ON AN IMPROVED FRICTION COUPLING AND BREAK, AND ITS APPLICATION TO HOISTS, WINDLASSES, AND SHAFTING, &c.

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The Frictional Apparatus forming the subject of the present paper has been successfully employed as a Clutch or Coupling and also as a Break. The applications already made are very varied, ranging upwards from the small friction bearings of toilet or swing glasses which yield a resistance of a few pounds only, to the "connector and break" of ships' windlasses for resisting a direct pull of thirty tons or more.

The apparatus consists of two series of friction discs, arranged alternately with each other upon a common axis, one series being carried by one shaft, and the other series connected to the other shaft or wheel which is required to be coupled with the first shaft. The discs on the first shaft cannot turn independently of it, but can slide lengthwise upon it towards or from each other: this series of discs are for convenience called the "shaft discs" in the following description. Arranged alternately with them are the discs of the other series, which have each a circular central opening sufficiently large to clear the shaft entirely; but at their outer edge they are slotted or made polygonal, or otherwise fitted in their outline to an external drum or cylinder containing them, so that they cannot rotate independently of the drum but may slide longitudinally within it. These discs are called for distinction the "intermediate discs;" and the drum containing them forms part of the spur wheel that is required to be connected to the shaft with a coupling or break action; or the drum is attached to a second shaft lying in line with the first, with which the second shaft is required to be coupled. So long as no longitudinal compression is applied to the discs, the shaft discs with the shaft carrying them are free to rotate independently of the intermediate discs and the drum containing them; but upon compressing the discs together longitudinally into frictional contact, the rotary motion of one series is either transmitted wholly to the other series, or is controlled or arrested by friction against the discs of the other series; and the double series of discs acts thus either as a coupling or as a break. The great advantage arising from the alternate arrangement of the discs is that the frictional effect of any pressure applied to couple them is repeated as many times as there are discs in the two series; that is, the number of all the discs is a constant multiplier for the friction produced between a single pair of the rubbing surfaces by any given pressure.

This principle of the multiplication of frictional surfaces is illustrated by the diagram Fig. 1, Plate 105, where instead of two series of discs there are shown two series of short flat plates, arranged like the discs alternately with each other. The one series A A are severally tied to the fixed pillar C, and each one of the other series B B has its sides in frictional contact with two of the first series. The applied pressure for frictionally coupling the two series is furnished by the weight D. Upon withdrawing any one of the series B in the direction shown by the arrow, a certain degree of resistance will occur, in consequence of the friction upon its two sides due to the pressure of the weight D. Upon withdrawing two of the series B together, twice as much resistance occurs; and if the whole series B B are simultaneously withdrawn, the resistance is further increased in proportion to the whole number in that series. The double series A B represented in the diagram having eight pairs of rubbing surfaces repeats eight times over the friction due to the weight D acting direct upon one pair of surfaces; and in this case therefore eight is a constant multiplier for the friction due to any given pressure at D. Hence, as the number of the plates or discs may be indefinitely increased, an indefinite increase or extension of frictional area may be obtained, without any reduction of the pressure per square inch upon the rubbing surfaces; in consequence of which the remarkable result is obtained of an indefinite increase in the total amount of friction with the same load.

It may be remarked as an illustration that this principle of the repetition of frictional surfaces is the basis of the structure of ordinary hempen ropes. In that case contiguous fibres present their surfaces to each other in frictional contact, and the frictional adhesion between them is due to the initial pressure given by the original twist in the strands, and to the resultant pressure arising from the oblique direction of the strain upon the fibres under a load; and a rope of an inch diameter is stronger than a half-inch rope because of the greater number of fibres in frictional union which it contains. The "coupling" pressure upon the fibres may be wholly removed by completely untwisting the strands of the rope; and the strength of the rope will then have disappeared, simultaneously with the loss of the frictional union of its fibres.

In Fig. 2, Plate 105, is represented a form of experimental friction break or coupling, composed of two series of circular friction discs A A and B B, the relative motion of the rubbing surfaces being circular, instead of in a straight line as in Fig. 1. The shaft discs A are made an easy fit upon the square shaft C, so that they may slide to or from each other upon the shaft into more or less intimate contact with the intermediate discs B; and the latter, when no coupling pressure is applied, are capable of turning freely upon the circular bosses of the shaft discs A. The coupling pressure is applied or withdrawn by means of the cranked lever D, the short forked arm of the lever compressing the discs longitudinally upon the shaft against the fixed pin E. So long as no compression is applied, the shaft C can rotate freely, carrying with it the discs A, which do not then transmit any driving force to the discs B; but upon compressing the discs into frictional contact with each other, the rotary motion of the shaft will be transmitted by the discs A to the intermediate discs B. The rotation of the shaft being maintained, and the discs B being held from turning by a cord F wound round the circumference of each, the tension upon each cord measures the friction between each two pairs of the circular rubbing surfaces; and the strain upon all the cords taken together is the total force which the whole series of intermediate discs B is then absorbing by break action upon the shaft discs A. The collective strain upon all the cords represents also the tangential force which under the same pressure the discs B will transmit at their circumference when employed as a coupling, together with the difference between the friction of motion and the friction of repose; this strain is indicated by the spring balance H, upon which all the cords pull by the intervention of the crossbar G. The ratio of the strain on the spring balance H to the coupling pressure applied by the lever D is constant for all pressures; that is, in the same coupling and break, or in one containing the same number of friction discs, which have the same pitch line or centre of friction, and are made of similar materials with their rubbing surfaces in the same condition. To illustrate this uniformity of action, the coupling pressure at D may be applied gently and increased by imperceptible gradations to any required extent, and in like manner gradually withdrawn again; and the tangential force indicated by the spring balance H will simultaneously rise and fall with the same steady regularity. The coupling pressure may also be applied and withdrawn very suddenly, or even with a jerk, and proportionate extremes of force will then be indicated with the same abruptness by the spring balance H; and this will be the case, whether the fluctuations of the applied pressure are faint, arising from very minute but sudden variations like rapid pulsations, or whether the variations are excessive as well as rapid. This sensitiveness of the friction coupling is due to the parallelism of its rubbing surfaces, since the frictional action between parallel plane surfaces necessarily fluctuates in true and instant correspondence with every variation of the applied pressure.

The power of the coupling and break, which might be increased if necessary so as to exceed the ultimate strength of the shaft without any sacrifice of sensitiveness, is due to the principle of repeating the frictional surfaces, whereby the total area of frictional contact can be increased indefinitely without diffusing or diminishing the initial pressure between the frictional surfaces; that is, every disc repeats without diminution the frictional effect produced by the applied pressure upon the first pair of surfaces. The arrangement of the double series of alternate discs possesses peculiar advantages in the varieties of adaptation of which it is susceptible, enabling it to be used under widely different conditions. Where the space available for a friction coupling or break is limited in a radial direction, so that the discs are required to be small in diameter, the necessary amount of friction is obtained by extending the coupling lengthwise along the shaft, employing an increased number of the discs to compensate for their small diameter. On the other hand, where the space is limited longitudinally upon the shaft, involving the use of fewer discs, their diameter can be increased to give the necessary amount of frictional surface.

The materials and structure of the discs may be very various. For the severest strains both series of discs are made of iron, one series being faced with wood segments placed endways of the grain. A coupling capable of very high duty, and one very compact in form, is obtained by employing thin sheet steel for the material of both series of discs, and facing one series with leather faces on both sides, the leather being attached by fine copper wire passed through small holes in the steel discs. For break purposes iron and wood discs are employed, and the wood discs are thoroughly saturated with linseed oil and the iron discs made smooth; the wear of the discs then becomes imperceptible. In consequence of the large amount of rubbing surface obtained, the lowest coefficient of friction suffices, and the break may therefore be always lubricated if desired, and is still sufficiently powerful. The pitch line or centre of friction of the discs is the circle dividing their working faces into two equal annular areas. By enlarging the central opening in the intermediate discs, so as to make their working face a narrow annular ring, the pitch line is thrown further outwards from the shaft, and the power of the coupling is thereby increased by increasing the leverage at which it acts; but for break purposes this reduction of the actual area is not always desirable, as it reduces the amount of wearing surface, though increasing the efficiency of the break.

For a coupling required to transmit motion and to cease doing so instantly at definite points in a revolution with exact precision, the intermediate discs are sprung apart by means of small springs placed near their edges, and the shaft discs are sprung apart by small spiral springs in their bosses, as shown in Fig. 2. This plan of springing the discs apart when the pressure is withdrawn renders the coupling applicable to vertical or inclined shafts, or to a shaft having other motions than simply round its own axis. By employing springs of graduated strength between the discs, a coupling or break may be arranged for obtaining a gradually increasing frictional action, by making only one pair of faces come into action first; and during the time that this one pair only is in contact the frictional action between them can be gradually augmented by a gently increasing pressure, until the springs separating the next pair of discs are sufficiently compressed to bring these also into action, and so on until any required number of discs are in action. When all the discs have thus been brought into action the frictional resistance of a break constructed upon this plan will still continue to increase under a further increase of pressure, until all relative motion between the two series of discs has ceased. This arrangement for bringing the discs successively into action will give a graduated effect uniformly increasing by delicate and scarcely perceptible grades up to the full power of the break; and it might be advantageously applied for such purposes as arresting rapid rotation in centrifugal drying machines.

The practical applications described in the present paper of this friction coupling and break are those only which have proved economical and preferable to other frictional appliances; but many other applications are now in progress. For the purpose of hoisting, nearly four hundred crabs, cranes, and hoists, constructed upon this principle, have now been put to work; and the results of their use during five years have proved quite satisfactory. A 5 ton crab on this construction at the Bardon Granite Quarries, Leicester, is now working as well as when first used about five years ago; and during that period it has had nearly constant work in lifting empty trucks.

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As friction couplings upon fixed driving shafts a considerable number of these couplings are at work, applied to small shafts of less than 3 inches diameter; and sufficient advantage has been found after nearly three years' trial to lead to the further adoption of the plan for much larger shafts, to which the coupling is now being applied accordingly.

In Figs. 3 to 5, Plate 106, is shown a portion of a 6 ton Hoisting Crab. Fig. 3 is a longitudinal section, and Figs. 4 and 5 are transverse sections showing separately one of the wood discs and one of the iron discs. The shaft discs A, made of wrought iron, are here five in number, with a square hole in the centre of each, fitting upon the square portion C of the shaft, Fig. 5. The four intermediate discs B are of elm wood, and engage with the external drum D by the slots in their edges, into which fit the longitudinal ribs on the inner surface of the drum, Fig. 4. The drum D forms a portion of the pinion casting E, which when uncoupled turns freely upon the shaft; and for the purpose of hoisting it is coupled with the shaft by the frictional action of the discs A B in the same manner as in the preceding examples. The coupling pressure is applied by the handwheel F, the boss of which is screwed to traverse upon the screwed part of the shaft; and by this means the discs are compressed together against the collar G, upon which the pinion turns when uncoupled. The shaft carries at its ends the usual winch handles, and is also provided with the ordinary ratchet-wheel to prevent it turning backwards when the winch handles are released. For lowering the load it is only necessary to turn the handwheel F backwards, unscrewing it slightly from its pressure upon the discs, until the load makes the pinion E run backwards; and the speed of lowering is controlled with great exactness or the descent of the load can be instantly arrested without exertion by again screwing the handwheel forwards upon the break. The advantages obtained in this case are despatch and safety; the winch handles never turn backwards in lowering, and the load is kept completely under control with the greatest ease.

In Figs. 6 and 7, Plate 107, is shown a Sack Hoist, as used without tackle blocks; and with the blocks it forms a convenient hoist for weights up to half a ton. Fig. 6 is an end elevation, and Fig. 7 a longitudinal section to a larger scale. The winding barrel D is loose upon the shaft, and is recessed at one end to form the break drum. The coupling and break is exactly similar to the one last described, the five iron shaft-discs fitting upon the square part of the shaft C, and the intermediate wood discs engaging with the ribs inside the drum D. The rope-wheel F is screwed to traverse upon a screwed portion of the shaft. A ratchet-wheel G fixed upon the shaft prevents it from turning backwards, and also forms a collar or abutment to receive the coupling pressure applied by the screwed boss of the rope-wheel. An endless rope passes over the rope-wheel, and on pulling the rope in the direction for hoisting, the rope-wheel advances upon the screw and compresses the friction discs, until the friction between them is sufficient to couple the winding barrel D to the shaft C. On continuing the hoisting motion the load is then raised, and is held suspended at any point by the ratchet-wheel G. For lowering the load it is only necessary to pull the rope in the opposite direction, and as the shaft cannot turn backwards on account of the ratchet-wheel, the rope-wheel is thereby withdrawn, relieving the friction discs from pressure; and the winding barrel being thus uncoupled from the shaft runs backwards on it with the load. The speed of lowering is under perfect control by holding the endless rope with one hand on each side, and applying the break as required to check the descent of the load, by pulling the rope slightly in the direction of hoisting, so as to screw the rope-wheel up against the friction discs. This arrangement of hoist has the advantage that both the hoisting and the lowering are done at pleasure by means of the single endless rope, which affords perfect control over the load at all times.

In Figs. 8 and 9, Plates 108 and 109, are shown portions of one of Messrs. Harfield's Ships' Windlasses for a 2 inch chain-cable, the frictional apparatus being employed as a "connector" or coupling, and also as a break. This application has been approved by the Admiralty, and the windlass has been introduced for use in the navy. Fig. 8 is a sectional plan and Fig. 9 a transverse section of the windlass, taken through the break drum. The cable-holder or chain-wheel C is cast in one piece with the break drum D; and when the friction discs are uncoupled, the chain-wheel can turn freely on the horizontal shaft E, which is supported in the cast-iron framework F F of the windlass. The shaft E is rotated by the pair of nipping wheels H keyed upon it, one of which only is shown in the drawing, each wheel being fitted with a nipping lever G; the pair of nipping levers receive an alternate up and down motion from a reciprocating sway beam, at the opposite ends of which the two levers G are attached, the beam being worked up and down by manual labour. In the downward movement of the nipping lever it slips down freely over the rim of the wheel H until it jams itself; and then in the upward movement it bites or nips the wheel and turns it forwards through a portion of a revolution: in this way by the alternate action of the pair of nipping levers the shaft E is rotated with a continuous motion in the direction of the arrow in Fig. 9.

The boss of the nipping wheel H projects inwards within the break drum D, Fig. 8, to a sufficient distance to carry the required number of friction discs; and its exterior is shaped with three solid keys J J, Fig. 9, which engage in corresponding slots in the iron shaft-discs A. There are six of the shaft-discs, which are made of wrought iron galvanised for preventing corrosion. The seven intermediate discs B B are made of teak wood, and are of square outline with the corners bevilled off, engaging with the drum D by their angles, as shown in Fig. 9. The coupling pressure for compressing the friction discs together is applied by means of the screw N turning loose on the shaft E and working in the nut M, to which the back plate K at the further end of the series of friction discs is connected by the three longitudinal bolts L passing through holes in the boss of the nipping wheel H; by turning the screw forwards the back plate K is tightened up towards the nipping wheel H, compressing the discs with the required pressure. The screw N is made with a capstan head, having recesses O round its circumference to receive a hand lever for turning it, when a heavy pressure is required upon the friction discs for coupling the chain-wheel C solidly to the nipping wheel H. For light pressures or for break action the screw is turned by the small handles P fixed round its circumference; and one quarter turn of the screw is sufficient to stop altogether the running out of the cable or to release it entirely.

One end only of the windlass is shown in the plan, Fig. 8, and the opposite end of the shaft E carries an exactly similar chain-wheel C and nipping wheel H; so that the continuous rotary motion given to the shaft E by the pair of nipping wheels H may be transmitted to either one of the chain-wheels C by applying the coupling pressure to the set of friction discs with which each chain-wheel is provided. As a connector this application of the friction discs offers the advantage of connecting the chain-wheel with the shaft of the windlass at any point in a revolution, without letting go of the cable or taking in any more of it; and as a break its power and compact form have proved very advantageous. A windlass of the size shown in Figs. 8 and 9 is suitable for a ship of 1800 tons register, the iron shaft-discs being 23 inches diameter and $\frac{1}{4}$ inch thick, and the intermediate teak discs 23 inches square and $\frac{3}{4}$ inch thick.

In an experiment with one of these windlasses of a smaller size, containing six pairs of the friction discs, upon which the coupling pressure was applied by a lever $3\frac{1}{2}$ feet long with the force of two men, the friction break served to hold and control a direct pull upon the cable of 34 tons, without injury to the friction discs. In this case the iron discs were $14\frac{1}{4}$ inches diameter and $\frac{3}{16}$ inch thick, as shown in Fig. 10, and the wood discs were $\frac{3}{4}$ inch thick with a centre hole 11 inches diameter, as shown in Fig. 11.

In Fig. 12, Plate 110, is shown a simple form of Shaft Coupling, employed to drive shaking or tumbling barrels at Messrs. Nettlefold's screw works, Birmingham. Fig. 12 is a longitudinal section, and Figs. 13 and 14 are transverse sections showing the iron and wood discs separately. The five iron discs A engage with solid keys on the long boss of the spur wheel E, within which the driving shaft C turns freely when no coupling pressure is applied to the discs. The drum D containing the six intermediate wood discs B slides on feathers on the shaft C, and the groove G on the outer end of the drum receives the forked end of a lever by which the coupling pressure is applied, compressing the discs against the fixed collar F on the shaft, and thereby coupling the spur wheel E to the shaft C. To prevent wear, the forked end of the lever is faced with segmental pieces of hardened steel; and the loss of power by end pressure upon the shaft is not found to be any serious amount. The advantage realised by this arrangement of frictional shaft coupling is the prevention of breakage to gearing and straps, which was previously of very frequent occurrence.

In Figs. 15 and 16, Plate 111, is shown a Safety Clutch, intended simply for preventing breakage by overstrains; it was constructed for driving agricultural machinery by the power of oxen. Fig. 15 is a longitudinal section, and Fig. 16 an end elevation and transverse section. The clutch forms a frictional connection between the two shafts C and E placed in line with each other, the shaft C carrying the four iron discs A, which slide on keys upon it, while the other shaft E carries the drum D securely keyed to it. A cover plate, through which the shaft C passes freely, is secured to the drum D by the six bolts G G passing through near its outer edge; and these bolts form the ribs or projections inside the drum for engaging with the five intermediate wood discs B. The coupling pressure is applied by the four set-screws H H, which are adjusted by hand to the required pressure. By this means the power which the clutch will transmit without slipping can be adjusted with nicety, according to the work to be done or the strength of the machines to be driven; and any sudden increase of resistance or of driving power, beyond the limit to which the clutch is adjusted, will cause the friction discs to slip upon one another, whereby all liability of injury or breakage is prevented.

In Figs. 17 and 18, Plate 112, is shown a Self-Engaging Friction Coupling, applied to shafting at Messrs. Whitbread's brewery in London. The driving shaft C carries the four iron discs A, as before, and the drum D containing the five intermediate discs B of elm wood is keyed on the driven shaft E. The coupling pressure is applied by the spiral springs I I, inserted between the inner end of the drum and an iron disc or cover plate K bearing against the first of the wood discs B. The plate K is connected by the bolts H with the exterior sliding collar G, which is grooved to receive the steel ring L carried by the forked end of the hand lever M; so that by means of this lever the coupling pressure can be taken off the friction discs at any time; and by locking the lever in this position with the pressure withdrawn, the coupling ceases to transmit the power from the driving shaft C, and the shaft E with the drum D accordingly remains at rest. On releasing the lever M, the coupling immediately throws itself into gear again, with a self-engaging action, by the springs I pressing the series of discs into frictional contact; and the two shafts are then coupled and revolve together, without any loss of power by end pressure.

In Fig. 19, Plate 113, is represented an application of the friction coupling as a Lathe Coupling, as applied by Messrs. Tangye of Birmingham to a three-spindle lathe. The drawing is a transverse vertical section through the lathe-bed and saddle. The friction coupling is applied to the back-traverse motion of the lathe, in place of the ordinary cone clutch so often employed in similar situations, which however is found not to transmit sufficient power nor in so convenient a manner for lathes of this description, where there are three cutting tools acting simultaneously. The back shaft K carries as usual a travelling wormwheel geared to the tangent wheel M, which is made with a projecting hollow boss L that contains the intermediate friction discs of elm wood. The iron shaft discs are carried on the hollow shaft N N, on which is also fixed the spur pinion O gearing with the ordinary traverse rack R by means of the spur wheels P P. Within the hollow shaft N is a rod T T, having at one end a large collar or plate to pull inwards against the friction discs; and on the other end of the rod T is a small cross lever S with screwed boss, by means of which the coupling pressure is applied upon the friction discs, when it is required to couple the tangent wheel M to the hollow shaft N.

In Figs. 20 and 21, Plate 114, is shown a form of Safety Pinion, intended to prevent the shaft to which it is applied from transmitting or receiving any excess of force beyond a fixed limit. The iron shaft discs A A, shown in section in Fig. 20, are here bevilled in one direction, and the intermediate discs B B, which in this case are also of metal, are bevilled in the opposite direction. This sectional form gives great compactness, allowing nearly double the number of discs of any given strength to be placed within the same longitudinal space upon the shaft C. The discs are tightened up with the required amount of coupling pressure by means of the nut E. The intermediate discs B are made larger in diameter than the shaft discs A, to a sufficient extent to allow of the pinion teeth F F being formed in the projecting rims of the intermediate discs, as shown in Fig. 21.

In Figs. 22 and 23, Plate 115, is shown a Sack Hoist, intended for small weights up to 5 cwts., and possessing the valuable property of being self-sustaining, so that the load can in no case run down of itself, but requires to be lowered continuously by the hand rope. The rope-wheel F and the winding barrel D are both loose upon the main shaft C, between the small fixed collar E and the large disc H cottered on the shaft; a ratchet-wheel G, Fig. 23, keyed on the shaft between the collar E and the rope-wheel, prevents the shaft from turning backwards. The boss of the rope-wheel F has its outer face made plain and smooth for frictional contact with the adjacent side of the ratchet-wheel G; and the flange K at the other end of the winding barrel D is in like manner faced to rub against the disc H. The side of the rope-wheel boss F that is adjacent to the winding barrel is formed with a spiral inclined face I or single convolution of a screw, which engages with a similar spiral incline J formed upon the end of the winding barrel D. The diameter of the other side of the rope-wheel boss which rubs against the ratchet-wheel G is made rather greater than the diameter of the screw inclines I and J; and the pair of rubbing faces formed by the flange K and the disc H are made as large as convenient, for the purpose of gaining break power in lowering.

The action of this construction of hoist is as follows. On turning the rope-wheel forwards, in the direction for raising the load, the inclined surface of the spiral between the rope-wheel and winding barrel tends to separate them endways, and thus produces an end pressure, which tightens together the external plain rubbing surfaces with a pressure proportionate to the load sustained by the winding barrel. The rope-wheel and winding barrel are thus jammed between the fixed collars E and H on the shaft, and the several parts of the hoist are thus firmly coupled together, so that the continued forward rotation of the rope-wheel F carries with it both the winding barrel D and the shaft C, thereby raising the load and turning the ratchet-wheel G forwards. For lowering the load, the rope-wheel being turned backwards by hand withdraws one incline from the other in the spiral clutch, and thereby relieves the friction surfaces from the end pressure, so that the winding barrel is released and the load can descend; but the descent of the load can only take place so long as this withdrawal of the inclines is continued by the rope-wheel continuing to be turned backwards by hand, allowing the winding barrel to follow. The moment the rope-wheel is stopped, the inclines become tightened again upon each other by the load acting on the winding barrel; the rope-wheel and winding barrel are thus again jammed endways between the friction surfaces of the ratchet-wheel G and disc H, which being held by the ratchet from turning backwards prevent the load from running down further. This arrangement accordingly provides the means of lowering as well as raising the load continuously and steadily and with perfect safety, avoiding the risk of injurious jerks on the chain; while at the same time the load is securely held suspended at any point at which the rope-wheel may be stopped.

In the construction of this hoist, the diameter and angle of the spiral inclines, and the diameter of the frictional surface presented by the ratchet-wheel, are so proportioned as not only to make the load self-sustaining at any point at which the hoisting force ceases, but also to render the lowering motion self-arresting; so that the descent of the load ceases as soon as the backward turning of the rope-wheel by hand is discontinued, and the winding barrel in running backwards under the influence of the load is not able to drive the rope-wheel before it by means of the inclines, however

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great may be the load suspended from the winding barrel. In the sack hoist shown in Fig. 22 this result is attained by making the diameter of the frictional surface of the ratchet-wheel a little greater than the diameter of the spiral inclines, the friction surfaces in this case being iron upon iron, and the pitch of the spiral being $\frac{1}{2}$ inch in a diameter of 4 inches, giving an angle of about 1 in 24 for the inclines. This very fine pitch is intended for light weights only, and for heavier loads a coarser pitch would be employed with a proportionately larger diameter for the friction surface of the ratchet-wheel. When the proportions of these parts have been suitably adjusted for sustaining any given load, the self-sustaining and self-arresting property of the hoist is not affected by any increase or diminution in the load, because any change in the load is attended with a proportionate change in the amount of end pressure produced by the inclines and in the consequent frictional resistance offered by the rubbing surface of the ratchet-wheel. Under any load whatever therefore the frictional resistance or adhesion between the rubbing surfaces of the ratchet-wheel and the rope-wheel boss, arising from the oblique action of the inclines, is always greater than the direct rotary driving force of the winding barrel upon the rope-wheel through the inclined faces of the spiral clutch. With the proportions above mentioned, the sustaining friction is so little in excess of the load that only a slight amount of force is sufficient to turn the rope-wheel backwards for lowering the load; and the rope-wheel being made heavy, to act as a flywheel, a tolerably vigorous pull upon the rope causes the wheel to make a number of revolutions backwards, allowing the winding barrel to follow and lower the load with proportionate rapidity; but as the frictional resistance slightly preponderates, the lowering takes place with perfect safety, and the load gradually ceases to descend as the rope-wheel loses its momentum. The lowering of the load therefore continues only so long as the backward motion of the rope-wheel is continued by hand, and the descending load comes to rest at any moment that the rope-wheel ceases to be turned backwards. The one endless rope thus affords the means of both raising and lowering weights continuously and steadily, by simply working the rope-wheel by hand in opposite directions; and at the same time all possibility of accident from the load running down of itself is avoided.

The frictional faces by which the load on the hoist is sustained are iron upon iron, where lubrication can be depended upon; but in other cases one wood face is introduced. This construction of hoist is also capable of very advantageous combination with the friction disc coupling and break previously described, where a large amount of break power is required; but for a variety of purposes the use of the spiral inclines renders the addition of the friction discs unnecessary.

In Figs. 24 and 25, Plate 116, is shown a Bracket-Winch or Side-Winch, constructed upon the same self-sustaining principle as the sack hoist last described, the lowering being done continuously by turning the handle of the winch backwards, so that the load is lowered slowly and cannot run down of itself. One of the spiral inclines or screw faces is here formed upon a collar I, fixed upon the shaft C of the winch, which is turned by the handle F; and the other corresponding incline J is formed upon the end of the winding barrel D, which is loose upon the shaft. The flange K at the other end of the winding barrel is faced to rub against the ratchet-wheel G, which runs loose upon the boss of the flanged collar E cottered on the shaft C, the ratchet-wheel being situated between the flange E of the collar and the flange K of the winding barrel. The shaft C and winding barrel D are carried in a trough-shaped casting or bracket L L; and a recess in the framing of the bracket contains the paul H, Fig. 24, of the ratchet-wheel G. The action of this winch is exactly similar to that of the hoist last described, the spiral inclines having the effect of jamming the winding barrel endways against the ratchet-wheel and the fixed collar E; and the frictional surfaces sustaining the load in this case are the two sides of the ratchet-wheel G, which are in contact respectively with the flange of the collar E and the flange K of the winding barrel.

In Figs. 26 and 28, Plate 117, is shown a portion of a self-sustaining Hoisting Crab, in which the application of the spiral inclines as already described is combined with the friction discs of the couplings and breaks previously described, the lowering of the load being performed slowly by continuously turning the handles of the crab backwards, in the same manner as last explained. The pinion D runs loose upon the shaft C of the crab, and is cast with a long boss of square exterior, which carries the two iron shaft-discs A A. The ratchet-wheel E, also turning loose upon the shaft C against a fixed collar, is cast in one piece with the break drum F, shown in section in Fig. 28, which contains the three intermediate wood discs B B. The collar G fixed upon the shaft has its end next to the pinion D formed into a spiral incline or screw face, which engages with the corresponding incline H formed upon the pinion D. The shaft C is rotated by the usual winch handles, and on turning it in the direction for hoisting, the inclines G and H ascending each other slightly produce a longitudinal pressure upon the friction discs A and B, thereby coupling the pinion D to the ratchet-wheel E, and both of them to the shaft C; the load is then raised by continuing to turn the shaft forwards, and is sustained at any point by the paul of the ratchet-wheel E. The lowering is done, as before, by turning the winch handles backwards, thereby relieving the friction discs from the pressure of the inclines; and the lowering takes place only so long as the winch handles continue to be turned backwards, and ceases as soon as they stop. The friction discs employed in this case serve to increase the area of the frictional rubbing surfaces and thereby diminish the wear upon them; they also afford the required amount of frictional connection with much less end thrust from the inclines, so that the longitudinal strain upon the shaft and collars is thereby reduced. The angle of the inclines may therefore be increased, and in the present instance it is made about 1 in 12, or a pitch of $\frac{5}{8}$ inch in a diameter of $2\frac{1}{2}$ inches.

In Figs. 27 and 28, Plate 117, is shown another arrangement of Hoisting Crab, in which the combination of the spiral inclines with the friction discs is applied in a different manner, and with a different result, allowing the load to be lowered quickly. The pinion P as before is loose upon the crab shaft I and its square boss carries the two iron shaft-discs A, the three intermediate wood discs B being contained in the drum O cast in one piece with the ratchet-wheel N, which is also loose upon the shaft I. The fixed collar L however, on which is formed one of the spiral inclines, engages with the other incline M formed in the present arrangement upon the ratchet-wheel N, instead of upon the pinion P as in the preceding case. In hoisting, the effect of the inclines is the same as previously described, jamming the ratchet-wheel N and pinion P against the fixed plain collar K upon the shaft, and putting an end pressure upon the friction discs A and B, sufficient to couple the pinion to the ratchet-wheel, and both of them to the crab shaft I. But in lowering, the result of the difference in the present arrangement is that it is only necessary to turn the winch handles very slightly backwards in order to relieve the friction discs entirely from the coupling pressure; the pinion P is thereby liberated altogether from the friction by which alone it was held, and the load is then free to run down of itself. This arises from the circumstance that, as the incline M is here formed upon the ratchet-wheel N, which is held by the paul from turning backwards, it is prevented from following the other incline L when the latter is withdrawn by turning the crab shaft backwards; a slight backward turn of the winch handles is consequently sufficient to remove the end thrust or jamming action of the inclines, thereby annihilating altogether the frictional resistance by which the load was sustained. The descent of the load can be checked or stopped altogether at any moment with break action by turning the winch handles forwards again in the direction for hoisting, so as to restore the coupling pressure upon the friction discs by the action of the inclines; and the winch handles thus form a ready means of applying or withdrawing the pressure upon the friction break. The load is therefore under perfect control at all times without danger to the men working the crab; and great despatch is obtained by making the winch handles serve the double purpose of hoisting the load and applying the break in its descent.

The preceding arrangement of crab, shown in Fig. 26, gives a very safe lowering motion, but only as quick a one as can be conveniently imparted by the continued backward rotation of the winch handles. The present arrangement, shown in Fig. 27, allows the load to run down freely of itself, but the rapidity of its descent is checked and controlled at pleasure by the application of the friction break by means of the winch handles. The absolute safety attending the self-sustaining slow-lowering crab is therefore wanting in the present quick-lowering crab; or rather the safety is here dependent upon the care exercised in applying the break.

The rather slow but unquestionably safe lowering motion obtained by the arrangement shown in Figs. 22 to 26 is considered by the writer to be of especial value for jib cranes and other hoisting apparatus, where it is necessary to guard against the framework or foundations being exposed to any injury from suddenly checking by break action a load descending at an excessive speed. This arrangement would also be useful and safe as a means of varying the angle of inclination given to the jib of derrick cranes, and retaining the jib securely in any desired position without risk of slipping. In like manner it could be applied to wind in or let out the guys or stays of sheer legs and other hoists of similar structure; and generally for any purpose where a very safe backward motion is required for any pinion or drum upon its shaft, this hold-fast or self-sustaining arrangement would be valuable. The combination of the spiral inclines with the friction discs, in the manner shown in Fig. 26, furnishes a powerful and continuously self-acting break; that is, as fast as the coupling pressure is withdrawn, permitting the load to descend, it is continuously restored again by the load itself, so that the load is thus entirely incapable of running away; and as the power of the discs for break action may be increased to almost any degree, any load, however great, may be lowered in this manner with absolute safety.

Mr. Weston exhibited a number of working models and specimens of the various applications of the friction coupling and break, and showed the raising and lowering of weights by the two constructions of sack hoist described in the paper, the first plan allowing the load to run down freely when released by the handwheel rope, which also served as a break to check the descent at any moment, while the second plan required the handwheel to be continuously turned backwards during the whole time of lowering.

Mr. E. A. COWPER thought the new arrangement of friction break or clutch was very good and would be available for many purposes. One of the most valuable applications of the plan appeared to him to be the frictional spur gearing shown in Figs. 20 and 21, where the safety pinion was composed of a series of pinions or toothed discs loose upon the shaft, alternating with plain discs fitted to the shaft, and by compressing the whole together endways each pinion was pinched equally between the shaft discs, so that each would do exactly the same amount of work, and the driving power transmitted by the whole pinion would be equally distributed across the entire breadth of the teeth of the spur wheel geared with the pinion. The two different modes of lowering the load in the two frictional crabs were also very good, the same principle of the inclined plane being employed in each case, either for relieving at once the whole end pressure on the friction discs, or for easing it off gradually by turning the winch handle backwards continuously. The latter plan had the advantage of being very safe and avoiding jerks, as the load could not run down of itself; and the former gave great facility for lowering very quickly in cases where there was not any danger from rapid lowering, as in the instance of lowering empty barrows &c. in connection with builders' scaffoldings. The thickness of the alternate iron and wood discs employed in the various couplings and breaks was certainly very small, the iron discs being only $\frac{1}{4}$ inch thick and the wood $\frac{3}{4}$ inch thick; and he enquired in reference to the wear and tear upon them, whether the wood discs being so thin had been found to give way in any case at the circumference under the strain to which they were subjected.

Mr. WESTON replied that in the early form of the windlass break the plan of holding the wood discs by means of notches fitting upon projecting ribs in the interior of the drum containing the discs, as shown in Fig. 4, was found insufficient, and the wood was liable to break away from the projections when subjected to a heavy strain;

and the square form for the outside of the wood discs was then resorted to, as shown in Fig. 11, with the corners of the square discs bevilled off, which was found to get over the difficulty completely, and had never failed. For cranes and crabs however the first form of discs answered well.

Mr. E. A. COWPER observed that the use of an iron disc interposed between two iron discs lined with wood, for the purpose of forming a friction clutch, had been adopted by Mr. Ramsbottom in the reversing rolling mill at Crewe, for connecting the engine shaft to the rolls (see Proceedings Inst. M.E. 1866 page 116); in that case however the two wood surfaces were nipped between the iron discs by bolts all round the circumference, each tightened up separately, so that the pressure could only be adjusted approximately in the first instance, and there was no means of altering it quickly for variations in the amount of driving power to be transmitted. The employment of a number of friction discs, as in the new arrangements now described, had the advantage that much less pressure upon the discs was required for transmitting the same amount of power; and by employing a sufficient number of discs in the coupling it might even be possible to throw a heavy mill in and out of gear, or to reverse it, by means of a friction coupling, with the power of only one man acting on a hand lever. He thought the several applications which had been described only required to be more known in order to be more generally used. One point that occurred to him was, that in the use of the incline or spiral clutch for putting the end pressure upon the frictional surfaces in the hoists described in the paper, if the inclination of the spiral were supposed to be 12 to 1, the end pressure produced by it would be twelve times as great as the load on the chain barrel, and consequently there would be a shearing strain of that amount upon the pin holding the fixed collar on the shaft.

Mr. WESTON replied that it was so, but as the loads lifted by that construction of hoist were not great, the end pressure upon the collar was not material; and it could be reduced to any required extent by the introduction of friction discs in combination with the inclines, as shown in the crabs.

The Chairman enquired whether any data could be furnished in reference to the amount of power that could be safely transmitted with a given extent of frictional surface, so as to allow of some idea being formed as to the number and size of discs required for a clutch to drive a rolling mill for instance; as the applications to shafting described in the paper did not appear to extend to the case of very large shafts.

Mr. Weston replied that the nearest approach to the case of a clutch for driving rolls in ironworks was the windlass break for ships, shown in Figs. 8 and 9, in which it was found that six pairs of the discs of a smaller size than there represented were amply sufficient to hold against a pull of 34 tons on a ship's cable. In that case the iron discs were $14\frac{1}{4}$ inches diameter, and the central hole in the wood discs was 11 inches diameter, the material of the discs being wrought iron and teak alternately; the end pressure upon the discs for sustaining the strain of 34 tons was applied by means of two men acting on the break screw (N, Fig. 8) by a hand lever 3 feet long.

Mr. W. F. Batho said he had introduced the friction coupling for driving the shafting and machinery at Messrs. Nettlefold's screw works which had been referred to in the paper, and it had been found of very great advantage there, and was now used in all cases where previously the ordinary clutches had been employed. It was a very ingenious application of a simple principle, which he thought was capable of very extensive adaptations. With regard to the wear of the wood discs, he had found this to be very slight, scarcely indeed amounting to anything appreciable; and the only way in which he could imagine that the coupling could be injured by a strain put upon it would be by the end pressure on the discs being very suddenly applied under a heavy strain, in which case the strain would be thrown upon the iron discs more in the manner of a blow, and might possibly occasion wear of the keys connecting the iron discs to the shaft, and so cause the discs to get loose and break the keys. He had not had any experience however of strains sufficiently heavy to produce such a result in any of the couplings that he had adopted.

Mr. Weston remarked that in the couplings intended for heavy strains the size of the main shaft gave the three keys holding the iron

M 2

discs sufficient leverage to withstand any concussive action arising from throwing the strain suddenly upon the coupling. This was satisfactorily proved by the results of working of the windlass break for ships' cables, which had been approved and adopted by the Admiralty; and the plan had also been used by Messrs. Harfield of London for driving ships' capstans by steam power. The durability of the wood discs in the couplings and breaks was sufficiently established by Mr. Penn's experiments on wood bearings, which had satisfactorily proved that under a pressure of even 1200 lbs. per square inch on lignum vitæ running on iron no perceptible wear took place during long continued working (see Proceedings Inst. M. E. 1856 page 27). In the present case the wood used for the discs in the ships' windlass was teak, which of course would not be so durable as a harder wood; but at the same time the pressure per square inch upon the friction discs was far less than in the above experiments. Elm was employed for the discs of the cranes and smaller hoists.

Mr. C. W. SIEMENS observed that in the experiments on wood bearings the rubbing surfaces were immersed in water, and he enquired whether the wood discs in the friction break were lubricated with oil or water.

Mr. WESTON replied that the wood discs were saturated with linseed oil before being put in their places, and when so treated he had not found they required any further attention or lubrication subsequently under any pressure that they were subjected to.

Mr. E. H. CARBUTT mentioned that a useful application of the wood friction discs on a small scale had been made to the bearings of looking-glasses, so as to hold the glass firmly in any position into which it might be turned; he had seen one of these small bearings very severely tested by being put in a lathe and run continuously for a week under pressure without lubrication, and no perceptible wear of the wood had been produced.

The CHAIRMAN observed that the double amount of friction arising from the two sides of a plate or disc being both in frictional contact had hitherto been recognised in general only as a difficulty to be overcome in connection with machinery; as in the case of a steam engine having two slide-valves, one on the back of the other, where the extra friction on the lower slide due to the double surface not infrequently occasioned breakage of its valve rod. This principle however of the friction increasing with the number of surfaces in contact, which had previously been only a source of trouble, had now been taken advantage of in a very ingenious manner in the construction of the friction coupling and break described in the paper. He had had the opportunity of seeing the shaft couplings on this plan at Messrs. Nettlefold's works, and considered that nothing could possibly work better than that arrangement; and he was therefore fully prepared to hear that it had been found entirely satisfactory in continued working, as had now been stated.

He proposed a vote of thanks to Mr. Weston for his paper, which was passed.

The following paper was then read :—

Fig. 1. *Model illustrating multiplication of frictional surfaces.*

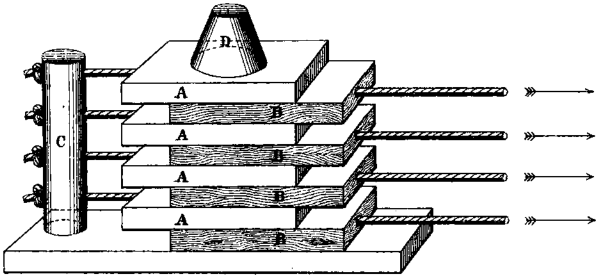
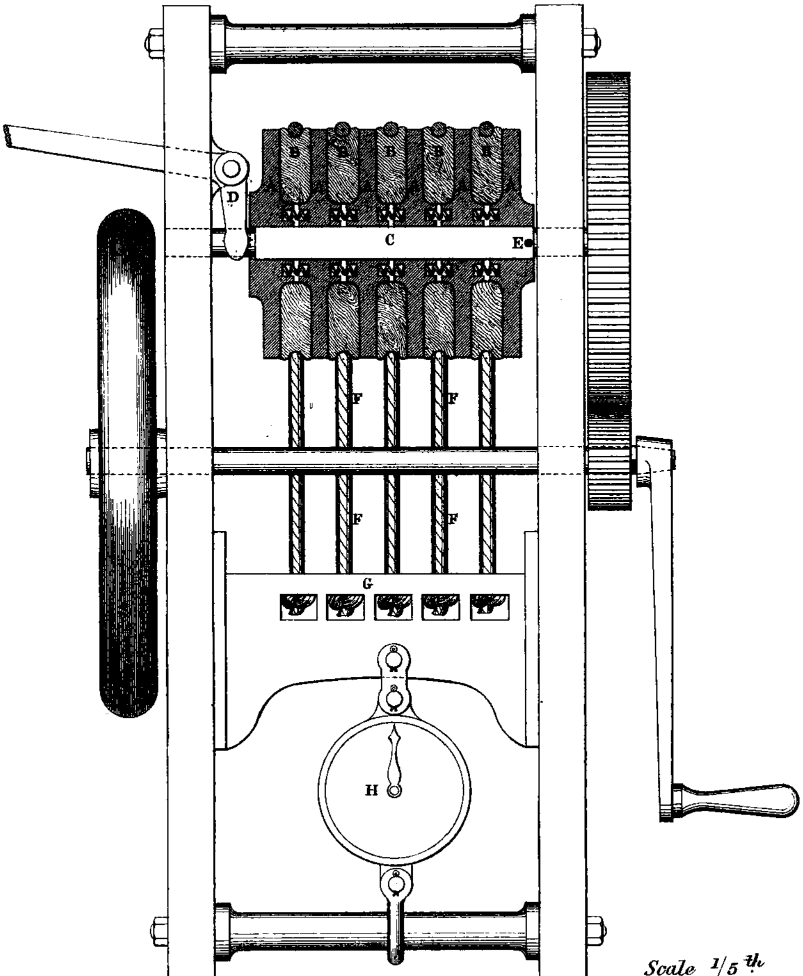


Fig. 2. *Experimental Disc Break.*



Scale 1/5th

FRICTION COUPLING AND BREAK. *Plate 106.*

Six-ton Hoisting Crab.

Fig. 3. *Longitudinal Section.*

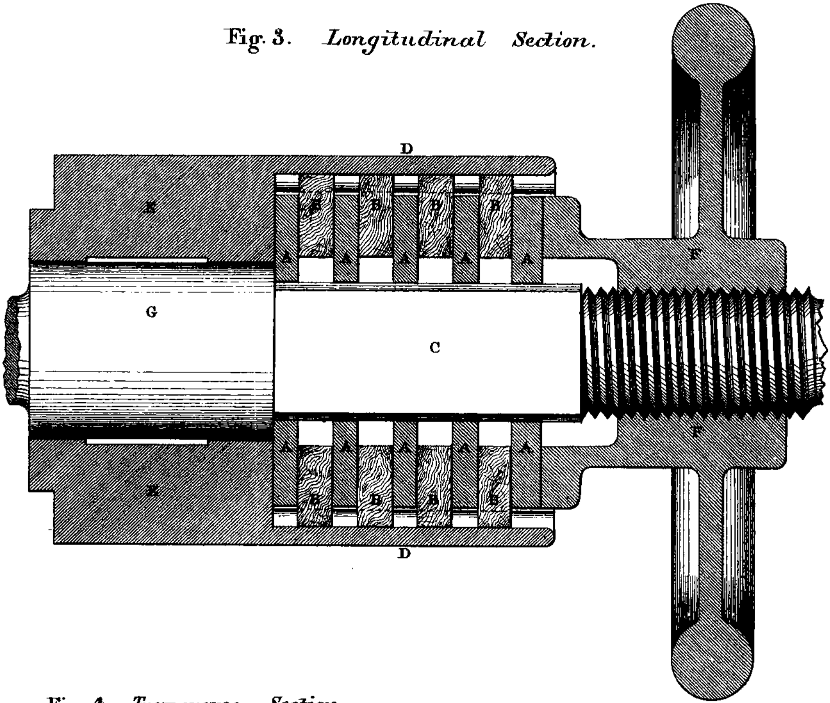


Fig. 4. *Transverse Section showing Wood Disc.*

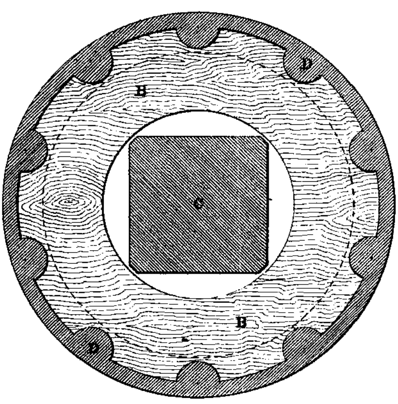
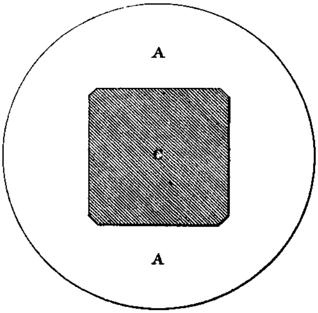


Fig. 5. *Transverse Section showing Iron Disc.*



(Proceedings Inst. M. E. 1868.)

Scale 1/3rd

0 1 2 3 4 5 6 7 8 *Inches.*

Sack Hoist,

stopped by rope in lowering,

for quick lowering.

Fig. 6. *End Elevation. Scale 1/10th.*

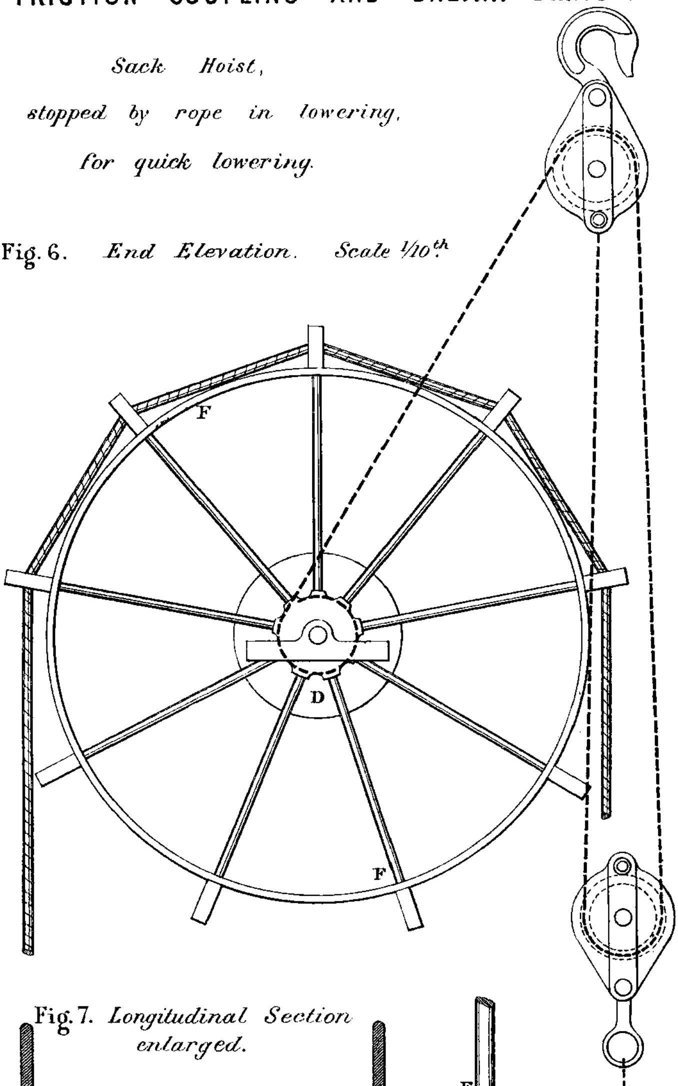
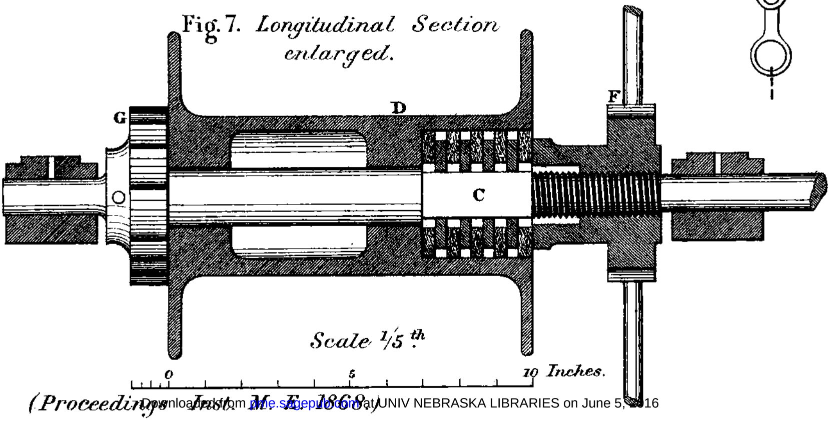


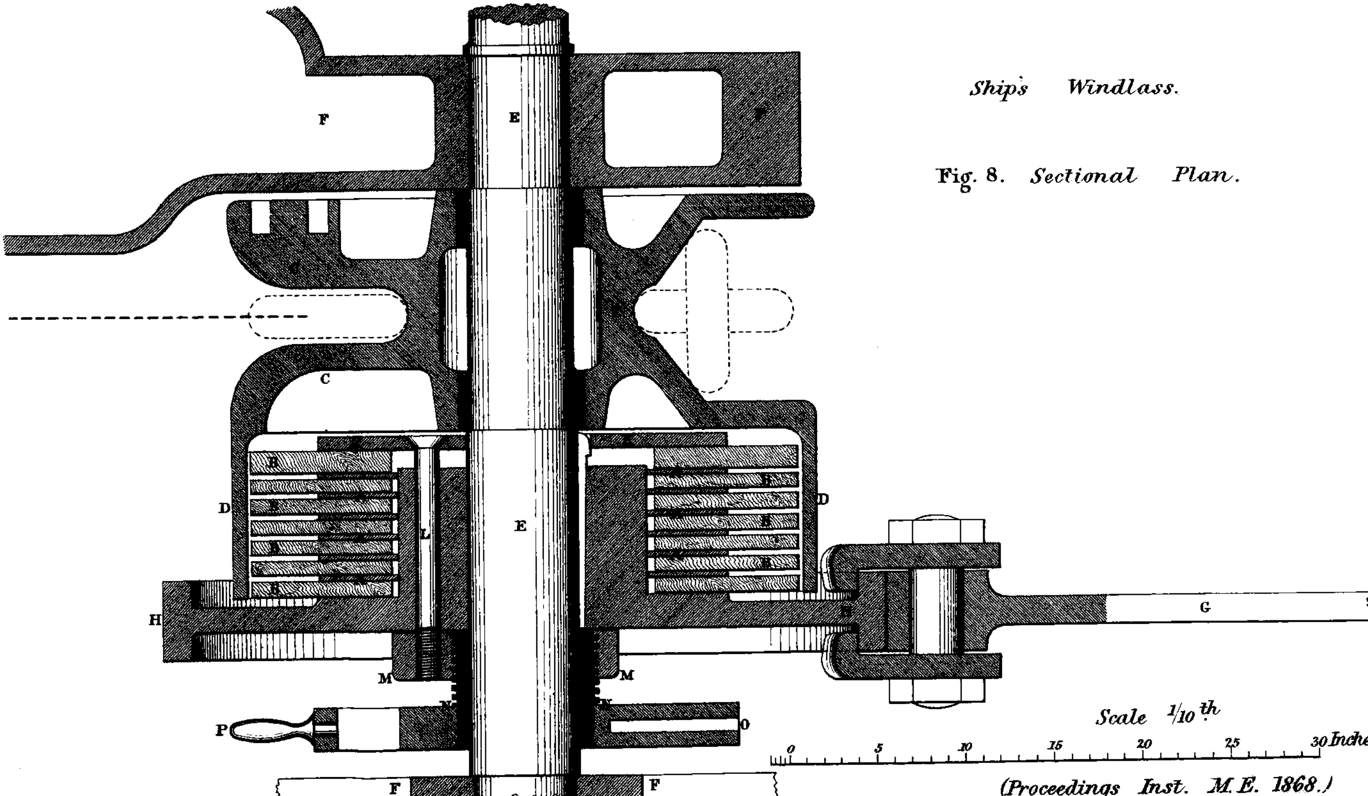
Fig. 7. *Longitudinal Section enlarged.*



FRICTION COUPLING AND BREAK.

Ship's Windlass.

Fig. 8. *Sectional Plan.*

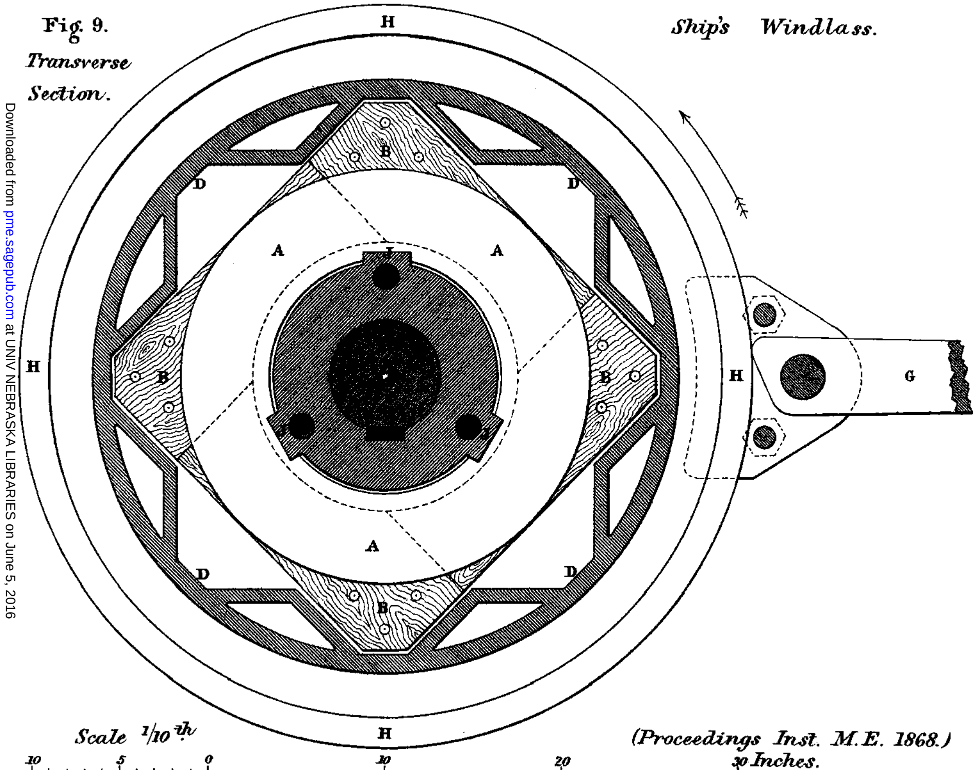


(Proceedings Inst. M.E. 1868.)

FRICTION COUPLING AND BREAK.

Ship's Windlass.

Fig. 9. *Transverse Section.*



Scale 1/10th.

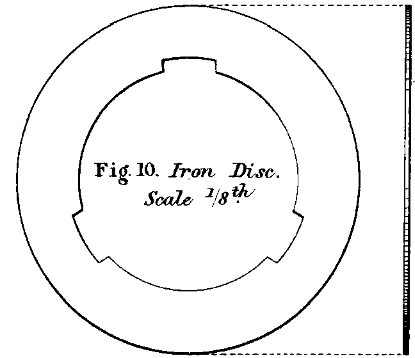


Fig. 10. *Iron Disc. Scale 1/8th.*

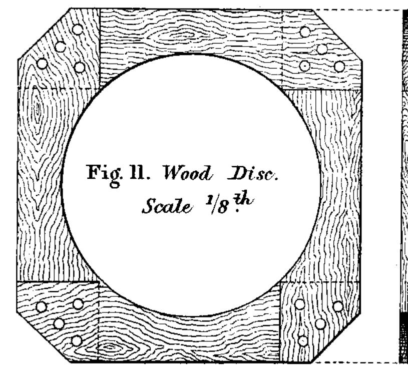


Fig. 11. *Wood Disc. Scale 1/8th.*

(Proceedings Inst. M.E. 1868.)

Shaft Coupling.

Fig. 12. *Longitudinal Section.*

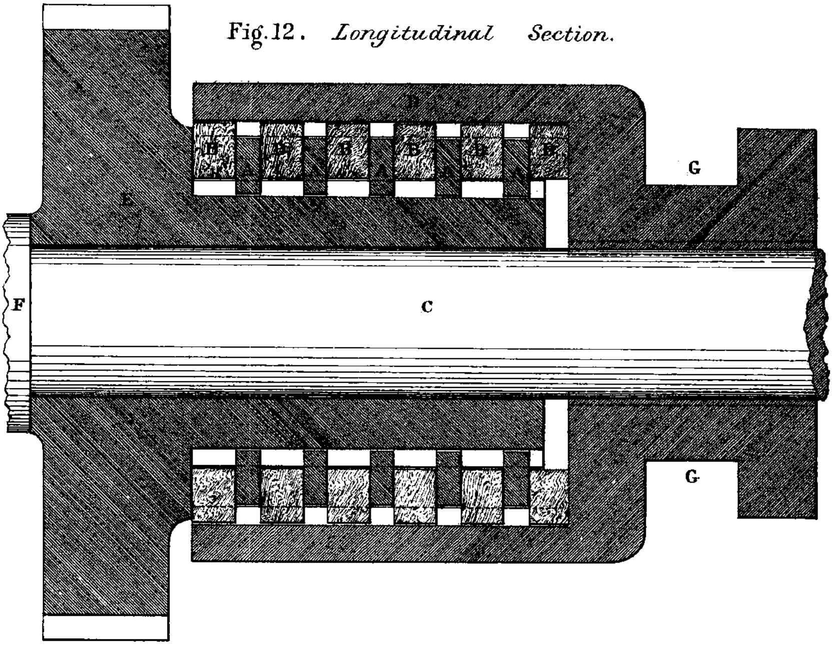


Fig. 13.
Transverse Section showing Iron Disc.

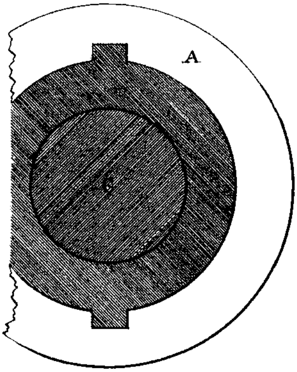
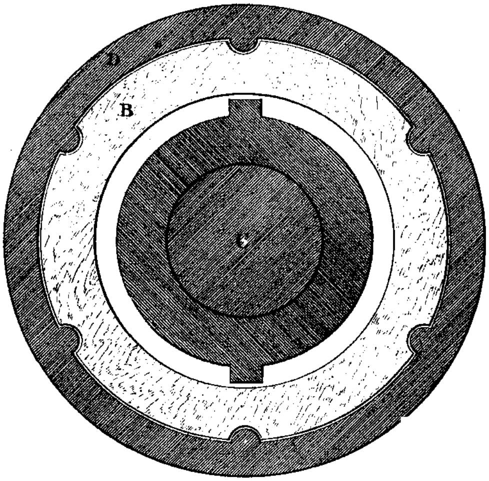


Fig. 14. *Transverse Section showing Wood Disc.*



Scale 1/4th. 0 1 2 3 4 5 6 7 8 9 10 *Inches.*

(Proceedings Inst. M. E. 1868.)

FRICTION COUPLING AND BREAK. *Plate III.*

Safety Clutch.

Fig. 15. *Longitudinal Section.*

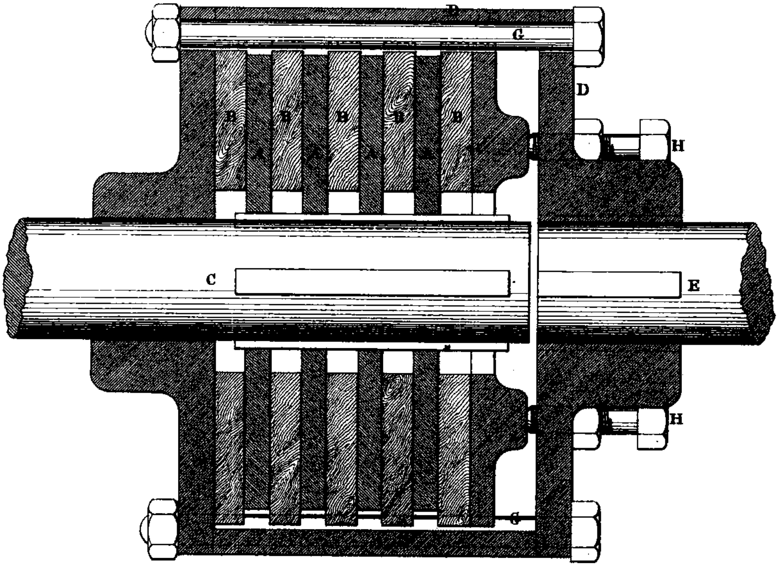
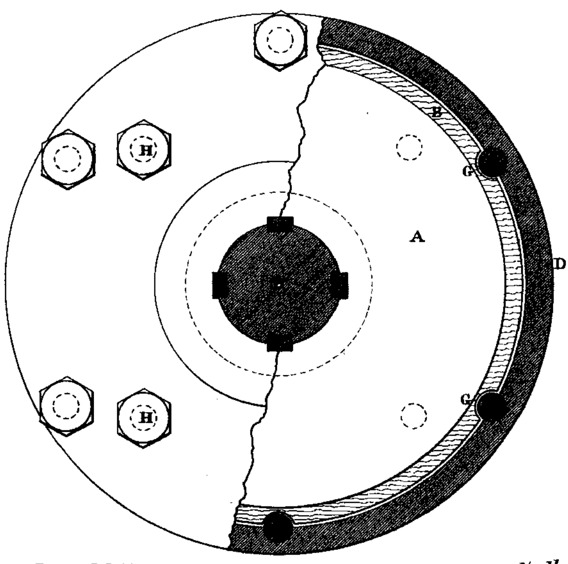
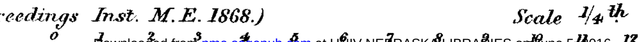


Fig. 16. *End Elevation and Transverse Section.*



(Proceedings Inst. M.E. 1868.) *Scale 1/4 th.*



Self-engaging Shaft Coupling.

Fig. 17. *Longitudinal Section.*

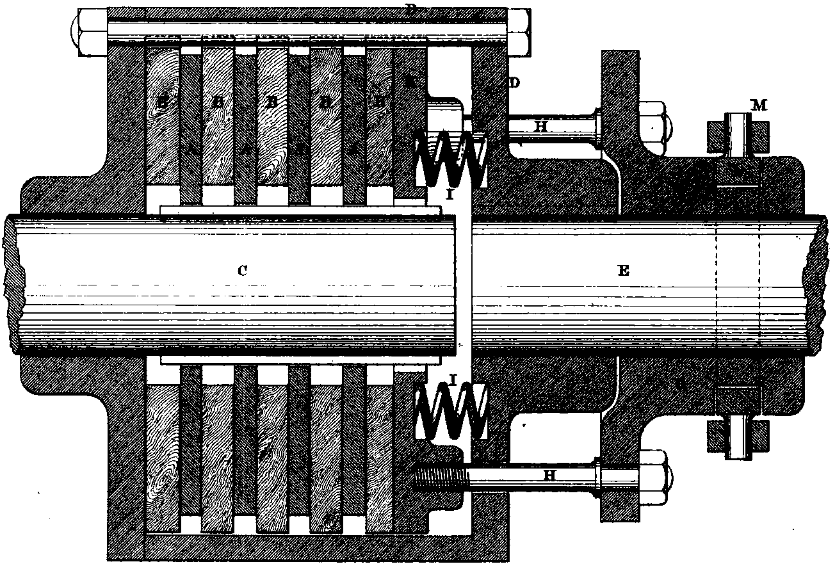
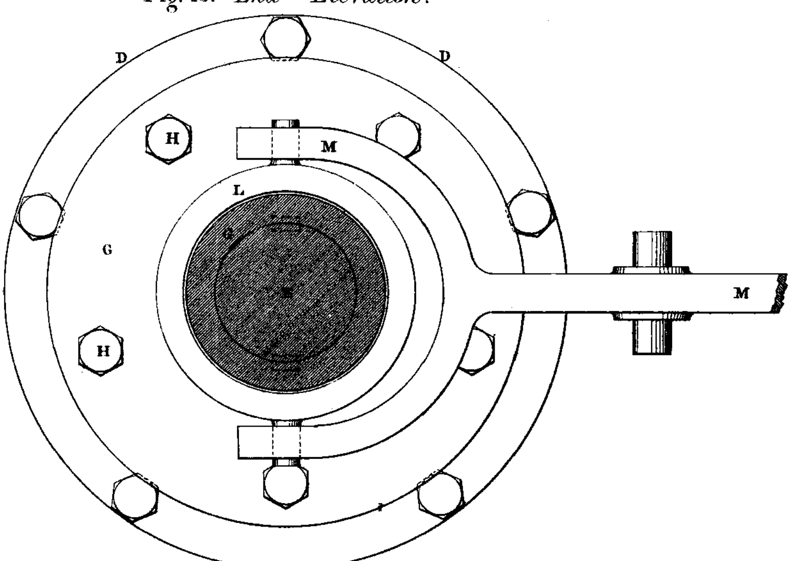


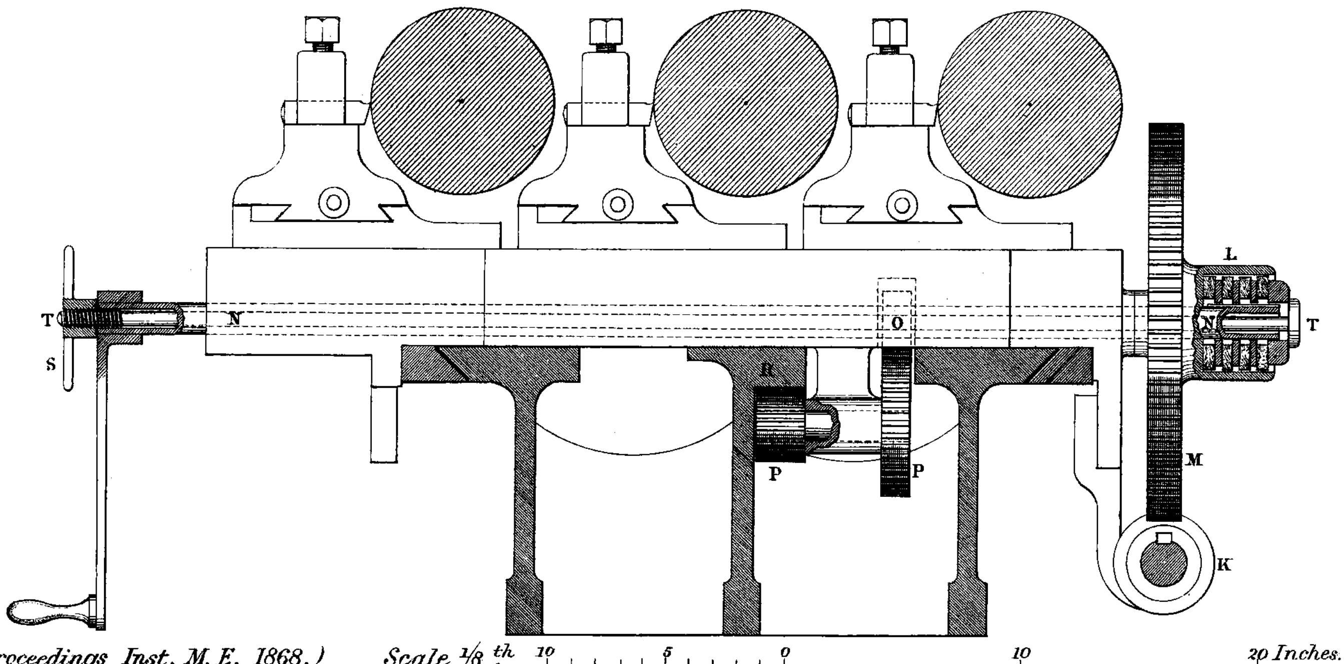
Fig. 18. *End Elevation.*



Scale 1/4 th 0 1 2 3 4 5 6 7 8 9 10 *Inches.*

(Proceedings Inst. M. E. 1868.)

Fig. 19. *Lathe Coupling.*



FRICTION COUPLING AND BREAK.

Safety Pinion.

Fig. 20. *Longitudinal Section.*

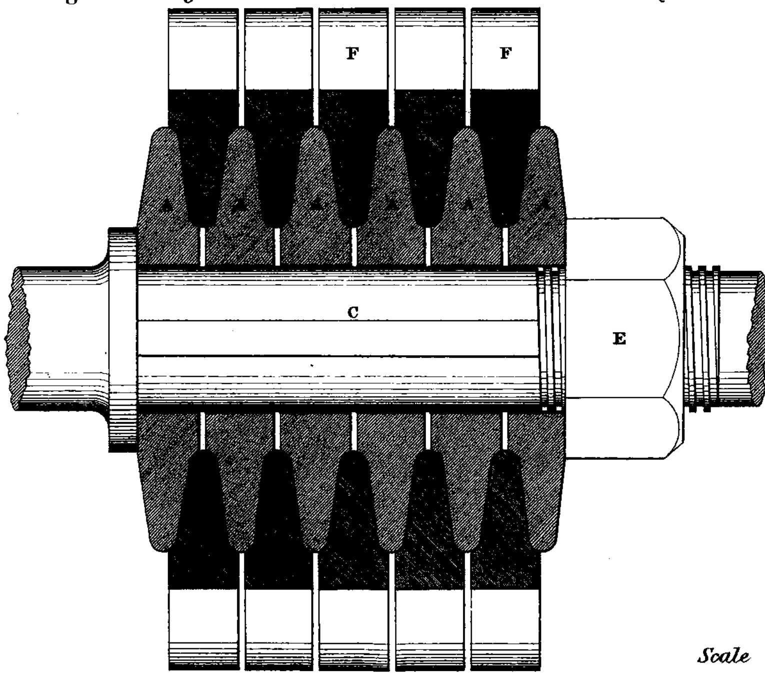
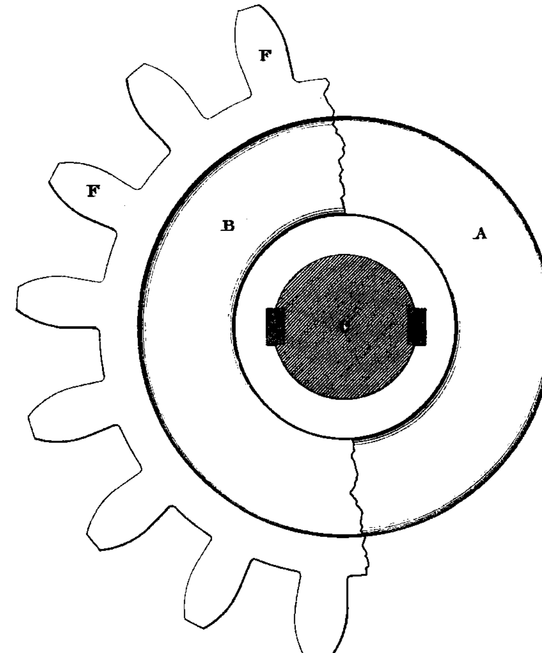


Fig. 21. *Transverse Section.*



Scale 1/5 th

0 5 10 15 20 *Inches.*

FRICTION COUPLING AND BREAK. *Plate 115.*

Sack Hoist,

lowered by rope continuously,

for slow lowering.

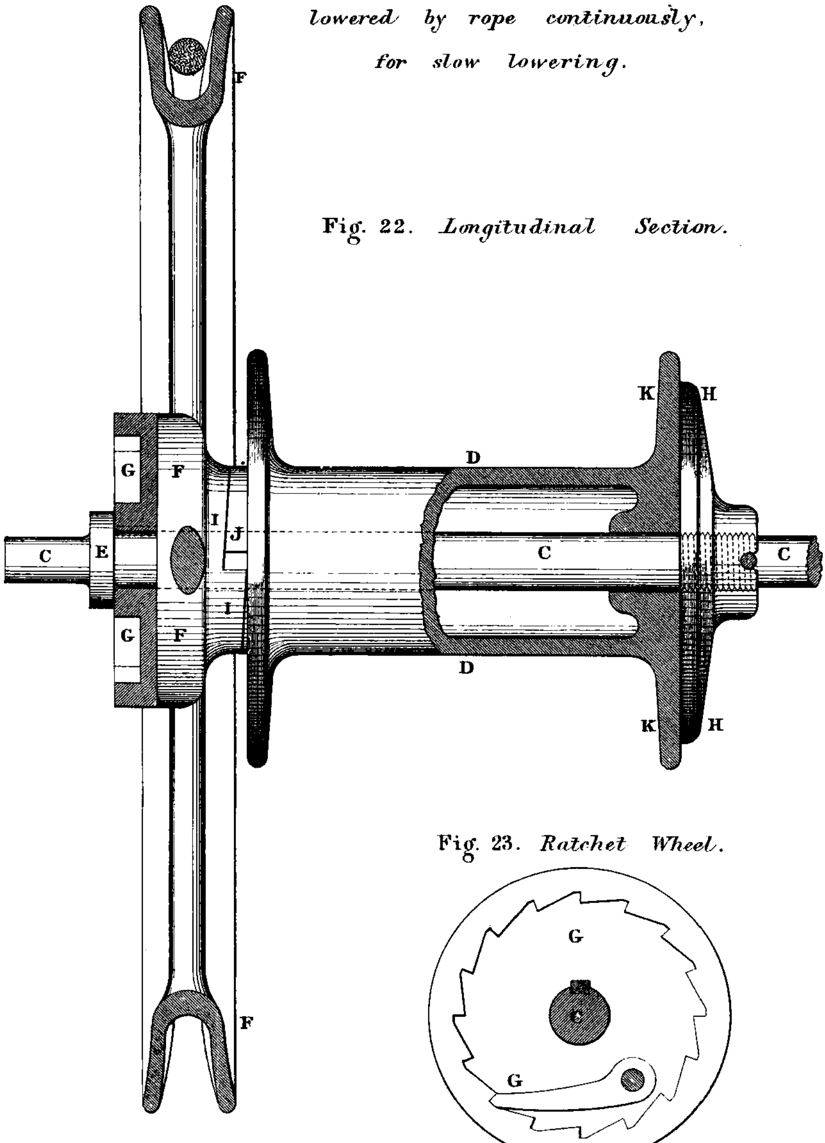


Fig. 22. *Longitudinal Section.*

Fig. 23. *Ratchet Wheel.*

Scale 1/4 *th.*

0 1 2 3 4 5 6 7 8 9 10 11 12 *Inches.*

(Proceedings Inst. M.E. 1868.)

FRICTION COUPLING AND BREAK.

Bracket Winch, lowered by handle continuously, for slow lowering.

Fig. 24. *End Elevation.*

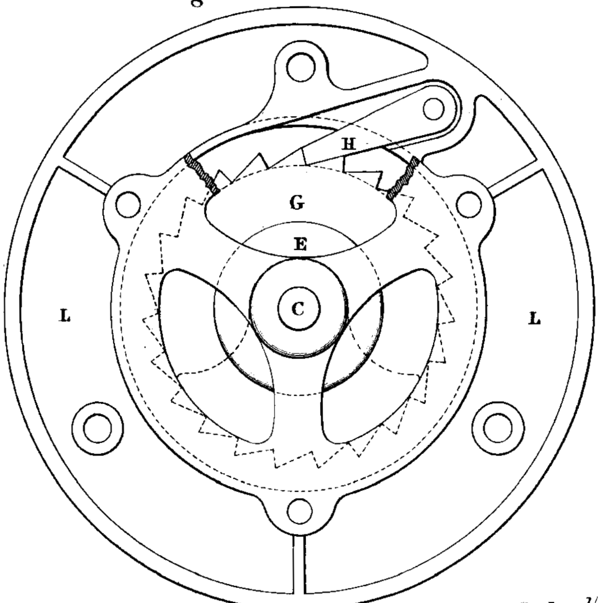
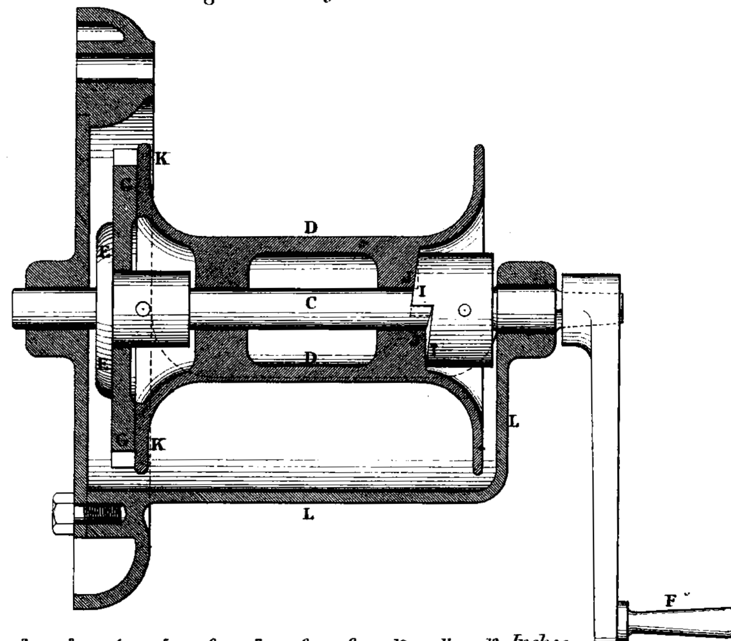


Fig. 25. *Longitudinal Section.*



Scale 1/4th

0 1 2 3 4 5 6 7 8 9 10 11 12 *Inches.*

(Proceedings Inst. M.E. 1868.)

Fig. 26. *Hoisting Crab, lowered by handle continuously, for slow lowering.*

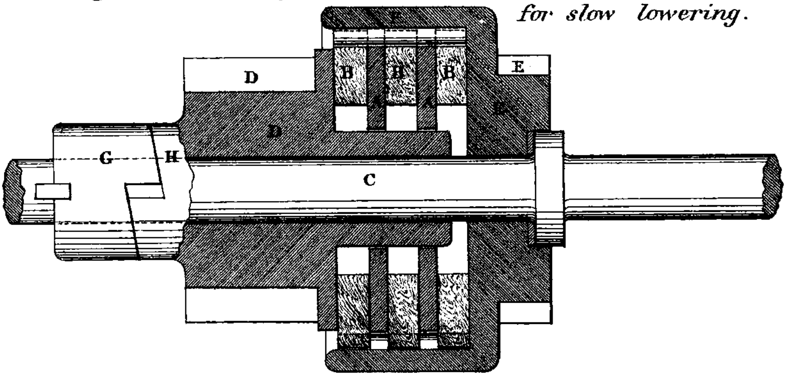


Fig. 27. *Hoisting Crab, stopped by handle in lowering, for quick lowering.*

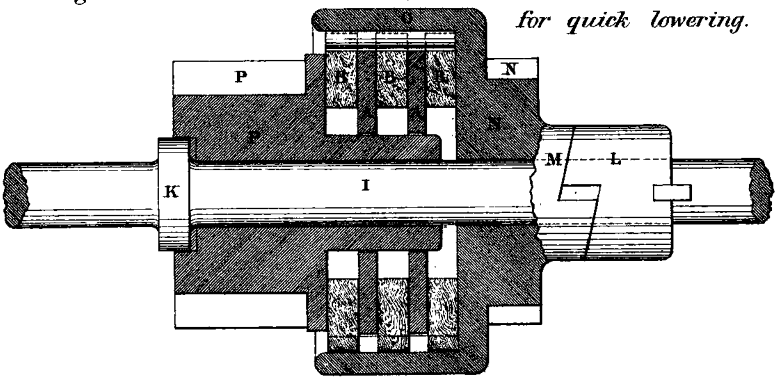
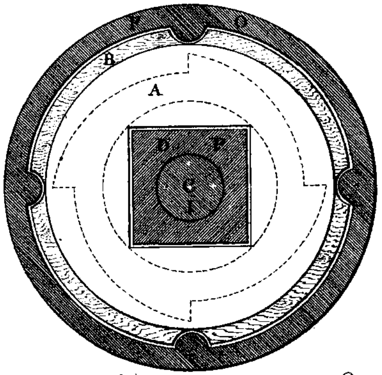


Fig. 28. *Transverse Section of both Crabs.*



(Proceedings Inst. M. E. 1868.)

Scale 1/3rd.

0 1 2 3 4 5 6 7 8 9 10 *Inches.*