CHAPTER VI.

OF ADJUSTMENTS.

257. **Adjustments Defined and Classed.**—The word "adjustments" was introduced by Professor Willis, in order to comprehend under one general term all contrivances for varying at will the comparative motions in a machine. Every adjustment may be regarded as an aggregate combination in which the action is temporary or intermittent; and the various kinds of adjustments might have been classed under the head of "Aggregate Combinations," in the preceding chapter; but it is more convenient to treat of them by themselves. Various contrivances which belong to the class of adjustments have already been described under the head of "Elementary Combinations," as well as of aggregate combinations: these will be specified in their order further on. Other contrivances belonging to the class of adjustments involve the application of the principles of dynamics and of the strength of materials, to such an extent that their description, at all events in detail, must be reserved for later divisions of this book.

When adjustments are classed according to the purposes to which they are applied, they may be arranged as follows:—

Traversing-Gear and Feed-Motions;
Engaging, Disengaging, and Reversing-Gear;
Gear for varying Speed or Stroke.

258. **Traversing-Gear and Feed-Motions in General.**—By *traversing-gear* is meant the mechanism by means of which a machine, consisting of framework and moving pieces, is shifted from place to place without being thrown out of connection with the driver from which it receives its motion; such, for example, as the mechanism by which the truck in a travelling crane, that carries the hoisting machinery, is made to move to different positions on a travelling platform, which itself is capable of being moved to different positions on a fixed framework; or the mechanism by which the arm in a drilling machine is made to move to various positions, carrying with it the boring-tool and the machinery by which that tool is driven; or that by which the tool-holder in a shaping machine is turned into various positions, according to the varying directions in which the strokes of the tool are to be made. By a *feed-motion* is meant the mechanism in a machine-tool by

means of which, after a stroke has been made, either the cutting-tool or the *work* (that is, the piece of material operated upon) is shifted into a new position, preparatory to making the next cut;—for example, in a lathe for turning axles, the feed-motion causes the tool to shift, at each revolution of the axle that is being turned, through a certain distance in a direction parallel to the axis of rotation; and in a sawing machine, the feed-motion causes the log of wood that is being sawn to advance through a certain distance either during or after each cut of the saw. Some feed-motions are continuous in their action; others are intermittent.

It is obvious that the general principles of traversing-gear, and of those feed-motions in which the tool is shifted, are those of *shifting-trains*, already stated in Article 228, pages 235 to 238. The consideration of traversing-gear and feed-motions in detail belongs to the subject of the construction of machinery, and must therefore be deferred.

SECTION I.—*Of Engaging, Disengaging, and Reversing-Gear.*

259. **General Explanations.**—Engaging and Disengaging-Gear, or sometimes Disengaging and Re-engaging-Gear, is the name given to those contrivances by means of which the connection between a follower and its driver can be begun and stopped at will;—in other words, by means of which the combination can be thrown *into gear* and *out of gear* when required. For brevity's sake, such contrivances may be called simply *Disengagements.* Disengagements may be classed in different ways. According to one mode of classification, they are distinguished into those which, in the communication of motion, act by *pressure*, and those which act by *friction*. Disengagements which act by pressure are precise and definite in their action; that is, the connection between the pieces that are thrown into gear at a given instant is established at once, in a certain definite position of the pieces, and with a certain definite velocity-ratio. Disengagements which act by friction are to a certain extent indefinite in their action; that is, the velocity-ratio corresponding to the complete establishment of the connection is produced by degrees; and the relative position of the pieces when the connection is completely established is uncertain. In certain cases the definite action of the former class of disengagements is necessary: in other cases it is unnecessary; and in these the frictional class of disengagements have a great advantage, because of their avoiding the shocks and straining actions which accompany sudden changes of velocity. The principles upon which such straining actions depend belong to the dynamics of machinery.

By another mode of classification, disengagements are arranged according to the kind of mechanism of which they consist, as follows:—

I. *Disengagements by means of Couplings;* where two pieces that turn about one axis are coupled or uncoupled at pleasure; so that when coupled, they turn as one piece. These may transmit motion either by pressure or by friction.

II. *Disengagements with Rolling Contact.*—These always transmit motion by friction.

III. *Disengagements with Sliding Contact.*—These transmit motion by pressure; and in most cases they act by throwing toothed wheels or screws into and out of gear.

IV. *Disengagements by Bands* transmit motion by friction.

V. *Disengagements by Linkwork* transmit motion by pressure.

VI. *Disengagements with Hydraulic Connection* transmit motion by the pressure of a fluid; and they are made to act by the opening and shutting of valves.

Reversing-Gear usually consists simply of a double set of engaging and disengaging-gear; that is to say, an arrangement of mechanism by means of which the follower can, when required, be thrown into gearing with one or other of two drivers that drive it in opposite directions, or may be disengaged from both.

It is obvious that all the combinations in which the connection is intermittent (enumerated in Article 219, page 231) are examples of self-acting disengagements; and that some of them (such as the escapements described in Article 164, pages 176 to 179) are examples of self-acting reversing-gear.

260. **Clutch.**—A clutch is a sort of coupling, in which one rotating piece drives another piece that turns about the same axis, by means of two or more projecting claws or horns, that fit into corresponding recesses, or lay hold of corresponding horns, on the second piece. In a disengaging clutch the driving piece is a cylindrical box or collar with suitable horns, which is capable of easily sliding lengthwise upon a rotating shaft, and is made to rotate constantly along with the shaft, by having in its internal cylindrical surface a slot or longitudinal groove, fitting a longitudinal key or feather that projects from the shaft. In the outer cylindrical surface of the clutch is a circular groove, into which there fit easily the rounded ends of the prongs of a forked hand-lever, by means of which the clutch can be shifted lengthwise on the shaft through a distance sufficient to engage its horns with or disengage them from those of the following piece. The following piece may be another length of shaft, turning about the same axis; or it may be a wheel or a pulley, loose upon the same shaft with the clutch.

Sometimes the acting faces of the clutch, instead of being planes traversing the axis of rotation, are inclined backwards as regards the direction of motion at an angle of 15°, or thereabouts. The effects of this are, that a certain forward pressure must be continually exerted by the lever on the clutch when in gear, in order to make it keep its hold; and that any sudden acceleration of one of the parts of the coupling causes the clutch to lose its hold, and thus prevents the transmission of a shock to the machinery which is driven by means of it.

261. **Friction-Clutch—Friction-Cones—Friction-Sectors—Friction-Discs.**—In the *friction-clutch* the following piece is a circular disc, having a hoop which grasps it, and which can be tightened or slackened by means of screws until the friction between the hoop and the disc is just sufficient to transmit the required power. The hoop has two projecting horns, corresponding to those of the clutch. When this combination is thrown into gear, the clutch instantly communicates its own velocity to the hoop; but the hoop at first slips on the disc, which is set in motion by degrees; and thus dangerous shocks are avoided.

In the *friction-cones* the driver, as in the case of the clutch, is a cylindrical box, turning along with the shaft, and capable of being shifted lengthwise by means of a hand-lever; but instead of horns, it has a disc with a rim turned to a very accurate and smooth convex conical surface. The follower is a disc whose rim is turned to a concave conical surface, exactly fitting that of the driver. When the driver is pushed forward by means of the lever, so as to press the two conical surfaces together, it gradually imparts its rotation to the follower by means of the friction of those surfaces. On drawing back the driver by means of the lever, the connection immediately ceases.

The angle of obliquity of the conical surfaces should be just great enough to prevent any risk of their becoming jammed against each other, so as to prevent disengagement; and for that purpose an angle of 10° or thereabouts is sufficient.

In the *frictional sector* coupling (invented by Mr. 1 ~~Bodmer~~) the follower is a cylindrical box, loose on the shaft, and carrying a circular disc-plate with a hoop-shaped rim. The inner cylindrical surface of that rim is turned true and smooth. The driver consists of a boss fixed on and turning with the shaft, and carrying an expanding disc composed of two sectors, with true and smooth cylindrical rims, fitting the inner surface of the rim of the followers. Those sectors can be simultaneously moved from or towards the shaft by means of right and left-handed screws, turned by levers and links; the links lie parallel to the shaft, and are jointed to a collar which is shifted by means of a forked lever, as in the ordinary clutch. When the sectors are moved outwards, they fit tightly to the inside of the hoop-shaped rim of the follower, and by their friction communicate to it the rotation of the shaft.

When moved inwards, they cease to touch that rim, and the connection ceases. (See Fairbairn *On Millwork*, Part II, Edition of 1863, pp, 91, 92.)

In Mr. R. D. Napier's disengaging-gear the pushing forward in the usual way of a cylindrical clutch-box causes two segmental pieces to grasp between them a drum that rotates with the shaft, and so to communicate rotation to a disc to which they are attached.

In the *friction-disc* disengagement (Mr. Weston's invention) a set of flat discs are made to turn along with the shaft by means of grooves and feathers, and are capable of shifting longitudinally to a small extent. Between each pair of that first set of discs is placed a disc belonging to a second set, which are loose on the shaft, but are made to turn along with it when required, by pressing them between the discs of the first set. The second set of discs, by means of grooves and feathers at their outer edges, carry along with them in their rotation a wheel or a pulley concentric with the shaft.

262. **Disengagements acting by Rolling Contact.**—A pair of wheels acting on each other by rolling contact may be engaged and disengaged when required by pressing them together and drawing them asunder, the axis of one of them being made moveable for that purpose; and this is practised in grooved frictional gearing of the kind described in Article 111, page 150.

The principle of another method of effecting engagement and disengagement by wheels in rolling contact is shown in fig. 213.

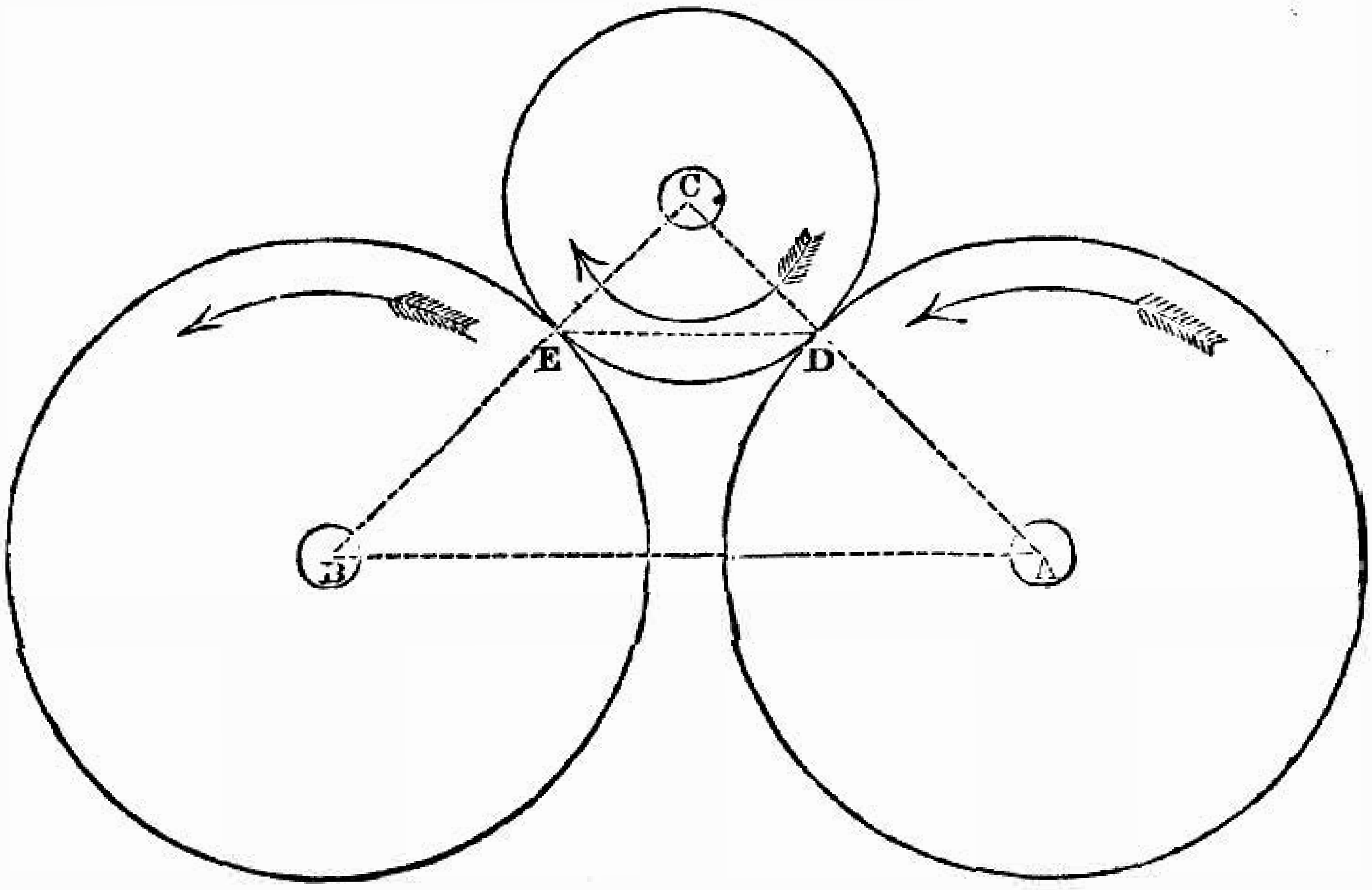

Fig. 213.

A and B are the traces of the fixed axes of a pair of equal wheels, whose surfaces do not touch each other: A being the driver and B the follower. C is the trace of the moveable axis of an intermediate idle wheel, which drives B, and is driven by A; D being the pitch-point of A and C, and E the pitch-point of C and B. The straight line D E is the common line of connection of the three wheels; and as pressure only, and not tension, can be transmitted along that line from the first wheel to the third wheel, the connection ceases if the motion is reversed. To disengage the wheels while in motion forwards, the axis C is shifted so as to put an end to the contact at D or at E, or at both those points.

The angles of obliquity, C D E = C E D, which the line of connection D E makes with the two lines of centres, A C and B C, ought to be a little greater than the "angle of repose" of the surfaces of the wheels, in order that the wheel C may not become jammed between the wheels A and B; but it ought not to be greater than is just sufficient to prevent the risk of jamming; in order that the force with which C must be pressed towards A and B may not become unnecessarily great. The value of that force and of the angles of obliquity will be considered under the head of the "Dynamics of Machinery;" meanwhile, in anticipation of that division of this treatise, the following values are given of the angle of repose for different surfaces:—

Cylindrical surfaces without grooves.
Metal on Metal; dry, 10°; slimy, 8°; greasy, 4°.
Metal on Oak; dry, 28°; wet, 14°.
Metal on Elm; dry, 13°.
Leather on Metal; dry, 29½°; wet, 20°; greasy, 13°.
Leather on Oak, 17°.
Grooved metal surfaces, as in frictional gearing; about 28°.

The construction, therefore, for designing this disengagement, when the centres A and B are given, is as follows: from the straight line A B lay off the equal angles C A B = C B A, each a little greater than the angle of repose; the intersection C will mark the centre of the required intermediate wheel. The proportion borne by its radius to the equal radii of the wheels A and B is in the main a matter of convenience; but should there be no reason to the contrary, all three radii may be made equal.

263. **Disengagements and Reversing-Gear acting by Sliding Contact.**—A pair of toothed wheels, whether spur, bevel, or skew-bevel, may be thrown into or out of gear by shifting one of them along its axis. This sort of disengagement belongs to the class in which motion is transmitted by pressure; so that the velocity-ratio and the relative position of the pieces are definite, and the communication of motion abrupt. Another way of making it act is to have the wheels always in gearing with each other, and to effect the engagement and disengagement of one of them by

means of a clutch upon the shaft that carries it; as in Article 260, page 295.

The most common kind of reversing-gear which acts by means of toothed wheels is shown in fig. 214; A is the driving-shaft, carrying a bevel-wheel which drives in contrary directions a pair of bevel-wheels, B, C, that turn loose on the driven shaft, D D. A double clutch, E, sliding along a feather on the latter shaft, is made, by means of a collar and lever, to lay hold of the one or the other of the bevel-wheels B, C, according to the direction in which the shaft D D is to rotate.

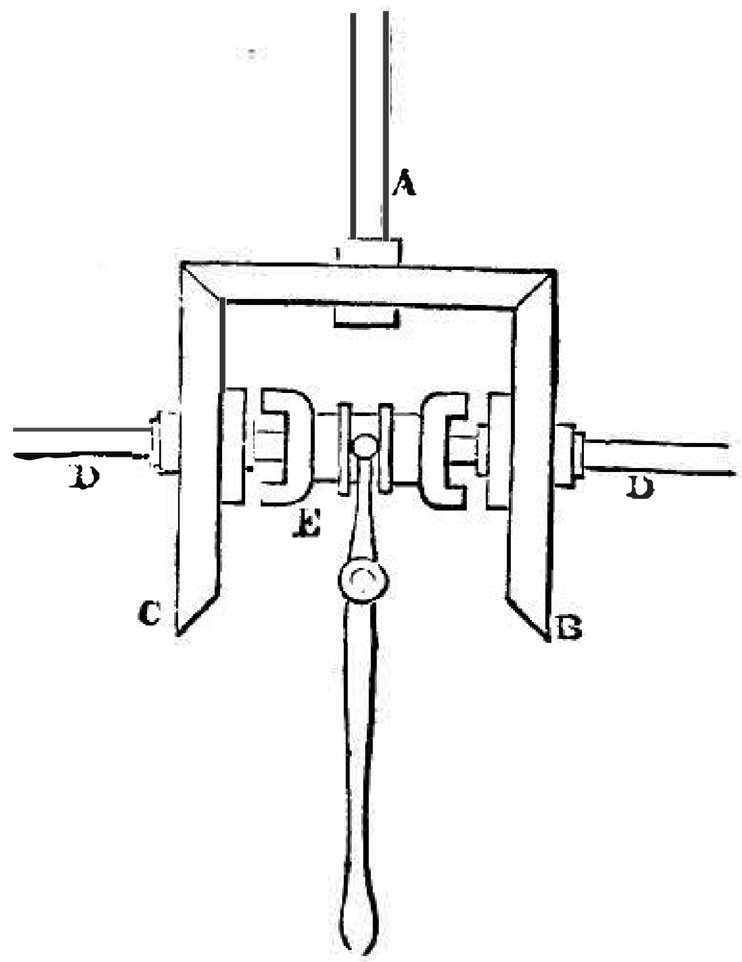

Fig. 214.

264. **Disengagements and Reversing-Gear by Bands.**—When rotation is transmitted from one shaft to another by means of a belt and a pair of pulleys, the form of engaging and disengaging-gear employed is the "*fast and loose pulley*" already described in Article 170, pages 184 and 185. The fork mentioned there is called a *belt-guide*, or *belt-shifter*. It is evident that the contrivance of the fast and loose pulley is applicable to belts alone, and not to cords and chains.

Reversing-gear by means of belts with fast and loose pulleys is arranged in the following way: on the driven shaft is one fast pulley, between two loose pulleys, one for each of the two belts, which run in opposite directions. In the act of reversing the motion, care should be taken that the belt which has been driving the fast pulley is shifted completely on to its own loose pulley before any part of the other belt is shifted on to the fast pulley.

A method of engaging and disengaging connection by bands, applicable to cords as well as to belts, is to tighten and slacken the band when required, by means of a *straining pulley*, as already described in Article 174, page 188.

265. **Disengagements and Reversing-Gear acting by Linkwork.**—Amongst disengagements acting by linkwork are all the examples of intermittent linkwork described in Article 194 to 197, pages 206 to 213; and in most of those examples, besides the periodical disengagement which takes place at each return stroke, there exists also the means of making a permanent disengagement, by fixing the click or catch so as to prevent it from taking hold of the

teeth. In fig. 146, page 207 (described at page 208), is an example of reversing-gear in linkwork.

In ordinary linkwork (as distinguished from click-and-ratchet-work) the means of disengagement consist in connecting the link with the pin at one of the connected points by means of a *gab* (as at A, fig. 215); that is, a deep notch with plane sides and a semi-cylindrical bottom, fitting the pin accurately but easily. The link is thrown out of gear when required, by moving the gab clear of the pin, either by hand or by suitable mechanism. Sometimes the gab is provided with spreading jaws, to enable it the more easily to lay hold of the pin when the connection is to be re-engaged.

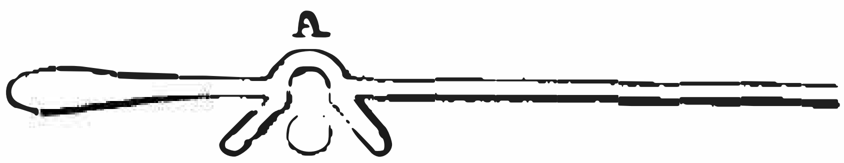

Fig. 215.

Another case of disengagement by linkwork is that of the *hooks in a Jacquard loom*. At each shot or stroke of the loom there are certain threads of the warp that have to be raised and lowered again, while other threads remain at rest; the order and arrangement of threads so treated being varied at each shot, in a manner depending on the pattern to be woven. In fig. 216, B C is a hook, of which the lower end is connected with a thread: the hook is kept in a nearly vertical position by passing easily through a hole at D in a horizontal sliding-bar, D E, called a *needle;* and the hooked upper end, at B, overhangs a horizontal bar or rail, A, which is carried by a frame having a vertical reciprocating motion, of the extent represented by A A′. In the position shown by full lines and capital letters the hook stands ready to be lifted by the rail A; but when the needle is drawn back to the position *d e*, the hook is made to assume the position C *d b*, shown in dotted lines, in which it stands disengaged from the rail, and remains at rest during the next stroke. The needles are usually drawn back by means of springs, and pushed forward by the forward stroke of a drum, F, which turns about a horizontal axis, and has also, along with that axis, a reciprocating motion in the direction of the length of the needles. The drum is

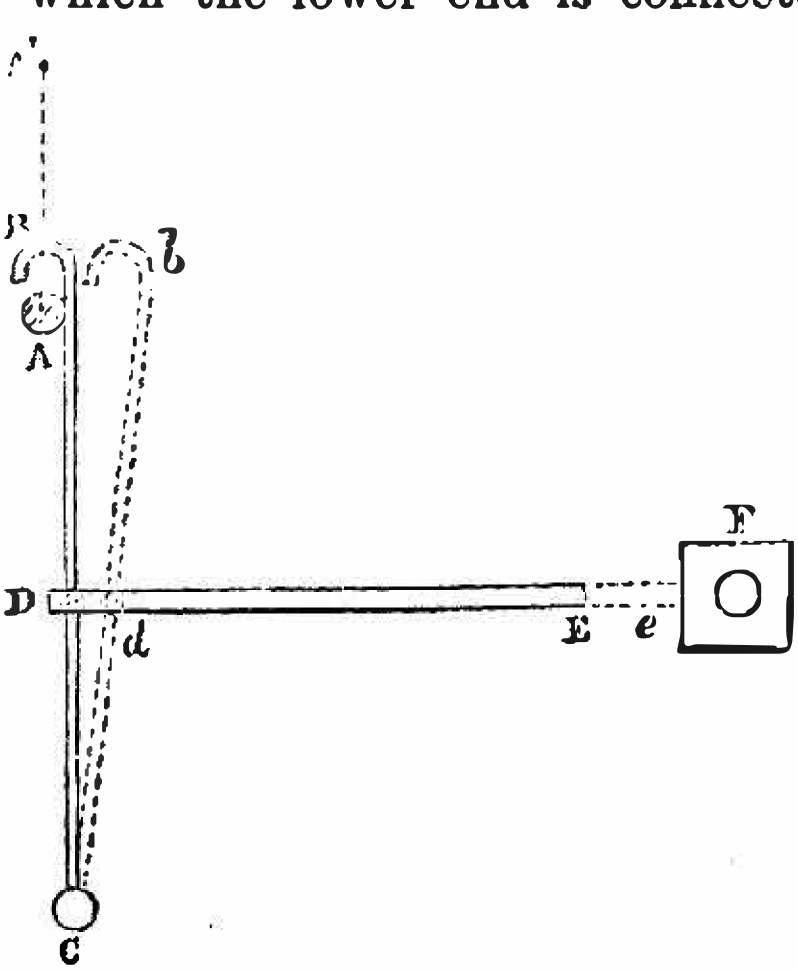

Fig. 216.

of the form of a polygonal prism, usually square, as in the figure; its acting face is covered with an oblong card (of pasteboard or sheet metal), having holes in it opposite the ends of those needles which are *not* to be pushed forward. The drum does not rotate during its forward stroke, when it is pushing the needles; but during the return stroke a catch pulls it round so as to bring a new face opposite the needles, with a new card upon it, having a proper arrangement of holes for the next stroke. The cards, in sufficient number to produce the entire pattern, are linked together at their longer edges, so as to form, as it were, a flat chain, which hangs over the drum, by whose rotation they are brought round one by one to act on the ends, E, of the needles.

The Jacquard Apparatus, of drum, cards, needles, and hooks, may be applied to many purposes besides that of lifting the threads of a warp.

266. **Disengagements acting by Hydraulic Connection—Valves.**— When the driver and follower are two pistons, and the former transmits motion to the latter by means of an intervening mass of fluid (as in Articles 207 to 211 A, pages 221 to 227), the engagement and disengagement are effected by opening and closing a valve in the passage through which the displaced fluid flows; as has been already stated in Article 211, page 224. If the forward motion of the driving piston is to go on while the valve is closed, some other outlet must be opened for the fluid which it displaces.

A reversing action takes place in hydraulic connection, when a stream of fluid is admitted, by means of suitable valves, so as to act alternately on the two sides of a piston, as in a double-acting water-pressure engine.

In all cases in which the motion of a piston driven by a fluid is reversed, an outlet, with a suitable valve, must be provided for the escape from the cylinder, during the return stroke, of the mass of fluid by which the previous forward stroke was produced.

267. **Principles of the Action of Valves.**—It would be out of place here to describe in detail the various kinds of valves used in machinery; and therefore a summary only of the general principles of their construction and action, so far as those principles can be considered as forming part of the Geometry of Machines, will now be given, chiefly abridged from *A Manual of the Steam Engine and other Prime Movers.*

Valves in general, considered with reference to the means by which they are moved, may be divided into three principal classes: —Valves, sometimes called *clacks*, which are opened and shut by the pressure of the fluid that traverses their openings, and are usually intended for the purpose of permitting the passage of the fluid in one direction only, and stopping its return;—valves moved by hand;—and valves moved by mechanism. When a piston drives a fluid, as in ordinary pumps, the valves are usually moved by the fluid: when the fluid drives the piston, it is in general necessary that the valves should be moved by hand or by mechanism. In water-pressure engines that work occasionally and at irregular intervals, such as hydraulic hoists and cranes, the valves are usually opened and shut by hand; in those which work periodically and continuously, they are moved by mechanism connected with the engine. Valves, when considered with reference to the kind of motion by which they open and shut the *ports*, or orifices to which they are fitted, may be distinguished into *Drop-valves*, which are opened and shut by being lifted up and set down; *Flap-valves*, which turn on a hinge; and *Slide-valves*.

The *seat* of a valve is the fixed surface on which it rests, or against which it presses.

The *face* of a valve is that part of its surface which comes in contact with the seat.

When a valve occurs *in the course* of a pipe or passage, the valve-box or chamber, being that part of the passage in which the valve works, should always be of such a shape as to allow a free passage for the fluid when the valve is open, so that the fluid may pass the valve with as little change of area of the stream as possible; and if necessary for that purpose, the valve-chamber may be made of larger diameter than the rest of the passage.

A valve moved by mechanism has almost always a periodical reciprocating motion, by which it is alternately opened and shut. The simplest mode by which that motion can be given is by a crank, or an eccentric, carried by some continuously-rotating piece, and acting through a rod; as in Articles 184 to 186, pages 196 to 198; and such is the ordinary way of moving *slide-valves*. *Drop-valves* are sometimes worked by the same kind of mechanism, with the addition of a contrivance for setting them down very gently, of the kind described in Article 190, pages 202, 203; or by means of cams or wipers (Articles 160 to 164, pages 170 to 175).

The principal forms of valves are the following:—

I. The *Bonnet-Valve* or *Conical Valve* is the simplest form of drop-valve, and is a flat or slightly arched circular plate whose face, being formed by its rim, is sometimes a frustum of a cone, and sometimes a zone of a sphere, the latter figure being the best. Its *seat*, being the rim of the circular orifice which the valve closes, is of the same figure with the face or rim of the valve, and the valve-face and its seat are turned and ground to fit each other exactly, so that when the valve is closed no fluid can pass. The thickness of a valve of this form is usually from a fifth to a tenth of its diameter, and the mean inclination of its rim about 45°.

To ensure that the valve shall rise and fall vertically, and always return to its seat in closing, it is sometimes provided with a *spindle*, moving through a ring or cylindrical socket. A knob on the end of the spindle prevents the valve from rising too high. When the valve is to be moved by hand or by mechanism, the spindle may be continued through a stuffing-box, and connected with a handle or a lever, so as to be the means of transmitting motion to the valve.

II. The *Ball Clack* is a drop-valve of the form of an accurately-turned sphere. When of large size, it is in general hollow, in order to reduce its weight. Its face is its entire surface: its seat is a spherical zone.

III. The *Divided Conical Valve* is composed of a series of concentric rings. The largest ring may be considered as a bonnet-valve, in which there is a circular orifice, forming a seat for a smaller bonnet-valve, in which there is a smaller circular orifice, forming a seat for a still smaller bonnet-valve, and so on. This arrangement enables a large opening for the passage of fluid to be formed with a moderate upward motion of each division of the valve.

IV. The *Double-beat Valve* is a drop-valve so contrived as to enable a large passage for a fluid to be opened and shut easily under a high pressure. Fig. 217 represents a section of the valve, with its seats and chamber, and fig. 218 a plan of the valve alone.

The valve shown in the figure is for the purpose of opening and shutting the communication between the pipes A and B.

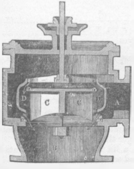

Fig. 217.

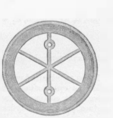

Fig. 218.

The pipe B is vertical, and its upper rim carries one of the two valve-seats, which are of the form of the frustum of a cone, and each marked a.

A frame C, composed of radiating partitions, fixed to and resting on the upper end of the pipe B, carries a fixed circular disc, whose rim forms the other conical valve-seat.

The valve D is of the form of a turban, and has two annular conical faces, which, when it is shut, rest at once on and fit equally close to the two seats, *a*, *a*. When the valve is raised, the fluid passes at once through the cylindrical opening between the lower edge of the valve and the upper edge of the pipe B, and through the similar opening between the upper edge of the valve and the rim of the circular disc.

The greatest possible opening of the valve is when its lower edge is midway between the disc and the rim of the pipe B, and is given by the following formulao—

Let

d_1 be the diameter of the pipe B;

d_2, that of the disc;

h, the clear height from the pipe to the disc, *less* the thickness of the valve;

A, the greatest area of opening of the valve; then

$$A = 3 \cdot 1416 \frac{d_1 + d_2}{2} \cdot h; \ldots\ldots\ldots\ldots\ldots\ldots (1.)$$

and in order that this may be at least equal to the area of the pipe B, viz., $\cdot 7854\ d_1^2$, we should have

$$h \text{ at least} = \frac{d_1^2}{2\,(d_1 + d_2)}; \ldots\ldots\ldots\ldots\ldots\ldots (2.)$$

which, if, as is usual, $d_1 = d_2$, gives

$$h \text{ at least} = \frac{d_1}{4}; \ldots\ldots\ldots\ldots\ldots\ldots (2\text{ A.})$$

but h is in general considerably greater than the limit fixed by this rule.

If the upper and lower seats are of equal diameter, the valve is called an *equilibrium-valve;* and this is the kind of double-beat valve most commonly used in steam engines. In water-pressure engines, pumps, and hydraulic apparatus generally, the lower valve-seat is generally made a little larger than the upper.

V. A common *Flap-Valve* is a lid which opens and shuts by turning on a hinge. The face and seat are planes.

A pair of flap-valves placed hinge to hinge constitute a "*butterfly clack.*" The chamber of a flap-valve should be of considerably greater diameter than the valve.

VI. A *Flexible Flap-Valve* consists of a piece of some flexible material, such as waterproof canvas or India rubber. It may be rectangular, so as to have one edge fixed to the seat, and the opposite edge attached to a bar, by moving which it is opened and shut; or it may be circular, and fixed to the seat at the centre; and this is the form usually adopted for self-acting flexible flap-valves in pumps. The seat of the flap consists of a flat horizontal grating, or a plate perforated with holes. To prevent a circular flap-valve from rising too high, it is usually provided with a guard, which is a thin metal cup formed like a segment of a sphere, grated or perforated like the valve-seat, to which it is bolted at the centre. When the valve is raised by a current from below, it applies itself to the bottom of the cup. When the current is reversed, the fluid from above, pressing on the valve through the holes in the cup, drives it down to its seat again.

VII. The *Disc-and-Pivot Valve*, or *Throttle-Valve*, consists of a thin flat metal plate or disc, which, when shut, fits closely the opening of a pipe or passage, generally circular in section, but sometimes rectangular. The valve turns upon two pivots or journals, placed at the extremities of a diameter traversing its centre.

When the valve is turned so as to lie edgeways along the passage, the current of fluid passes with very little obstruction: when it is turned transversely, the current is stopped, or nearly stopped. By placing the valve at various angles, various openings can be made. If the valve, when shut, is perpendicular to the axis of the pipe, the opening for any given inclination of the valve to that axis is proportional to the *coversed-sine of the inclination.* If the valve is oblique when shut, the opening at a given inclination is proportional to the *difference* between the *sine of that inclination* and the *sine of the inclination when shut.*

The *face* of this valve is its rim; its *seat* is that part of the internal surface of the passage which the rim touches when the valve is shut; and those surfaces ought to be made to fit very accurately, without being so tight as to cause any difficulty in opening the valve.

One of the journals of the valve usually passes through a bush or a stuffing-box in the pipe, so as to afford the means of communicating motion to the valve from the outside.

VIII. *Slide-Valves.*—The *seat* of a slide-valve consists of a plane metal surface, very accurately formed, part of which is a rim surrounding the orifice or *port*, which the valve is to close, and from $\frac{1}{4}$ to $\frac{1}{20}$ of the breadth of that orifice, while the remainder extends to a distance from the orifice equal to the diameter of the valve, in order that the valve, when in such a position as to leave the port completely open, shall still have every part of its face in contact with the seat.

The valve is of such dimensions as to cover the port together with that portion of the seat which forms a rim surrounding the port. The face of the valve must be a true plane, so as to slide smoothly on the seat. As to the periodical motion of slide-valves, see the next Article.

Rotating slide-valves are sometimes used, in which the valve and its seat are a pair of circular plates, having one or more equal and similar orifices in them. The passage is opened by turning the valve about its centre until its openings are opposite to those of the seat, and shut by turning it so that its openings are opposite solid portions of the seat. (See page 314.)

IX. *A Piston-Valve* is a piston moving to and fro in a cylinder, whose internal surface is the *valve-seat.* The *port* is formed by a ring or zone of openings in the cylinder, communicating with a passage which surrounds it; and by moving the piston to either side of those openings, that passage is put in communication with the opposite end of the valve-cylinder.

X. *Cocks.*—This term is sometimes applied to all valves which are opened and shut by hand; but its proper application is to those valves which are of the form of a frustum of a cone, or conoid, turning in a seat of the same figure.

In the most common form of cock, the seat is a hollow cone of slight taper, having its axis at right angles to the pipe in whose course it occurs. The valve is a cone fitting the seat accurately, and having a transverse passage through it of the same figure and size with the bore of the pipe, so that in one position it forms simply a continuation of the pipe, and offers no obstruction to the current, while, by turning it into different angular positions, the opening may be closed either partially or wholly.

268. **Periodical Motion of Slide-Valves.**—The motion of a slide-valve driven by a crank or an eccentric is a case of *approximate harmonic motion*, as already described in Article 239, page 250; and in most cases which occur in practice, it may be treated, without material error, as if it were exact harmonic motion: that is to say, the *travel* or *length of stroke of the slide* is twice the eccentric-arm; the slide is in its *middle position* when the eccentric-arm is sensibly at right angles to the line of its dead-points; in other words, when the *phase* of its revolution is sensibly 90°; and the *displacement* of the slide from its middle position at any given instant is sensibly equal to the eccentric-arm multiplied by the cosine of the phase. For example, in fig. 220 (page 308), the straight line F A L, bisected in A, represents twice the eccentric-arm; so that A F and A L respectively represent the displacements of the slide at the two dead-points of the revolution of the eccentric, when the phase is respectively 0° and 180°. On those two lines as diameters describe two equal circles, A H F G A, and A N L P A; then, when the phase is $= \angle$ F A D, the dis-

placement is = A G; and when the phase is = $\angle$ F A M, the displacement is = A N, in the contrary direction to that of the displacement A G.

Under the geometry of machinery are comprehended the rules by which the movement of the slide-valve of an engine is made to bear certain relations to that of the crank with which the piston is connected. The following are terms used in those rulese—

The two opposite sides of the port, or oblong opening in the seat of a slide-valve, are distinguished as the *induction-side* and the *eduction-side;*—the former being the side at which the fluid enters the port; the latter, the side at which it is discharged.

The *lap*, or *cover*, of a slide-valve at one of its edges is the extent to which that edge overlaps the adjoining edge of the port which it covers when the slide-valve is in its middle position. In fig. 219 is a section of part of a vertical slide-valve and its port; W is the lower port of a cylinder; X, the lower half of the slide-valve, in its middle position; U is the *induction-side*, and V the *eduction-side*, of the port; C is the *induction-edge*, and P the *eduction-edge* of the valve; U C is the *lap on the induction-side*, and V P the *lap on the eduction-side:* the hollow part of the valve opposite X is called the *exhaust-cavity*.

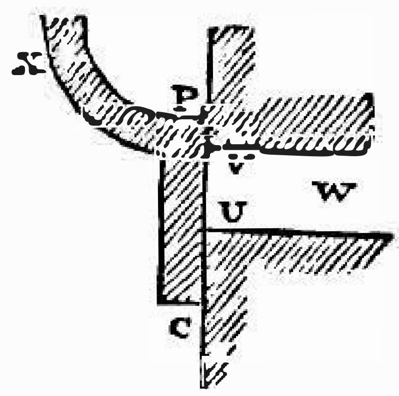

Fig. 219.

It is evident that the opening and closing of the port at either side take place at the instants when the displacement of the slide in a direction *away* from that side is equal to the lap at that side; and that the port remains open at that side so long as the displacement in the proper direction is greater than the lap. Thus, the port W remains open at the side U, so long as the displacement of the slide towards P is greater than U C; and at the side V, so long as the displacement of the slide towards C is greater than V P. If the lap at either side is nothing, the opening and closing at that side take place in the middle position of the slide; and the port remains open at that side during half a revolution of the eccentric.

The instant at which the port is first opened at the induction-side is called the instant of *admission;* that at which it is closed, of *suppression*, or *cut-off;* that at which it is first opened at the eduction-side, the instant of *release;* that at which it is closed at the eduction-side, the instant of *compression*.

By the *angular advance* of the eccentric is to be understood the angle at which the eccentric-arm stands in advance of that position, which would bring the slide-valve to mid-stroke when the crank is at its dead-points: in other words, the excess above 90° of the phase of the eccentric when the phase of the crank is 0°; or in symbols, phase of eccentric – phase of crank – 90°. When the slide is at its middle position at the same instant at which the crank is at a dead-point, the angular advance is nothing.

RULE I.—Given, the positions of the crank at the instants of admission and cut-off; to find the proper angular advance of the eccentric, and the proportion of the lap on the induction-side to the half-travel of the slide.*

In fig. 220, let A B and A C be the positions of the crank at the beginning and end of the forward stroke; let the arrow show the direction of rotation; let X x be perpendicular to B C; let A D be the position of the crank at the instant of cut-off, and

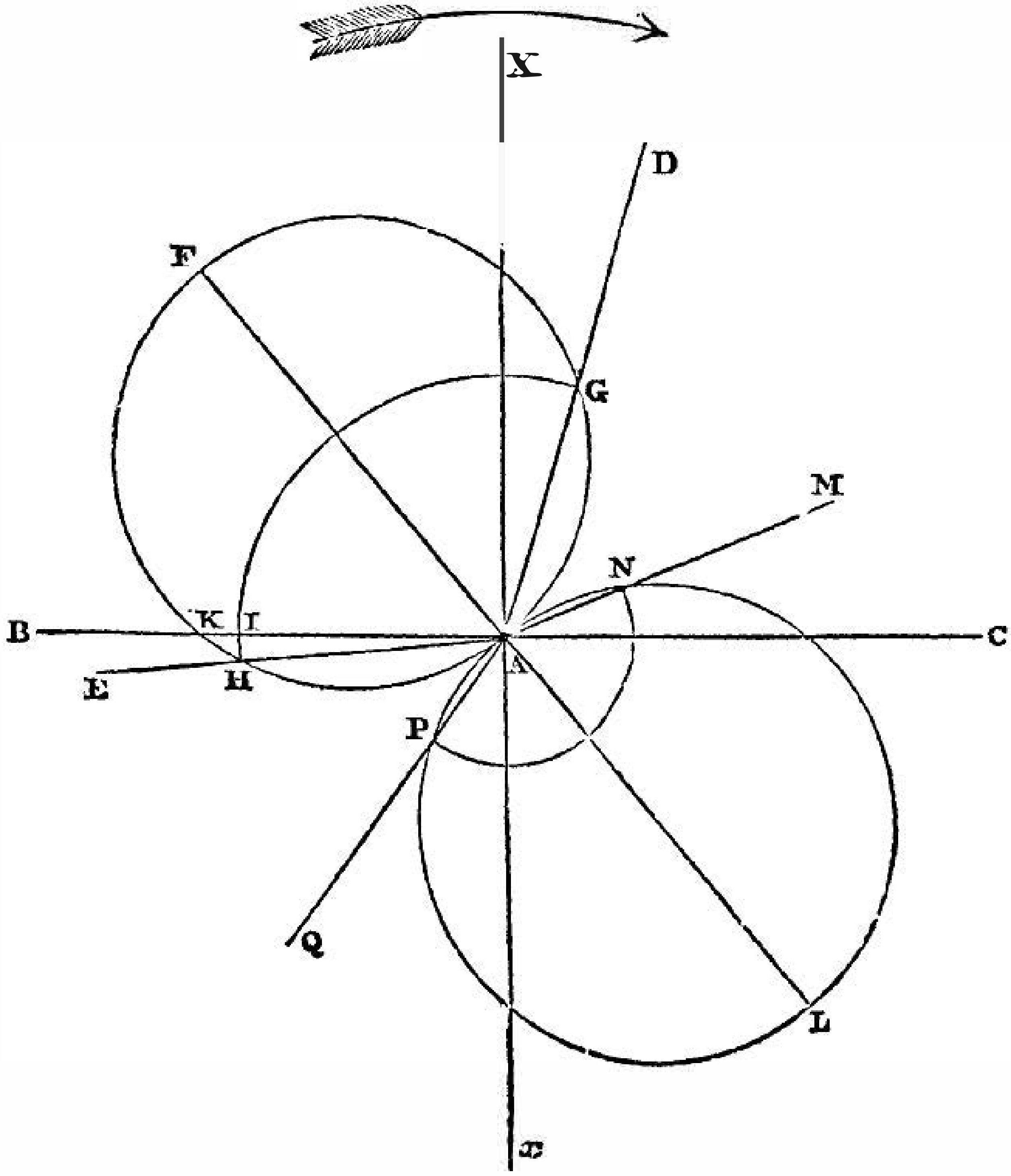

Fig. 220.

A E its position at the instant of admission. Draw A F, bisecting the angle E A D; A F will represent the position of the

* The method used in this and the following rules is that of Professor Dr. Zeuner, of the Swiss Federal Polytechnic School at Zürich, published in his treatise on Slide-valve Gearing, entitled, *Die Schiebersteuerungen*.

crank at the instant when the slide is at the *forward end* of its stroke; and F A X will be the *angular advance of the eccentric.*

Lay off the distance A F to represent the half-travel; and on A F as a diameter describe the circle A H F G, cutting A D in G and A E in H; then $\frac{AG}{AF} = \frac{AH}{AF}$ will be the *required ratio of lap at the induction-side to half-travel;* and A G = A H will represent that lap, on the same scale on which A F represents the half-travel.

On the same scale, I K represents the *width of opening of the valve at the beginning of the stroke,* sometimes called the "*lead of the slide.*" Strictly speaking, this is the lead of the induction-edge of the slide only; the lead of the centre of the slide being A K; that is, its distance from its middle position at the beginning of the forward stroke.

Rule II.—Given, the data and results of the preceding rule, and the position, A M, of the crank at the instant of release; to find the ratio of lap on the eduction-side to half-travel, and the position of the crank at the instant of compression. Produce F A to L, making A L = A F; on A L as a diameter draw a circle cutting A M in N; then $\frac{AN}{AL}$ will be the *required ratio of lap at eduction-side to half-travel.*

About A draw the circular arc N P, cutting the circle A L again in P; join A P; then A P will be the required *position of the crank at the instant of compression.*

Rule III.—Given, the data and results of Rule I., and the position, A Q, of the crank at the instant of compression; to find the ratio of lap at the eduction-side to half-travel, and the position of the crank at the instant of release. Produce F A as before; on A L = F A as a diameter draw a circle cutting A Q in P; $\frac{AP}{AL}$ will be the *required ratio of lap at the eduction-side to half-travel.*

About A draw the circular arc P N, cutting the circle A L again in N; join A N; A N will be the position of the crank at the instant of release.

Rule IV.—Given, the angular advance of the eccentric, the half-travel of the slide, and the lap at both sides; to find the positions of the crank at the instants of admission, cut-off, release, and compression. Draw the straight lines B A C and X A x perpendicular to each other; and take B and C to represent the dead-points. Let the arrow denote the direction of rotation. Draw F A L, making the angle F A X = the angular advance of the eccentric; and make A F = A L = half-travel. On A F and

A L as diameters, draw circles. About A, with a radius equal to the lap at the induction-side, draw an arc cutting the circle on A F in H and G; also, with a radius equal to the lap at the eduction-side, draw an arc cutting the circle on A L in N and P. Draw the straight lines A H E, A G D, A N M, A P Q. These will represent respectively the positions of the crank at the instants of *admission*, *cut-off*, *release*, and *compression*.

The eccentric may act on the slide, not directly, but through a train of levers and linkwork. The effect of this on the application of the rules is merely to substitute for the actual eccentric-arm a virtual eccentric-arm equal to the half-travel of the slide.

The effects of the link-motion, of double slides, and of moveable slide-valve seats, in modifying the length and position of the virtual eccentric-arm, have been already described in Articles 239 to 241, pages 250 to 260.

SECTION II.—*Of Adjustments for Changing Speed and Stroke.*

269. **General Explanations.**—All methods of changing the velocity-ratio of an elementary combination in a machine operate by changing the position of their line of connection; for on the position of that line the velocity-ratio depends, according to the principle already explained in Article 91, page 78. In some cases the combination contains two or more pairs of acting surfaces (such as wheels or pulleys), one or other of which can be thrown into gear according to the velocity-ratio required; and then it is in general necessary to stop the motion in order to change the velocity-ratio. In other cases there are contrivances for changing the velocity-ratio by degrees while the machine is in motion.

In the case of linkwork the change of velocity-ratio is often connected with a change of length of stroke.

Many of the most ordinary and useful adjustments for changing speed have already been described under the head of elementary or of aggregate combinations; and in such cases it will be sufficient in the present section to refer to the place where the detailed description is to be found.

Adjustments for changing speed, like engaging and disengaging-gear, may in most cases be distinguished into two classes, according as the connection is made by pressure or by friction. In the former case the change of velocity-ratio is definite, and in most instances sudden; in the latter case, gradual, and to a certain extent indefinite.

270. **Changing Speed by Friction-Wheels.**—To obtain changes of speed by means of friction-wheels, a pair of parallel shafts are to be provided with as many pairs of wheels as there are to be different velocity-ratios; each pair of wheels being connected with each other, not directly, but by means of an intermediate idle wheel,

which can be thrown into or out of gear at pleasure, as in the second method of disengagement described in Article 262, page 297; the only difference being that whereas in that Article the two principal wheels of the pair are described as being equal, in the present case they will in general be unequal. The rule as to the obliquity of the line of connection is the same. (See page 298.)

A combination of friction-wheels in which the velocity-ratio is changed by degrees during the motion, is shown in fig. 221. (It forms part of Morin's Integrating Dynamometer.) A is a plane circular disc, turning about an axis perpendicular to its own plane. B is a wheel driven by the friction of the disc against its edge; and it turns about an axis that cuts the axis of A at right angles. The angular velocity of B varies proportionally to its distance from the centre of A, and is varied by altering that distance.

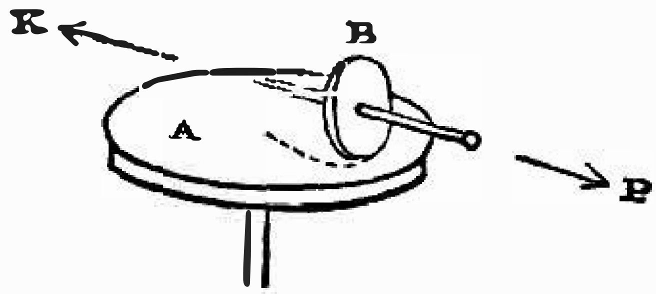

Fig. 221.

271. **Changing Speed by Toothed Wheels.**—The ordinary method of producing precise and definite changes of the angular velocity-ratio of two rotating shafts is by means of *change-wheels:* that is to say, there are several pairs or trains of wheels, suited to a certain series of velocity-ratios; and one or other of those pairs or trains of wheels is thrown into gear according to the comparative speed that is wanted at the time.

Sometimes the wheels are made so as to be put on the shafts and taken off at pleasure. If an intermediate idle wheel is not used, between two shafts connected by pairs of change-wheels, there must be as many pairs of change-wheels as there are different velocity-ratios; because the sum of the geometrical radii of each pair must be equal to the line of centres; but by the help of an intermediate idle wheel, any two wheels which are not so large as to touch each other may be put into connection; so that by a proper choice of numbers of teeth, the number of different ratios may be made equal to the product of the number of different wheels that can be fitted on one shaft into the number that can be fitted on the other after the first has been fitted.

Change-wheels are frequently arranged so as to be thrown into or out of gear by shifting the whole series longitudinally along with the shaft that carries them. For example, in fig. 222 A A and B B are a pair of parallel axes; and the transverse lines marked 1, 2, 3, &c., represent the radii of two series of change-wheels carried by shafts turning about those axes respectively. To each wheel of one series there corresponds a wheel in the other series, marked with the same figure; and any such pair can be thrown into gear when required, by shifting the shaft A longitudinally. To place the wheels on the shafts so as to occupy the least possible space, the following rules are to be observed:—Let b denote the breadth of the rim of a wheel, plus a small allowance for clearance. Range the radii of the wheels on A in such a manner that the greatest shall be in the middle, with a diminishing series on

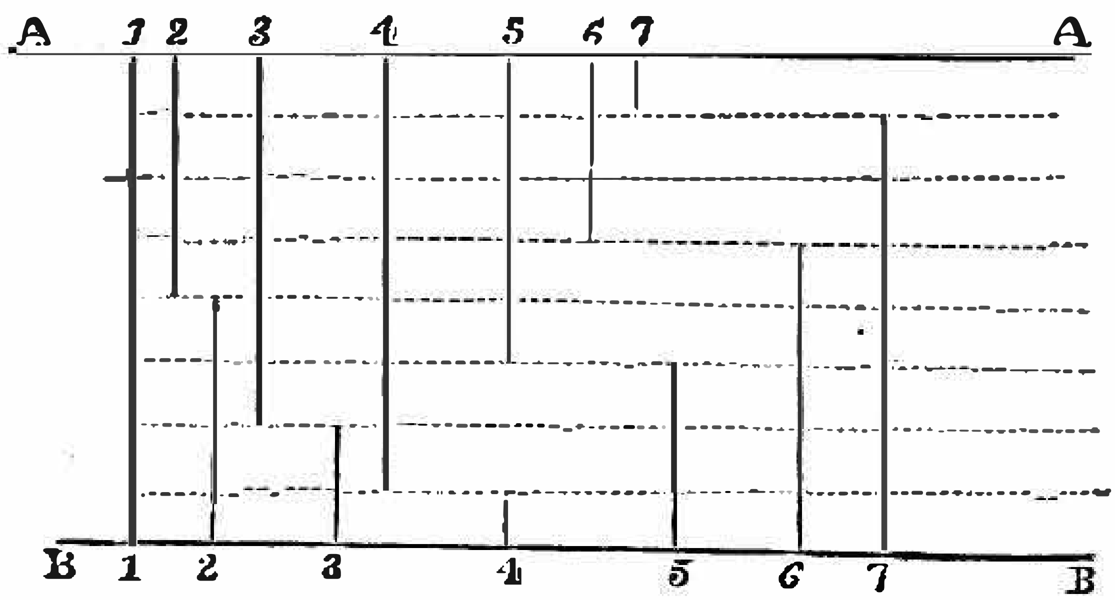

Fig. 222.

each side of it. Then, commencing at the two ends of the double series, make the two endmost intervals between the middle planes of the wheels on the axis A ($\overline{1\,2}$ and $\overline{7\,6}$ in the figure), each $= b$; the pair of intervals next them ($\overline{2\,3}$ and $\overline{6\,5}$ in the figure), each $= 2\,b$; the next pair ($\overline{3\,4}$ and $\overline{5\,4}$), each $= 3\,b$; and so for any number of intervals that may be required. Then make the interval between the middle planes of each pair of wheels on the axis B greater by *one breadth*, b, than the corresponding interval on the axis A.

272. **Changing Speed by Bands and Pulleys.**—The most convenient way of changing the velocity-ratio of rotation of a pair of shafts, where absolute precision in the ratio is not required, is by means of "*speed-cones*," which have already been described in Article 175, page 185. When a series of pulleys is used with radii changing step by step, the motion must be stopped in order to shift the band from one pair of pulleys to another; and this is applicable to cords as well as to belts. When tapering conoidal pulleys are used, the belt can be shifted, and the velocity-ratio gradually changed, while the machinery is in motion; and this is applicable to belts only.

273. **Changing Stroke in Linkwork.**—The principles upon which the length of stroke in linkwork depends have been explained in Article 186, page 197. When a piece receives a reciprocating motion from a lever, a crank, or an eccentric, the simplest way of changing the length of stroke is to change the distance of the connected point in the lever, crank, or eccentric, from its axis of motion. In the case of a continuously rotating crank or eccentric, this can be done by means of an adjusting screw, the motion being

stopped when an alteration is to be made; but in the case of a reciprocating lever, the pin to which the connecting-rod is jointed may be carried by a stud, capable of sliding in a slot in the lever, and having its position in that slot adjusted by means of a rod and a handle which can be shifted while the machinery is in motion. Sufficient examples of the latter kind of action have already been given under the head of link-motions, in Article 240, pages 253 to 260.

Fig. 223 represents a train of linkwork proposed by Willis, for adjusting the velocity-ratio and comparative length of stroke of two reciprocating points. The points to be connected are marked D and E; and D A and E A are their lines of stroke, intersecting each other in A. A B is a train-arm centred at A, and capable of being adjusted to any required angular position. At B, the other end of the train-arm, is centred the reciprocating lever B C, equal in length to B A, and connected with the points D and E by the links C D and C E.

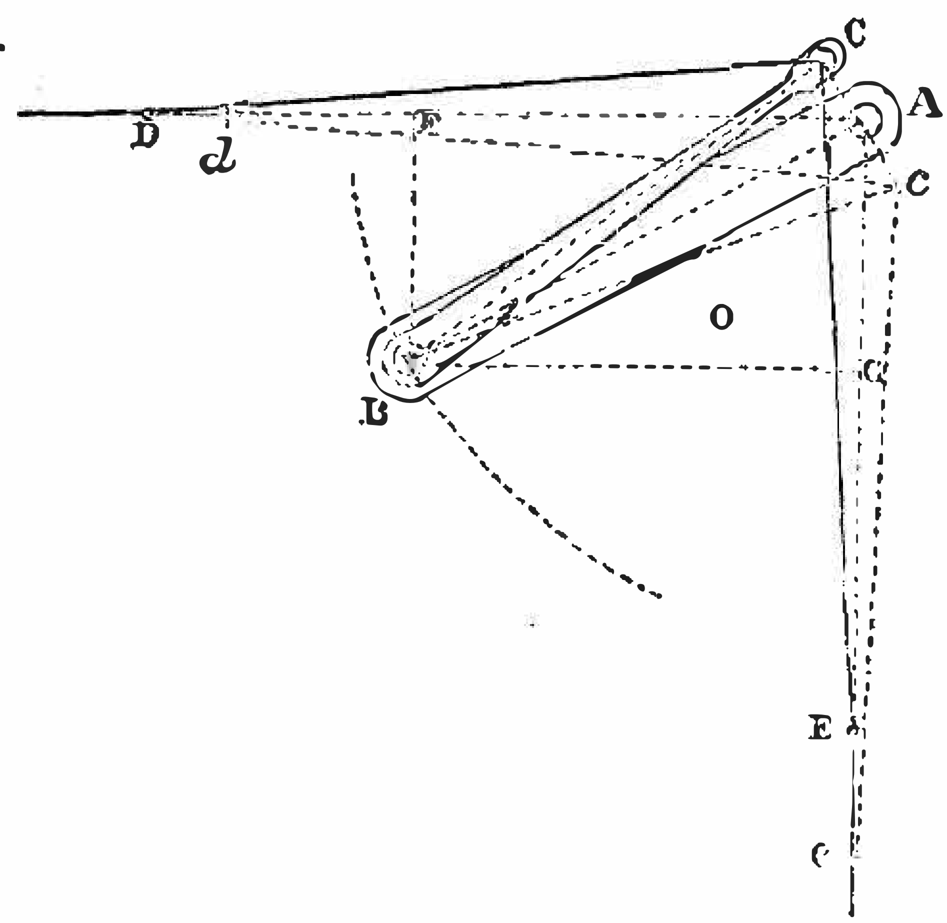

Fig. 223.

While the lever B C oscillates through a small angle to either side of B A, the motions of D and E are very nearly equal to the component motions of C along A D and A E respectively; that is to say, we have, at any given instant, the following proportion very nearly exact:—

$$\begin{array}{ccccc} & \text{Velocity of C} : & \text{velocity of D} : & \text{velocity of E} \\ :: & \text{B A} & : \quad \text{B F} & : \quad \text{B G}; \end{array}$$

in which B F and B G denote the lengths of perpendiculars let fall from B on A D and A E respectively; and the same proportions hold very nearly for the lengths of stroke of those three points; hence those proportions can be made to assume any required value while the mechanism is in motion, by adjusting the position of the train-arm A B.

274. **Changing Speed with Hydraulic Connection.**—The comparative speed of a piston driven by a fluid may be altered by altering the number of driving-pistons which force the fluid into the cylinder of the driven piston at the same time. For example,

in some hydraulic presses it is desirable to diminish step by step the ratio which the velocity of the press-plunger bears to that of the pump-plungers; and that is done by forcing water into the press-cylinder at first by means of several pumps at once, and diminishing their number as the process goes on, until at last only one is kept at work.

Addendum to Article 267, Page 306.

Slide-Valves.—Another class of rotating slide-valves is that in which the seat of the valve forms part of a cylindrical surface, usually concave; the face of the valve forms an arc of a corresponding cylindrical surface, convex when the seat is concave; and the reciprocating motion of the valve takes place by rocking, or oscillating rotation, about the axis of the cylindrical surfaces. The "Corliss" valves are an example of this.

A straight-sliding slide-valve and its seat are also sometimes of a cylindrical form, the reciprocating motion taking place parallel to the axis of the cylinder.

There are instances of plane-faced slide-valves which have motions of curvilinear translation, produced by aggregate combinations of linkwork: for example, Hunt's slide-valves.