal disk, A, generally corrugated, and the deflection of the disk under the pressure gives motion to a toothed sector, *e*, which gears with a pinion on the spindle of the pointer.

501. Mercurial barometer. Longer leg of bent tube, against which is marked the scale of inches, is closed at top, and shorter one is open to the atmosphere, or merely covered with some porous material. Column of mercury in longer leg, from which the air has been extracted, is held up by the pressure of air on the surface of that in the shorter leg, and rises or falls as the pressure of the atmosphere varies. The old-fashioned weather-glass is composed of a similar tube attached to the back of a dial, and a float inserted into the shorter leg of the tube, and geared by a rack and pinion, or cord and pulley, with the spindle of the pointer.

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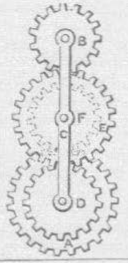

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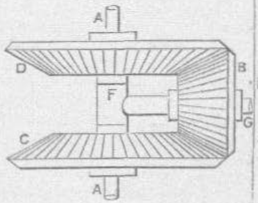

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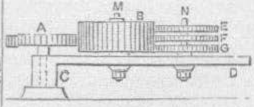

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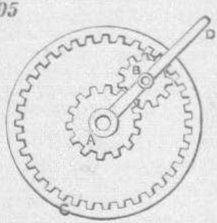

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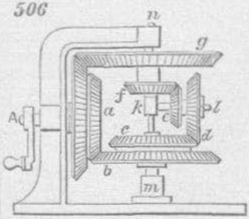

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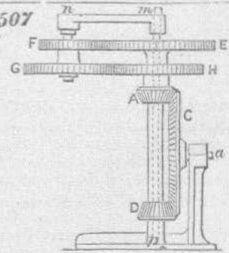

502. An "epicyclic train." Any train of gearing the axes of the wheels of which revolve around a common center is properly known by this name. The wheel at one end of such a train, if not those at both ends, is always concentric with the revolving frame. C is the frame or train-bearing arm. The center wheel, A, concentric witht this frame, gears with a pinion, F, to thet same axle with which is secured a wheel, E, that gears with a wheel, B. If the first wheel, A, be fixed and a motion be given to the frame, C, the train will revolve around the fixed wheel and the relative motion of the frame to the fixed wheel will communicate through the train a rotary motion to B on its axis. Or the first wheel as well as the frame may be made to revolve with different velocities, with the same result except as to the velocity of rotation of B upon its axis.

In the epicyclic train as thus described only the wheel at one extremity is concentric with the revolving frame; but if the wheel, E, instead of gearing with B, be made to gear with the wheel, D, which like the wheel, A, is concentric with the frame, we have an epicyclic train of which the wheels at both extremities are concentric with the frame. In this train we may either communicate the driving motion to the arm and one extreme wheel, in order to produce an aggregate rotation of the other extreme wheel, or motion may be given to the two extreme wheels, A and D, of the train, and the aggregate motion will thus be communicated to the arm.

503. A very simple form of the epicyclic train, in which F, G, is the arm, secured to the central shaft, A, upon which are loosely fitted the bevel-wheels, C, D. The arm is formed into an axle for the bevel-wheel, B, which is fitted to turn freely upon it. Motion may be given to the two wheels, C, D, in order to produce aggregate motion of the arm, or else to the arm and one of said wheels in order to produce aggregate motion of the other wheel.

504. "Ferguson's mechanical paradox," designed to show a curious property of the epicyclic train. The wheel, A, is fixed upon a stationary stud about which the arm, C, D, revolves. In this arm are two pins, M, N, upon one of which is fitted loosely a thick wheel, B, gearing with A, and upon the other are three loose wheels, E, F, G, all gearing with B. When the arm, C, D, is turned round on the stud, motion is given to the three wheels, E, F, G, on their common axis, viz., the pin, N; the three forming with the intermediate wheel, B, and the wheel, A, three distinct epicyclic trains. Suppose A to have twenty teeth, F twenty, E twenty-one, and G nineteen; as the arm, E, C, D, is turned round, F will appear not to turn on its axis, as any point in its circumference will always point in one direction, while E will appear to turn slowly in one and G in the other direction, which—an apparent paradox—gave rise to the name of the apparatus.

505. Another simple form of the epicyclic train, in which the arm, D, carries a pinion, B, which gears both with a spur-wheel, A, and an annular wheel, C, both concentric with the axis of the arm. Either of the wheels, A, C, may be stationary, and thet revolution of the arm and pinion will give motion to the other wheel.

506. Another epicyclic train in which neither the first nor last wheel is fixed. *m*, *n*, is a shaft to which is firmly secured the train-bearing arm, *k*, *l*, which carries the two wheels, *d*, *e*, secured together, but rotating upon the arm itself. The wheels, *b* and *c*, are united and turn together, freely upon the shaft, *m*, *n*; the wheels, *f* and *g*, are also secured together, but turn together freely on the shaft, *m*, *n*. The wheels, *c*, *d*, *e* and *f*, constitute an epicyclic train of which *c* is the first and *f* the last wheel. A shaft,t.A, is employed as a driver, and has firmly secured to it two wheels, *a* and *h*, thet first of which gears with the wheel, *b*, and thus communicates motion to the first wheel,t *c*,oftheepicyclictrain.and.thewheel,*h*,drives the wheel, *g*, which thus gives motion tot the last wheel, *f*. Motion communicatedt in this way to the two ends of the train produces an aggregate motion of the arm, *k*, *l*, and shaft, *m*, *n*.

This train may be modifiedt; for instance, suppose the wheels, *g* and *f*, to be disunited, *g* to be fixed to the shaft, *m*, *n*, and *f* only running loose upon it. The driving-shaft, A, will as before communicate motion to the first wheel, *c*, of the epicyclic train by means of the wheels, *a* and *b*, and will also by *h* cause the wheel, *g*, the shaft, *m*, *n*, and the train-bearing arm, *k*, *l*, to revolve, and the aggregate rotation will be given to the loose wheel, *f*.

507. Another form of epicyclic train designed for producing a very slow motion. *m* is a fixed shaft upon which is loosely fitted a long sleeve, to the lower end of which is fixed a wheel, D, and to the upper end a wheel, E. Upon this long sleeve there is fitted a shorter one which carries at its extremities the wheels, A and H. A wheel, C, gears with both D and A, and a train-bearing arm, *m*, *n*, which revolves freely upon the shaft, *m*, *p*, carries upon a stud at *n* the united wheels, F and G. If A have 10 teeth, C 100, D 10, E 61, F, 49, G 41, and H 51, there will be 25,000 revolutions of the train-bearing arm, *m*, *n*, for one of the wheel, C.