(No Model.) 10 Sheets—Sheet 1.

F. H. RICHARDS.

SEWING MACHINE.

No. 574,573. Patented Jan. 5, 1897.

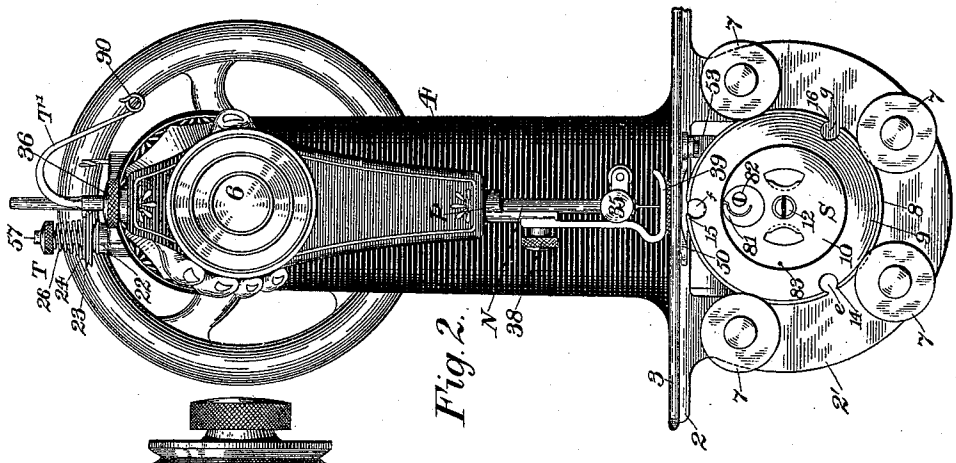

Fig. 2.

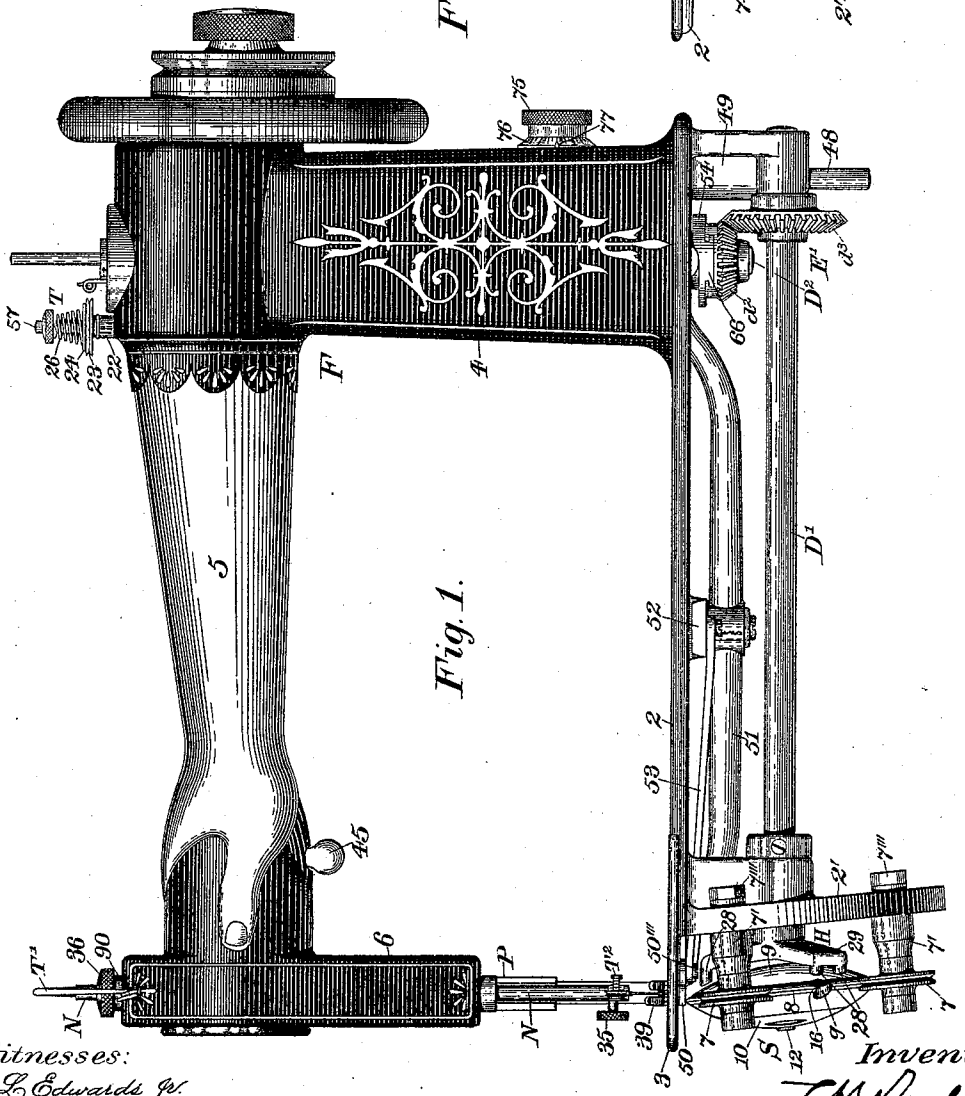

Fig. 1.

Witnesses:
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Inventor:
F. H. Richards

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(No Model.) 10 Sheets—Sheet 2.

F. H. RICHARDS.

SEWING MACHINE.

No. 574,573. Patented Jan. 5, 1897.

Fig. 3.

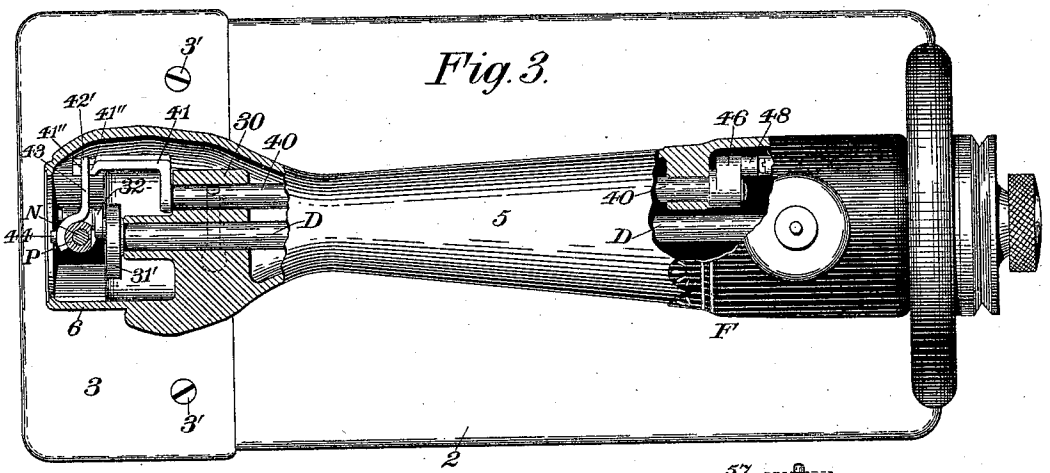
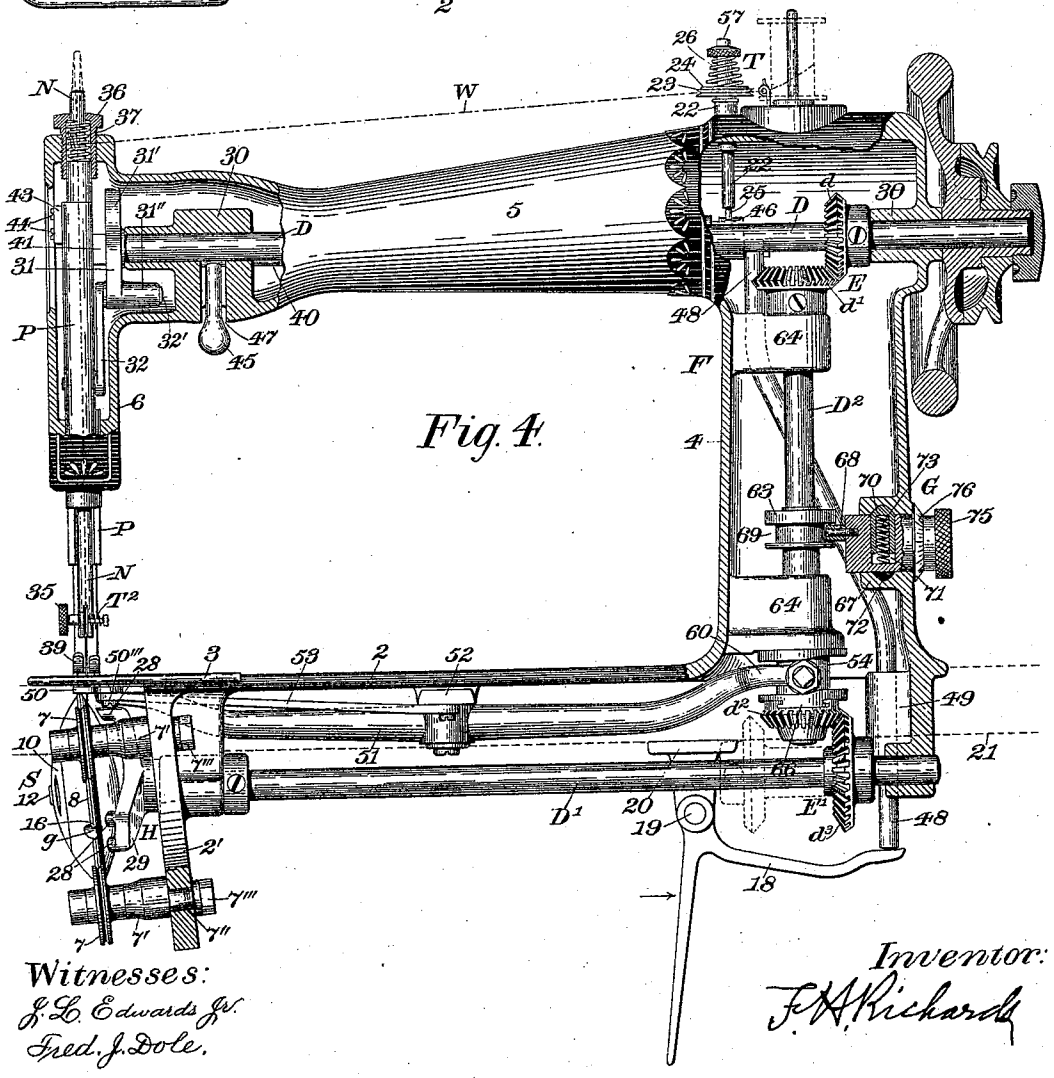


Fig. 4.



Witnesses:
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Inventor:
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(No Model.) 10 Sheets—Sheet 3.

F. H. RICHARDS.

SEWING MACHINE.

No. 574,573. Patented Jan. 5, 1897.

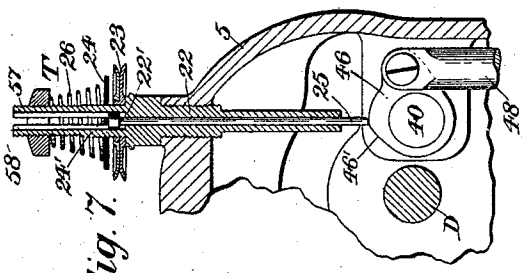

Fig. 7.

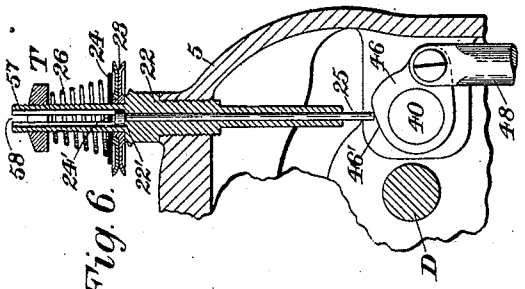

Fig. 6.

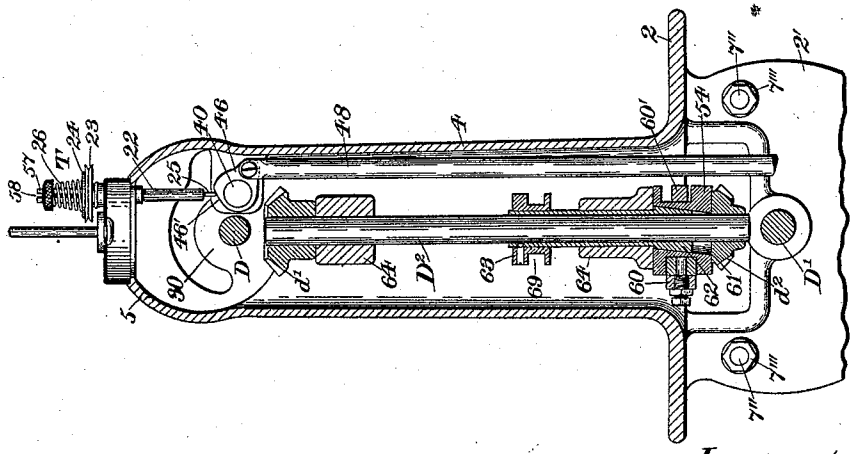

Fig. 5.

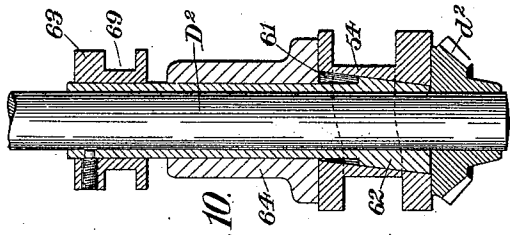

Fig. 10.

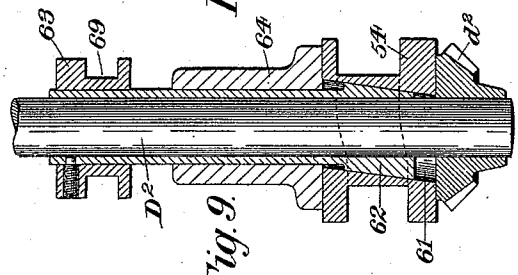

Fig. 9.

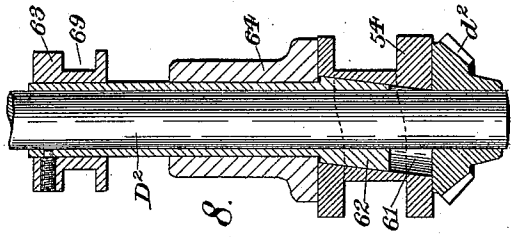

Fig. 8.

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(No Model.) 10 Sheets—Sheet 4.

F. H. RICHARDS.

SEWING MACHINE.

No. 574,573. Patented Jan. 5, 1897.

Fig. 14.

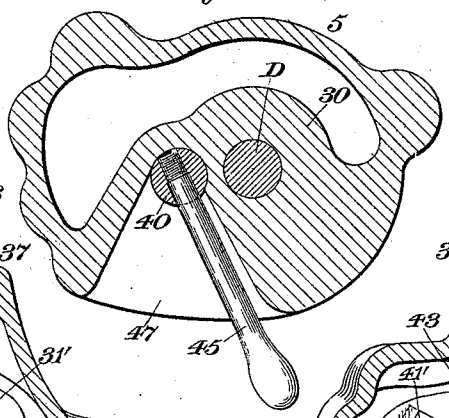


Fig. 11.

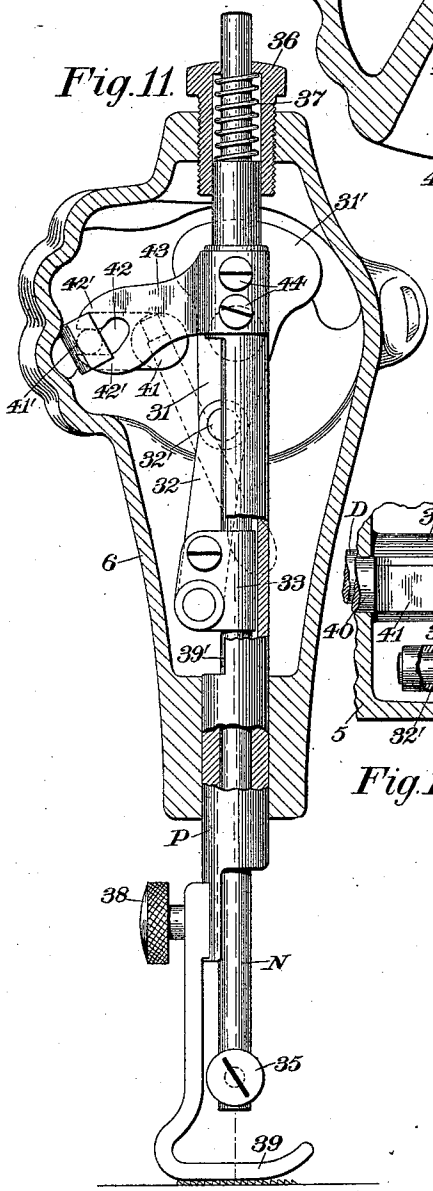


Fig. 13.

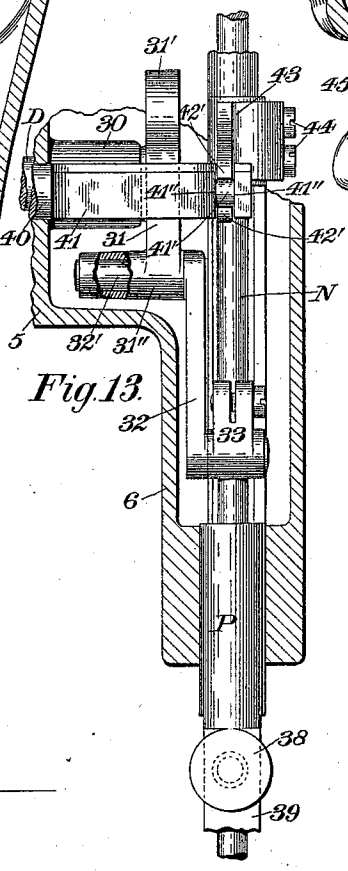
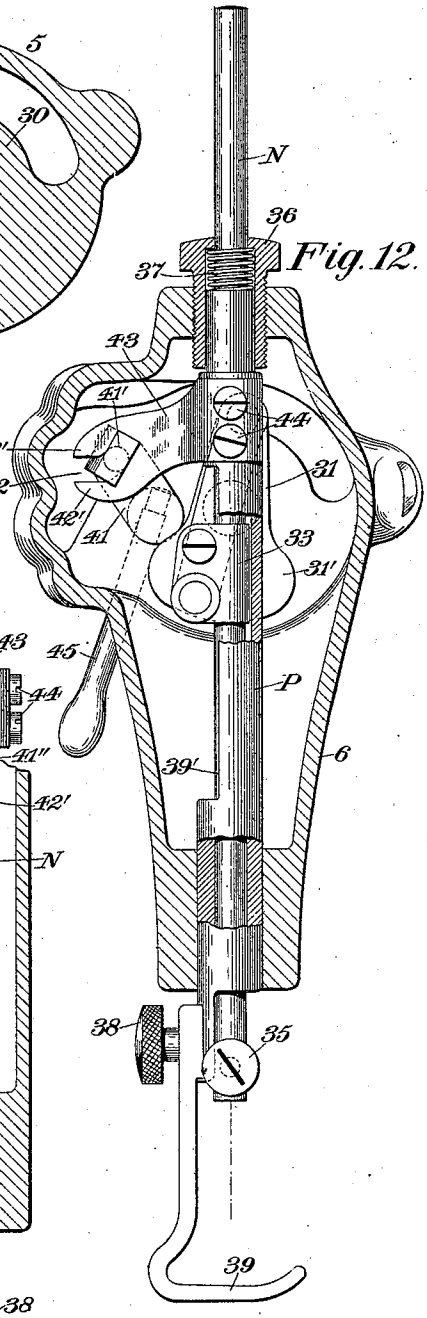


Fig. 12.



Witnesses:
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Fred J. Dole.

Inventor:
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(No Model.) 10 Sheets—Sheet 5.

F. H. RICHARDS.

SEWING MACHINE.

No. 574,573. Patented Jan. 5, 1897.

Fig. 15.

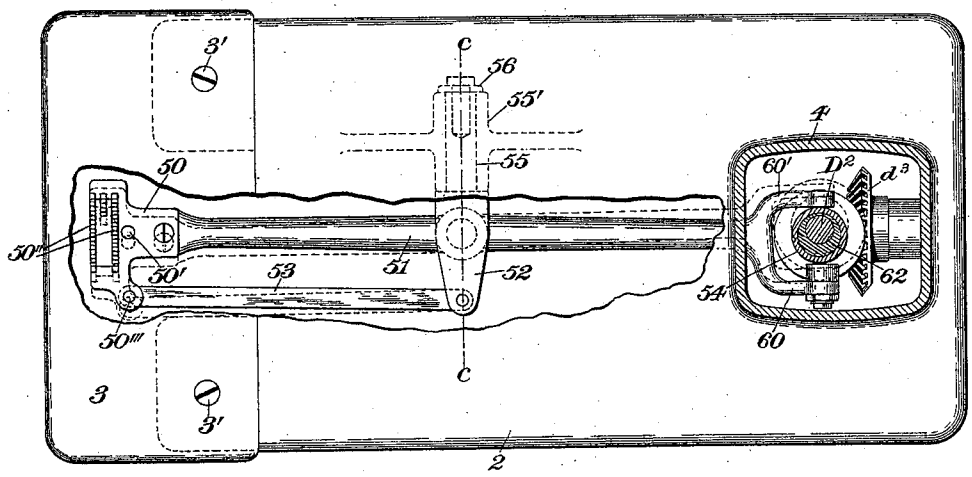


Fig. 16.

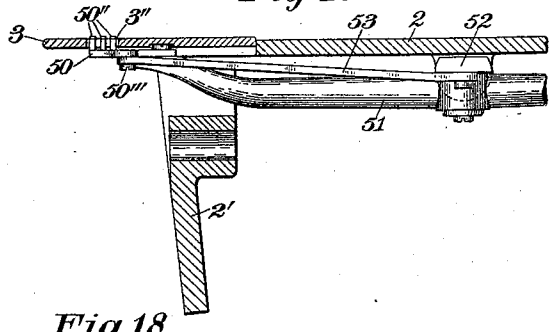


Fig. 17.

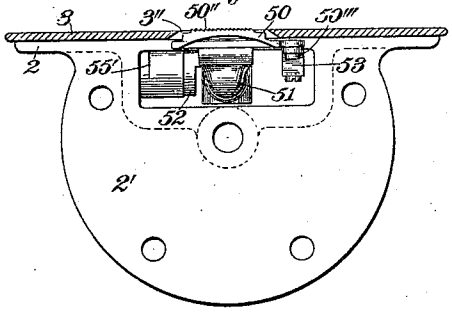


Fig. 18.

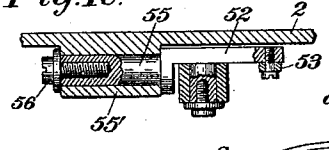


Fig. 19.

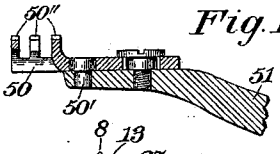


Fig. 20.

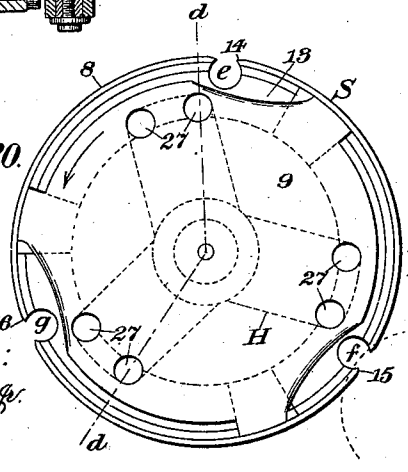
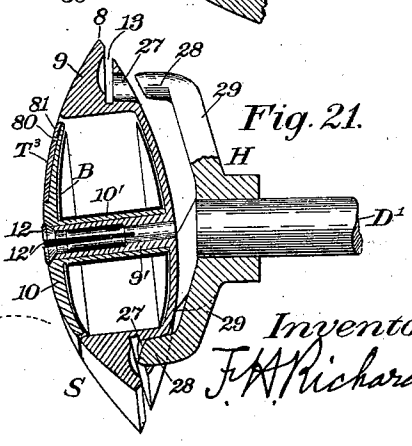


Fig. 21.



Witnesses:
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Inventor:
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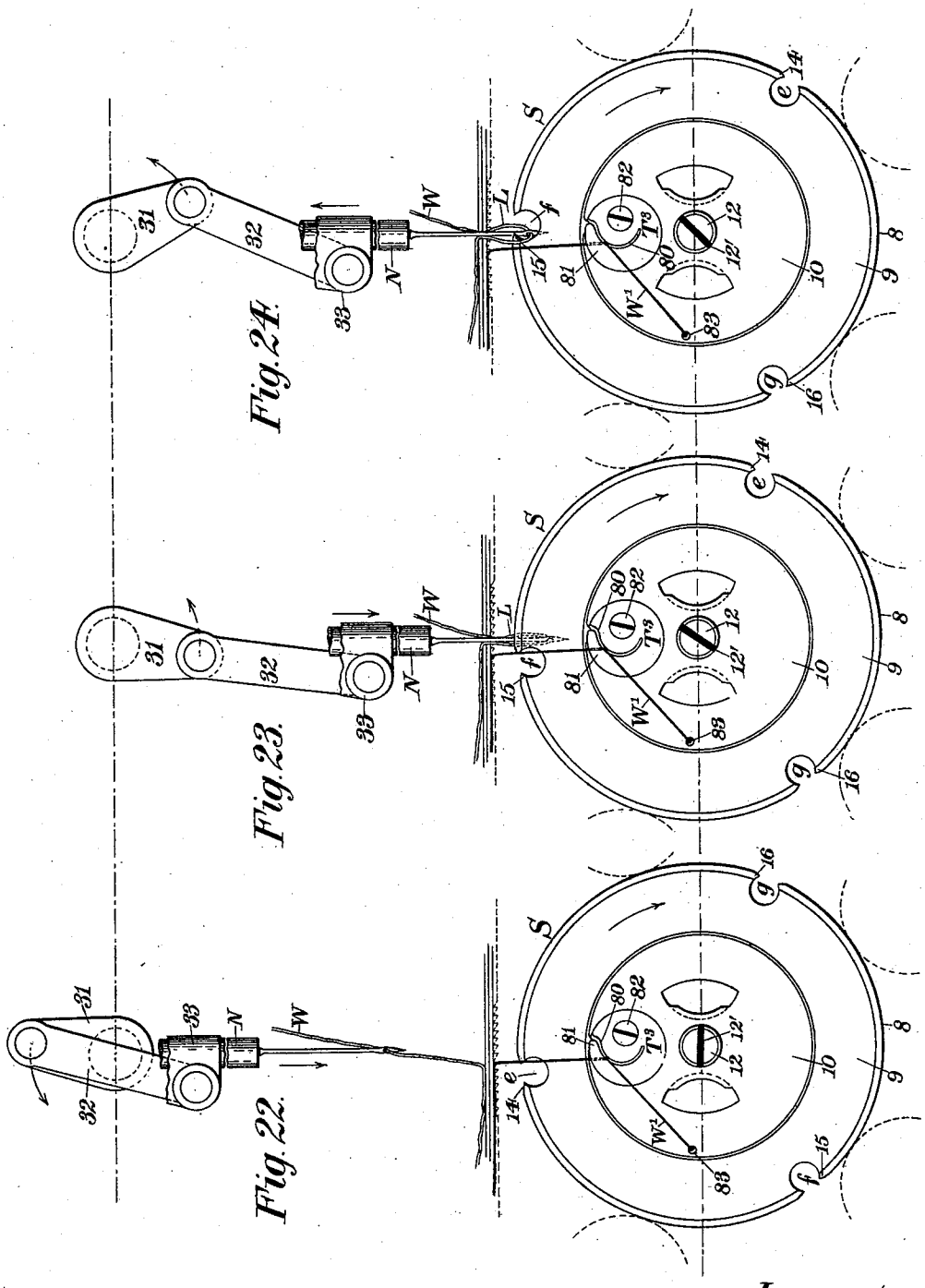
F. H. RICHARDS.

SEWING MACHINE.

No. 574,573. Patented Jan. 5, 1897.



Witnesses:
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(No Model.) 10 Sheets—Sheet 7.

F. H. RICHARDS.

SEWING MACHINE.

No. 574,573. Patented Jan. 5, 1897.

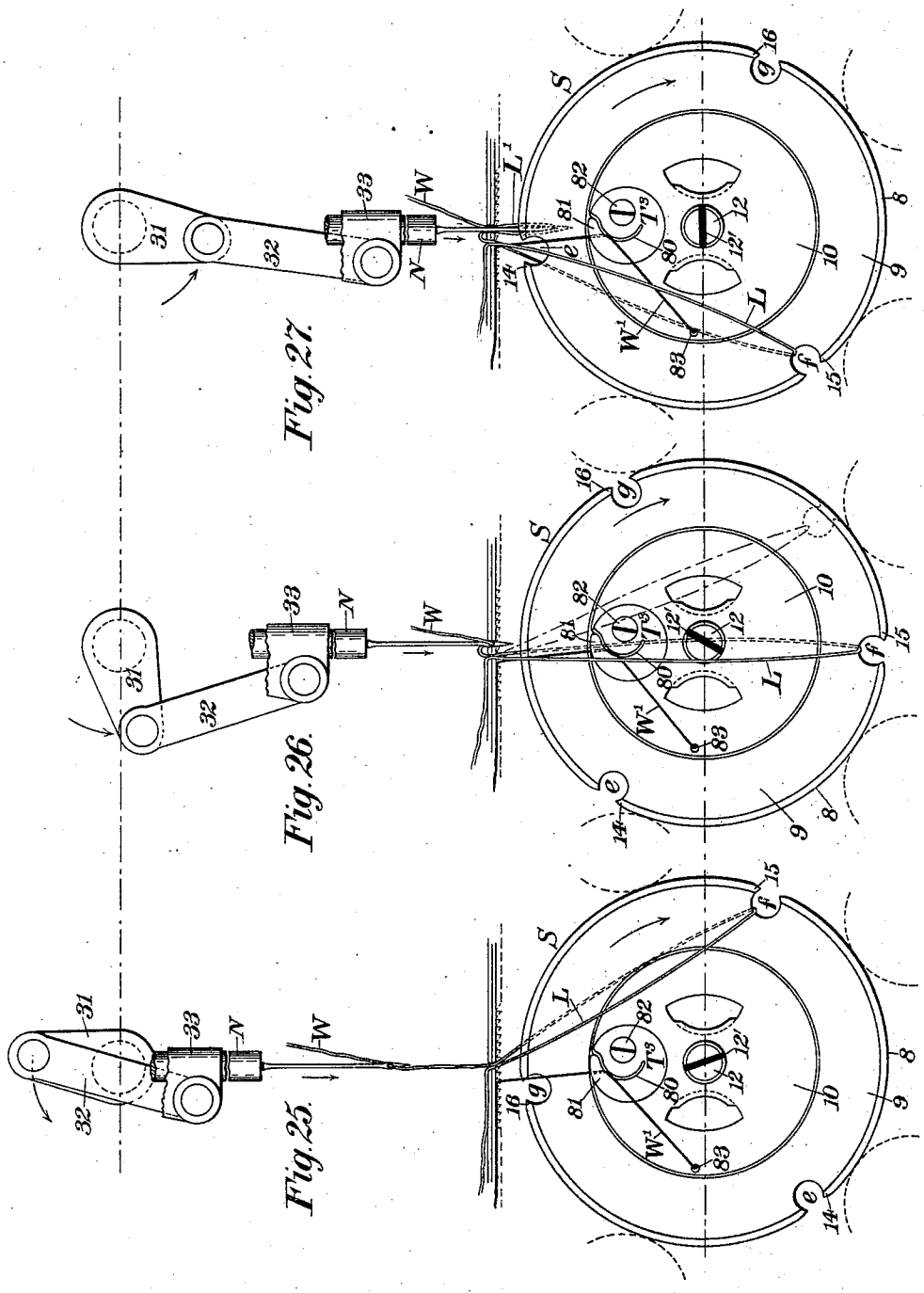

Fig. 27.

Fig. 26.

Fig. 25.

Witnesses:
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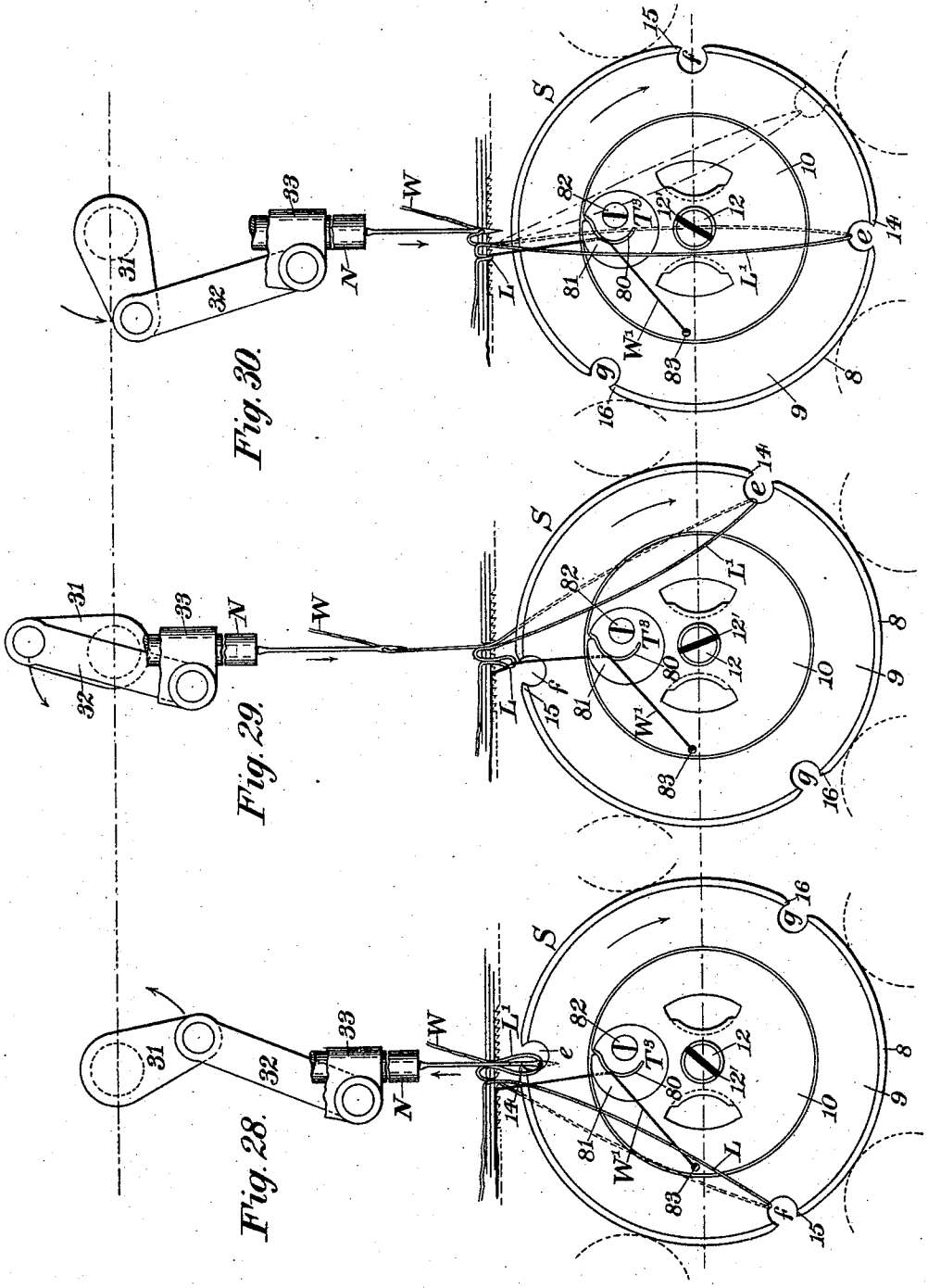
(No Model.) 10 Sheets—Sheet 8.

F. H. RICHARDS.

SEWING MACHINE.

No. 574,573. Patented Jan. 5, 1897.



Witnesses:
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(No Model.) 10 Sheets—Sheet 9.

F. H. RICHARDS.

SEWING MACHINE.

No. 574,573. Patented Jan. 5, 1897.

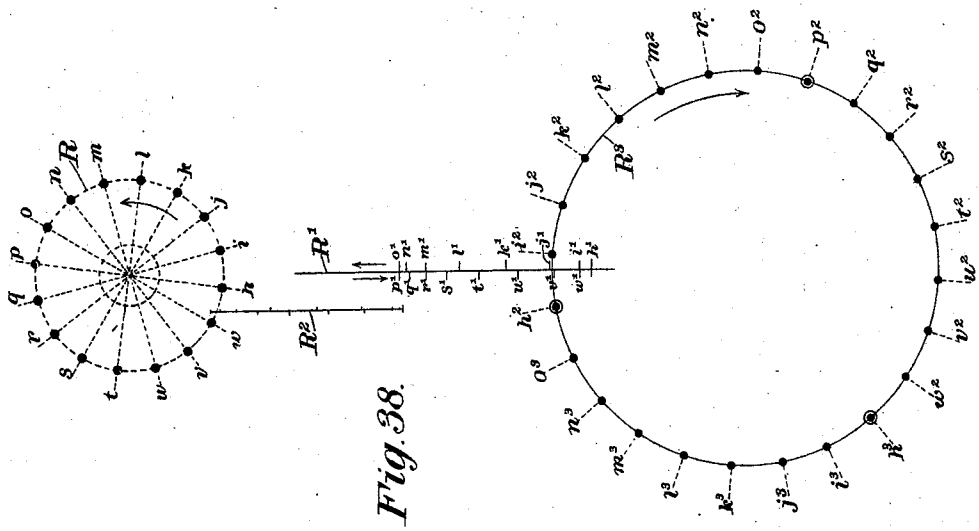

Fig. 38.

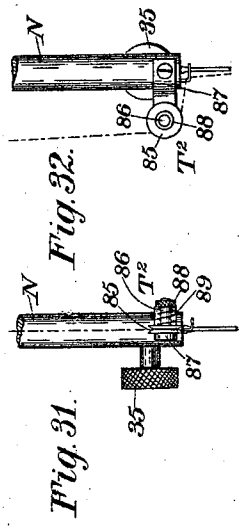

Fig. 32.

Fig. 31.

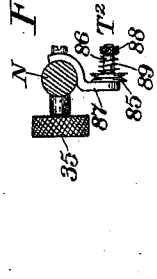

Fig. 33.

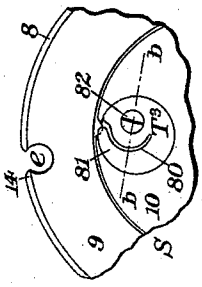

Fig. 35.

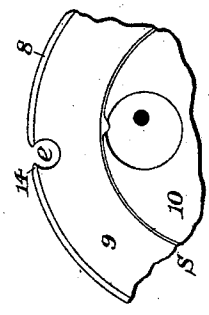

Fig. 34.

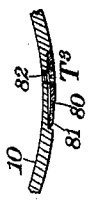

Fig. 37.

Fig. 36.

Witnesses:
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F. H. RICHARDS.

SEWING MACHINE.

No. 574,573. Patented Jan. 5, 1897.

Fig. 39.

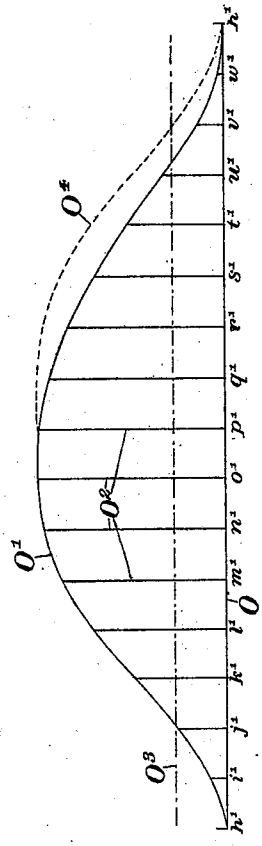
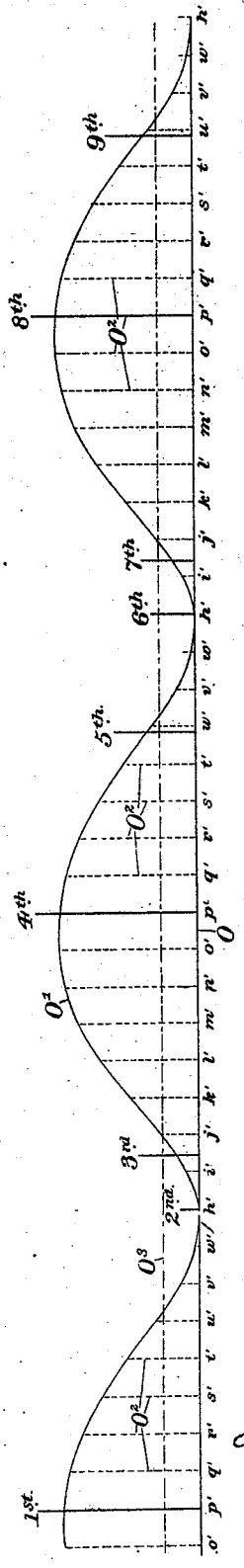


Fig. 40.



Witnesses:
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Fred. J. Dole.

Inventor:
F. H. Richards

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

FRANCIS H. RICHARDS, OF HARTFORD, CONNECTICUT.

SEWING-MACHINE.

SPECIFICATION forming part of Letters Patent No. 574,573, dated January 5, 1897.

Application filed December 15, 1894. Serial No. 531,931. (No model.)

To all whom it may concern:

Be it known that I, FRANCIS H. RICHARDS, a citizen of the United States, residing at Hartford, in the county of Hartford and State of Connecticut, have invented certain new and useful Improvements in Sewing-Machines, of which the following is a specification.

This invention relates to sewing-machines, and has special reference to that class of sewing-machines in which a revoluble shuttle or loop-taker is employed for making the stitch, and in which the loop of the needle-thread is engaged by the loop-taker and is carried entirely around the same to inclose a second or lower thread and form a lock-stitch, or in which one loop of the needle-thread is carried by the loop-taker through a preceding loop to form a chain-stitch.

The object of my present invention is, primarily, to provide a sewing-machine of the class specified having an improved organization of needle-bar mechanism, presser-bar mechanism, loop-taking devices, feed mechanism, and actuating mechanism, and to bring these elements into such relation as to secure a greater efficiency and accuracy in operation as compared with machines of this class of usual construction; also, to facilitate the assembling and disassembling of the parts of the machine and at the same time secure compactness, durability, and low cost of construction.

Another object of my invention is to provide, in connection with the needle-bar and loop-taker of a sewing-machine of the class specified, actuating mechanism therefor of an improved and simplified construction and organization adapted for simultaneously imparting relatively varying movements to said needle-bar and loop-taker of a predetermined ratio, whereby, for instance, the needle-bar may have three complete reciprocations while the loop-taker makes two complete revolutions, to thereby complete one stitch and start another stitch at each complete revolution of the loop-taker.

Another object of my invention is to furnish a sewing-machine having a needle-bar and presser-bar in substantially axial coincidence one with the other and in which the needle-bar is carried within bearings formed in the presser-bar to thereby concentrate the applied force of the presser-foot at a point in direct axial alinement with the needle-bar and at the same time economize in the space required for assembling the needle-bar and presser-bar within the head of the sewing-machine.

In the drawings accompanying and forming part of this specification, Figure 1 is a front elevation of a sewing-machine embodying my present invention. Fig. 2 is an end view of the sewing-machine as seen from the left hand in Fig. 1. Fig. 3 is a plan view of the sewing-machine, portions thereof being broken away to more clearly illustrate certain of the details. Fig. 4 is a sectional front elevation of the sewing-machine, showing the needle-bar in its lowest position and also showing, in connection with its presser-bar-lifting shaft, an auxiliary lifting device located below the bed-plate of the machine and adapted for operating said lifting-shaft. This figure also shows in full and dotted lines two oppositely-disposed driven gears in connection with each other and carried upon the shuttle-actuating shaft and adapted for reciprocally meshing with opposite faces, respectively, of a driving-gear to facilitate changes in the direction of movement of the shuttle-actuating shaft of the machine, as seen from the right hand in Fig. 1. Fig. 6 is a cross-sectional view of a portion of the arm of the machine, on an enlarged scale, showing the presser-bar-lifting shaft, a portion of its operating-rod, and the tension device controlled by said presser-bar-lifting shaft, said figure showing said parts in their operative position, the lifting-shaft being depressed and the tension device being in position to exert a tension upon the needle-thread. Fig. 7 is a view similar to Fig. 6, showing said parts in their normal or inoperative position. Figs. 8, 9, and 10 are enlarged sectional views of the feed-lever-actuating device and the regulator therefor, said figures, respectively, showing three different positions of the regulator and illustrating the operation of these devices. Figs. 11 and 12 are sectional end views of portions of the sewing-machine head on an enlarged scale, as seen from the left hand in Fig. 1, said figures showing two extreme positions of the needle-bar and presser-bar and their actuating devices. Fig. 13 is a sectional rear elevation of a por-

tion of the head of the machine as seen from the left hand in Fig. 11. Fig. 14 is a cross-sectional view of a portion of the arm of the machine, showing the depressing-arm for the presser-bar-operating shaft. Fig. 15 is a sectional plan view of the bed-plate of the sewing-machine, showing the feed-dog, feed-lever, and the actuating mechanism therefor, a portion of the bed-plate being broken away and two positions of said parts being shown in full and dotted lines, respectively. Fig. 16 is a vertical longitudinal section of a portion of the bed of the machine, showing a portion of the feed mechanism in front elevation. Fig. 17 is a cross-sectional view of a portion of the bed of the machine, showing a portion of the feed mechanism in end elevation, as seen from the left hand in Fig. 15. Fig. 18 is a cross-sectional view taken in line *c c*, Fig. 15, looking toward the right hand in said figure and showing a portion of the feed mechanism, said figure being drawn on an enlarged scale. Fig. 19 is a longitudinal section of a portion of one end of the feed-lever, showing the feed-dog in connection therewith. Fig. 20 is a detailed view of the loop-taker or shuttle as seen from the right hand in Fig. 21, the end of the driving-shaft and the driver for rotating said shuttle being shown in dotted lines. Fig. 21 is a cross-sectional view of the shuttle, taken in dotted line *d d*, Fig. 20, looking toward the right hand in said figure and showing a portion of the actuating mechanism in connection therewith. Figs. 22 to 30, inclusively, are detached views of the loop-taker, the needle, and a portion of the needle-actuating devices in operative relation to a piece of fabric to be stitched, said figures illustrating, respectively, certain successive positions of the aforesaid parts during the operation of forming a stitch. Figs. 31, 32, and 33 are front, side, and cross-sectional views, respectively, of the lower portion of the needle-bar, showing the resistance device for holding the upper thread against retractive movement. Fig. 34 is a side view of a portion of the shuttle or loop-taker and cap, showing the bearing or seat for the tension device for the lower-thread; and Fig. 35 is a similar view showing the tension device secured thereto. Fig. 36 is a front view of the tension device detached. Fig. 37 is a cross-sectional view of a portion of the shuttle and its tension device, taken in dotted line *b b*, Fig. 35. Figs. 38 and 39 are diagrammatic views showing the principal relative positions of the needle and shuttle during one cycle of movements of the needle-bar, said Fig. 38 showing a multiplicity of successive and relative positions of the needle, needle-bar, and the needle-bar-actuating crank and of the shuttle or loop-taker, and Fig. 39 showing by graphical diagram the relative paths of movement of the needle and shuttle and also illustrating their relative velocities. Fig. 40 is a diagrammatic view similar to Fig. 39, but upon a reduced scale, for illustrating a series of cycles of movement of the needle and shuttle, and particularly for illustrating the successive positions of the needle during the operations of inaugurating and completing a stitch in the peculiar manner and by the mechanism herein described.

The framework of the machine, which framework is designated in a general way by F and which may be of any suitable conformation, comprises the horizontal bed-plate 2, having the bracket 2′ and the removable throat-plate 3 at one end thereof, the hollow upright 4 at the opposite end of the bed-plate, the hollow horizontal arm 5 above and in horizontal alinement with the bed-plate, and the vertical needle-bar-receiving head 6 at the outer end of the arm 5 and in vertical alinement with the throat-plate 3.

In the organization thereof herein shown and described the stitch-forming mechanism comprises, in part, a reciprocatory needle-bar supported at opposite ends for longitudinal movement in shiftable bearings in the head of the machine, a loop-taker or shuttle, supported for continuous rotary movement in a plane oblique to the path of movement of and below the needle-bar, and having a series of equidistantly-disposed loop-receiving spaces in the periphery thereof, the walls of which loop-receiving spaces constitute hooks adapted for engaging the loop of the needle-thread, means in operative connection with and adapted for simultaneously imparting comparative but relatively varying movements of a predetermined ratio to the needle-bar and loop-taker, and fabric-feeding mechanism in operative connection with and controlled by the needle-bar-actuating means, all of which will be hereinafter more fully described.

In the preferred embodiment of my invention herein shown and described the needle-bar or needle-carrier (designated by N) and the presser-bar or fabric-clamp (designated by P) are axially coincident and practically constitute a unitary device, and therefore when referring to these parts as a unitary structure they will be hereinafter termed the "combined fabric-clamp and needle-carrier."

The shuttle or loop-taker, which owing to its peculiar construction will be herein termed the "three-hook" shuttle or loop-taker, and which is designated in a general way by S, is in the form thereof herein shown somewhat similar in a general way to the shuttle or loop-taker shown and described in my Patent No. 558,662, dated April 21, 1896. In the present instance the loop-taker is shown peripherally supported on rolls below the bed-plate 2 and needle-bar N for rotary movement in a plane obliquely to the path of movement of the needle-bar in a manner hereinafter described, and as clearly shown in Figs. 1, 2, and 4 of the drawings, said rolls frictionally engaging the edge or track 8 of the shuttle. Said loop-taker or shuttle S, which will usually be of the same general confor-

mation as the shuttle described in my said patent, comprises, when the same is assembled, the annularly-recessed or cup-shaped member 9, which member constitutes the shuttle proper and has an inwardly-projecting stem or hub 9′, the lower-thread guide 10, which guide constitutes the cap for the cop-case formed within the shuttle and has a cylindrical hub 10′ and is revolubly carried upon the hub of the member 9, and the detent 12, extending into the hub 9′ and removably holding the parts assembled. This detent or cop-holding device is in the nature of a headed pin split longitudinally, as at 12′ at the head thereof, to form resilient holding-arms adapted for impinging the interior of the hub 9′ of the member 9, as will be readily understood by reference to Fig. 21 of the drawings. The lower thread-carrying bobbin B, sometimes called the "cop" or "spool," is revolubly and removably supported upon the hub 10′ of the said removable cap. The shuttle or loop-taker S is provided at one side thereof with a tension device T^3, adapted for regulating the tension of the lower thread, as will be hereinafter more fully described.

The loop-taker or shuttle S, in the preferred form thereof herein shown, has a substantially annular needle-receiving groove 13, formed in the periphery thereof at one side of the track 8, adapted for receiving the point of the needle during the reciprocation of the needle-bar. Said loop-taker also has formed in the periphery thereof three equidistantly-disposed loop-receiving openings or spaces, (designated by *e*, *f*, and *g*, respectively,) which openings or spaces extend transversely through the periphery or track 8 of the loop-taker and form loop-engaging hooks 14, 15, and 16, respectively, said hooks being adapted for engaging the loops of the needle-thread W as these are formed, and for carrying the same entirely around the loop-taker to inclose the lower thread W′, carried by the loop-taker or shuttle S, to thereby form a lock-stitch, as will be hereinafter more fully described. Formed in one side of the shuttle or shuttle member 9, near the periphery thereof, are a series of driver-sockets 27, herein shown as six in number, arranged in three pairs, said pairs being preferably concentric to the axis of the loop-taker and equidistantly disposed relatively to each other, as clearly shown in Figs. 20 and 21 of the drawings, which sockets are adapted for receiving the corresponding driving-pins 28 upon the driving-arms 29 of a shuttle-driver, (designated in a general way by H,) as will be hereinafter more fully described.

As a means for revolubly and peripherally supporting the shuttle or loop-taker S in a plane at an inclination to the path of movement of the reciprocating needle-bar N and obliquely to the axial line of the shuttle-actuating shaft, and also as a means for maintaining a fixed relation in the movement of the shuttle relative to the needle-bar, I have provided an antifrictional shuttle-carrier which in the form thereof herein shown comprises a series of circumferentially-disposed track-rolls 7, herein shown as four in number, revolubly carried upon laterally-adjustable track-roll carriers 7′. These carriers are herein shown in the nature of studs having crank-pins or eccentrically-disposed shanks 7″, which extend through transverse recesses in the bracket 2′ and are provided with nuts 7‴ at the ends thereof, by means of which said studs are adjustably secured to said bracket and by means of which the positions of the track-rolls may be changed relatively to the periphery of the shuttle which they support, as will be understood by reference to Figs. 2 and 4 of the drawings. These track-rolls are or may be of duplicate construction and interchangeable with one another, and will in practice be so disposed relatively to the periphery of the shuttle that at no time in the rotation of said shuttle will more than one of the loop-receiving spaces be contiguous to a track-roll. These track-rolls will in practice be peripherally grooved to receive and engage the peripheral track 8 of the shuttle, which track is preferably wedge-shaped in cross-section, as most clearly shown in Fig. 21 of the drawings.

In order to provide a clear space unobstructed by supporting means at the upper edge of the shuttle contiguous to the throat-plate, the track-rolls are so disposed relatively to the periphery of said shuttle that two of said track-rolls engage the periphery of said shuttle at points each side of and below the axis of said shuttle, and the other two track-rolls engage the periphery of said shuttle at points slightly above the axis of the shuttle and considerably remote from a vertical line drawn through said axis, thereby leaving at the upper portion of the shuttle a clear space of considerable magnitude immediately adjacent to the throat-plate and path of movement of the needle through which the loop of the needle-thread, after being carried around the shuttle to inclose the lower thread, may readily pass without interference from the supporting means during the operation of forming the stitch. This organization leaves a considerable portion of the upper face of the shuttle accessible from above, which is advantageous in sewing-machines of this class. It will also be seen by reference to Figs. 3 and 4 of the drawings that the bed-plate 2 of the machine terminates, at the free end thereof, at a point between the upright 4 and the axial line of the needle-bar, and that the shuttle, the shuttle-carrier, and shuttle-driver are all located forward of this end of the bed-plate and are readily accessible from the working end of the machine.

As a convenient means for facilitating the inspection and cleaning of the shuttle the throat-plate 3, which is most clearly shown in Fig. 2 of the drawings, is made to extend from the front to the rear side of the bed-plate of the machine and practically constitutes an

extension of the bed-plate or the working table of said machine and is removably fixed to the bed-plate of the machine by means of screws 3′, the throat 3″ thereof being in vertical alinement with the needle-bar N. It will be seen that by the removal of said throat-plate the shuttle, shuttle-carrier, and driver are fully exposed to view and are accessible, practically, at all sides thereof.

The means for adjusting the track-rolls relatively to the shuttle is or may be substantially the same as the track-bearing mechanism described and claimed in United States Patent No. 551,196, granted to me December 10, 1895, to which reference may be had for a more detailed description of these parts, the novelty thereof in the present instance residing in the particular organization relatively to and in combination with certain other features of the sewing-machine, as will be pointed out in the claims.

The driving or actuating apparatus or mechanism for the needle-bar, loop-taker, and feed device of the sewing-machine is practically a unitary mechanism comprising a train of three coöperatively-connected actuating mechanisms, one of which mechanisms directly constitutes an actuating mechanism for the needle-bar, another for the loop-taker, and another for the feed device, and all of which mechanisms coact to effect a predetermined comparative relation of movement between said needle-bar, loop-taker, and feed device.

The combined needle-bar, loop-taker, and feed-actuating mechanism, in the preferred organization thereof herein shown and described, comprises two remotely-disposed shafts D and D′, located horizontally one above the other in parallelism, the shaft D being in direct operative relation with the needle-bar N and the shaft D′ being in direct operative relation with the loop-taker or shuttle S; an intermediate vertical shaft D^2; a one-to-one train of gears E, operatively connecting the needle-bar-actuating shaft D and the intermediate shaft D^2, and a two-to-three train of gears E′, operatively connecting the intermediate shaft D^2 and the loop-taker-actuating shaft D′.

As a convenient means for accelerating the upward stroke of the needle-bar or for effecting a relatively slow downward stroke and a relatively rapid upward stroke of the needle-bar, whereby the loop of the needle-thread may be drawn entirely off from the preceding hook of the loop-taker and out of the path of movement of the succeeding hook, as hereinafter more fully described, the upper horizontal shaft D, which will hereinafter be termed the "needle-bar-actuating shaft" and which is journaled at or near its opposite ends in suitable bearings 30 in the arm 5 of the machine, is operatively connected with the needle-bar by means of a linkage connection comprising a crank 31, carried at the forward end of the needle-bar-actuating shaft, and a connecting-link 32, pivotally connected at its upper end with the crank and pivotally connected at its lower end to the needle-bar at one side the longitudinal axis of the needle-bar. This linkage connection is so disposed relatively to the needle-bar and actuating-shaft that its neutral or dead-center position will be inclined relatively to the longitudinal axis of the needle-bar, as illustrated most clearly in Fig. 11 of the drawings. It is desired in this connection, however, that other means than that herein shown and described for effecting a relatively slow downward movement and a relatively rapid upward movement of the needle-bar may be employed within the scope and limits of my invention.

The crank 31, which is preferably secured to the outer end of the shaft D, is shown provided with a weighted extension 31′ at the free end thereof and is provided at its opposite end with a transverse elongated bearing 31″, in which is journaled the stud or pin 32′ on the upper end of the connecting-link 32, which link is pivotally secured by another stud or pin at the lower end thereof, and at one side the axis of the needle-bar to a strap 33, adjustably clamped or secured to the needle-bar, as most clearly shown in Figs. 11, 12, and 13 of the drawings.

As a means for directly actuating the loop-taker or shuttle from the horizontal shaft D′ and as a means for holding said shuttle in a fixed peripheral relation with the peripherally-disposed track-rolls and concentric to a fixed axis of rotation and thereby prevent radial movement of the shuttle when a loop-receiving space or opening comes opposite or contiguous to a supporting periphery of a track-roll during the rotation of said shuttle I have provided, in connection with the shaft D′, a shuttle-supporting driver H, which driver in the form thereof herein shown has a series of radially-disposed arms 29, each having at the free end thereof two outwardly-projecting shuttle driving and supporting pins 28, the pins of the successive arms of the driver being adapted for successively engaging in the corresponding driving-sockets 27 of the shuttle for rotating the same and also for maintaining said shuttle against radial movement or vibratory movement during the rotation thereof.

By reference to Figs. 20 and 21 of the drawings, which clearly illustrate the relations of the shuttle S and driver, it will be seen that each pair of driving-sockets 27 is located in close proximity to and but slightly one side of a peripheral loop-receiving opening. Furthermore, it will be seen, owing to the vertical inclination of the shuttle, that during the rotation of said shuttle the driving-pins of the arms of the driver successively engage the shuttle when said arms have advanced to a position slightly below a horizontal line drawn through the axis of the driver, and that when one or two arms of the driver is in or approximately in a vertical position both driving-pins of said arm or

arms are extended into their respective receiving or driving sockets in said shuttle, thereby so taking hold of said shuttle as to control the same against lateral or swinging movement as the loop-receiving openings immediately adjacent to said pins pass over the periphery of the supporting-rolls, notwithstanding only four such rolls are employed. This construction and organization of shuttle and driver therefor, as will be readily seen, materially reduces peripheral frictional wear to which the shuttle would be subjected if it were entirely dependent upon the track-rolls for support, and consequently is conducive to accuracy in operation.

The "one-to-one" train of gears E, which operatively connect the needle-bar-actuating shaft D and the intermediate or vertical shaft D^2, consists, in the form thereof herein shown, of two substantially duplicate bevel-gears d and d', respectively, in intermeshing engagement and fixed one to the needle-bar-actuating shaft and the other to the intermediate shaft.

The "two-to-three" train of gears operatively connecting the intermediate shaft D^2 and shuttle-actuating shaft D' consists of a relatively small bevel-gear d^2, secured to the intermediate shaft, and a relatively large bevel-gear d^3, secured to the shuttle-actuating shaft, the difference in size of these two last-mentioned bevel-gears being such as to secure a comparative velocity to the shuttle-actuating shaft and intermediate shaft, the ratio of which will be as two to three, the shuttle-actuating shaft making but two complete revolutions during three complete revolutions of the intermediate shaft. This particular organization of driving mechanism hereinbefore described, referring more particularly to the arrangement of the one-to-one train of gears and the two-to-three train of gears relatively to the needle-bar-actuating shaft and intermediate shaft and to the intermediate shaft and shuttle-actuating shaft, respectively, secures to the needle-bar-actuating shaft and intermediate shaft simultaneous movements of coinciding velocities which, for the purpose hereinafter described, is of material importance in the efficient operation of the machine and also secures simultaneous movements to the shuttle-actuating shaft and intermediate shaft of relatively varying velocities of a predetermined ratio, as is requisite for the proper operation of the shuttle relatively to the needle-bar. The intermediate shaft D^2 in the organization of the sewing-machine mechanism herein shown and described not only constitutes a convenient operative connection between the needle-bar-actuating shaft and shuttle-actuating shaft, but also constitutes an actuator for the feed mechanism of the sewing-machine, as will be hereinafter described.

From the foregoing description, and by a comparison of the several figures of the drawings, it will be seen that the organization of the driving mechanism is such that while the three shafts—viz., the needle-bar-actuating shaft D, the shuttle-actuating shaft D', and the intermediate shaft D^2—are practically dependent upon each other for effective operation, each shaft has a special and independent function, to wit, the shaft D is in operative connection with and reciprocates the needle-bar, the shaft D' is in operative connection with and rotates the shuttle, and the shaft D^2 is in operative connection with and actuates the feed mechanism, and it will furthermore be seen that each of said shafts and the bearings for the same performs a certain and approximately equal proportion of the entire work, thereby securing a more perfect balancing of the working parts and also securing a greater accuracy and durability in the operation of the machine than would be the case if one shaft carried a much larger proportion of the load than another.

The combined needle-bar and fabric-clamp, in the preferred form thereof herein shown, consists, as before stated, of the needle-bar N and presser-bar P, supported for independent reciprocatory movement one within the other. The needle-bar is preferably in the nature of a round rod, symmetrical from end to end and axially bored at the lower end thereof to receive the needle, which needle is held in place in said needle-bar in the usual manner by a set-screw 35. The presser-bar, which is preferably of cylindrical form and constitutes a guide for the needle-bar, is supported for sliding movement at its lower end in a vertical bearing formed in the lower end of the head 6 of the machine-frame, and is similarly supported at its upper end in a bearing 36, preferably adjustably secured to the upper end of the head of the machine and adapted for adjustment longitudinally of the presser-bar. This bearing 36 at the upper end of the presser-bar will usually be externally screw-threaded and screwed into the upper end of the head of the machine, and (in this organization) constitutes the adjusting member of the pressure-regulating device for said presser-bar, the other member of said pressure-regulating device consisting of a spiral spring 37, surrounding the needle-bar N and interposed between the upper end of the presser-bar and the outer end wall of the journal-bearing, as clearly illustrated in Figs. 11 and 12 of the drawings.

Removably secured to the lower end of the presser-bar by means of a screw 38 is a presser-foot 39, which may be of any usual or suitable construction. The adjustable bearing 36 and resistance-spring 37 in the organization thereof herein shown and described constitutes a simple and effective pressure-regulating device for the presser-bar, and, in operation, when it is desired to increase or decrease the effective pressure of the presser-foot upon the fabric being operated upon it is only necessary to screw the bearing 36 inward or out-

ward, which increases or decreases the effective resistance of the spring 37 with relation to the presser-bar, as will be readily understood by a reference to said Figs. 11 and 12 of the drawings.

As will be seen by reference to Figs. 11, 12, and 13 of the drawings, the presser-bar, at the middle portion thereof, is for a considerable length cut away at one side thereof, as shown at 39′, to form a slideway for the strap 33, which forms the connection between the needle-bar and its actuating mechanism, said slideway 39′ being of sufficient length to permit a free unobstructed reciprocation of the needle-bar, irrespective of its position relative to the presser-bar or when the presser-bar is in a depressed or elevated position.

As a convenient, simple, and effective means for elevating and depressing the presser-bar P, and also as means for preventing the accidental rotation of said presser-bar, I have provided in connection therewith a presser-bar-lifting shaft or rock-shaft 40, which carries at its forward end, adjacent to said presser-bar, the crank-arm 41. The outer end 41′ of this crank engages in a cam-groove 42 between the fingers 42′ at the outer end of a laterally-projecting arm 43, which is fixed at its inner end, as shown at 44 in Figs. 11, 12, and 13, to the presser-bar. Said crank-arm 41 has bearing-faces 41″ in engagement with opposite sides, respectively, of the arm 43, which faces are adapted for preventing accidental rotative movement of said presser-bar. As a means for operating or rocking said presser-bar-lifting shaft 40 to raise or lower the presser-bar, this shaft is shown provided at opposite ends thereof with two oppositely-disposed laterally-projecting rocking arms 45 and 46, respectively, the one 45 of which extends through a transverse opening 47 in and is operable from the outside of the horizontal arm 5 of the machine and will be herein termed the "presser-bar-depressing arm." The other arm 46 is in the nature of a cam and is adapted not only for elevating the presser-bar through the medium of the presser-bar-actuating shaft, but is also adapted for simultaneously operating a tension device, (designated in a general way by T,) as will be hereinafter more fully described, it constituting a presser-bar-lifting arm and "tension-device operator," it may properly be so termed. The presser-bar-depressing arm 45 is designed to be operated by hand somewhat after the manner of the presser-bar-lifting arms or levers in sewing-machines of ordinary construction, whereas the presser-bar-lifting arm 46 is designed to be operated by the knee of the operator from below the bed of the machine, and for this purpose I have provided in connection with said lifting-arm 46 a vertically-disposed lifting-rod 48, which is usually pivotally connected at its upper end with said arm 46, and may be supported for sliding movement in a vertical bearing 49 in the framework of the machine. The lower end of the lifting-rod 48 projects somewhat below the bed of the machine and may be operated by a lifting-lever 18, fulcrumed upon a stud 19, secured to a bracket 20, which bracket may be fixed to the table 21, (shown in dotted lines in Fig. 4,) upon which the machine is supported. This operating-lever 18 is shown of the so-called "bell-crank" type, one arm of which is in bearing-engagement with the lower end of the lifting-rod 48 and the other arm of which depends into a position to be engaged and shifted by the knee of the operator.

As will be seen by reference to Fig. 4 of the drawings, force applied to the depending arm of the lifting-lever 18 in the direction of the arrow in said figure will push the lifting-rod upward and will, through the medium of the presser-bar-lifting arm 46, partially rotate the presser-bar-lifting shaft 40 and lift the presser-bar from the position shown in Figs. 4 and 11 to the position shown in Fig. 12. This operation also causes the arm 46 to actuate a tension device, (designated in a general way by T,) which is connected with the arm of the machine at points in vertical alinement with the path of movement of said lifting-arm 46, as will be hereinafter more fully described. The operation of the presser-bar-operating mechanism will be readily understood by a comparison of Figs. 3, 4, 5, 6, 7, 11, 12, and 13 of the drawings with each other and with the preceding description of the same.

In the preferred form thereof herein shown and described (see Figs. 15 to 19, inclusively) the feed mechanism for the sewing-machine comprises a feed-dog 50, which may be of any suitable conformation, which feed-dog is serrated at its upper edge and extends through the recess or throat 3″ in the throat-plate 3; a feed-dog carrier or feed-lever 51, pivotally carried for vertical and horizontal oscillation by a bracket or feed-lever carrier 52; a link 53, connecting the feed-lever carrier and feed-dog and adapted for maintaining the feed-dog in substantial parallelism with the line of its longitudinal movement; a feed-lever-actuating cam 54 in adjustable rotative connection with the intermediate shaft D^2 of the machine and adapted (through the medium of said shaft and connections hereinafter described) for imparting alternating vertical and horizontal oscillations to the feed-lever, and a regulating device, hereinafter described, in connection with and adapted for adjusting the cam 54 laterally relatively to its rotating means to increase or decrease the effective throw of the feed-lever and thereby regulate the feed. As illustrated most clearly in Figs. 15 and 19, the feed-dog 50 is pivotally connected at 50′ to the forward end of the feed-lever 51, and is pivotally connected at 50‴ to the forward end of the parallel link 53, said pivotal points being in alinement and in parallelism with the path of movement of the fabric-engaging portion 50″ of the feed-dog 50. The opposite end of the link 53 is pivotally

connected with the outer end of the feed-lever carrier 52, said link being so connected to said feed-dog and feed-lever carrier as to have at all times a parallel movement with relation to the forward end of the feed-lever or that end of the feed-lever intermediate to the feed-dog and feed-lever carrier, as will be readily understood by reference to Fig. 15 of the drawings, in which two positions of said parts are shown by full and dotted lines, respectively. The feed-lever carrier is shown having a pivot-pin 55 at the inner end thereof journaled at one end in a bearing 55′, preferably formed integral with the bed-plate of the machine at the under side thereof, said feed-lever carrier being held against longitudinal displacement by means of a shouldered screw 56, screwed into the inner end of the pivot-pin 55 and bearing against the inner face of the bearing 55′, as illustrated most clearly in Fig. 18 of the drawings.

In the usual form thereof herein shown the feed-lever 51 is bifurcated at that end adjacent to the intermediate shaft D^2 to form cam-engaging arms 60 and 60′, adapted for engaging the feed-lever-actuating cam 54 at opposite sides of the axis thereof, as will be readily understood by reference to Fig. 15 of the drawings. This feed-lever-actuating cam 54, which will herein be termed the "feed-cam," is, in the form thereof herein shown, in the nature of a collar having a longitudinal opening or bore 61 therethrough adapted for receiving a sliding cam-shifting wedge 62, carried upon and adapted for longitudinal movement with relation to the intermediate shaft D^2, said bore being obliquely disposed relatively to and preferably intersecting the longitudinal axis of the collar or feed-cam 54. This wedge constitutes the regulator for determining the effective movement of the feed-lever, said wedge being of cylindrical form and being provided at its upper end with a circumferentially-grooved collar or head 63 and being adjusted longitudinally of the shaft D^2 by means of an adjusting device, (designated in a general way by G,) carried in the frame of the machine and in operative connection with the sliding wedge or adjusting member 62, as will be hereinafter more fully described.

As a means for fixedly securing the feed-cam as against longitudinal movement upon the shaft D^2, said feed-cam is preferably supported between the relatively small gear d^2 at the lower end of said shaft and the lower journal-bearing 64 of said shaft, as clearly shown in Figs. 4, 5, 8, 9, and 10 of the drawings, and as a means for so securing said feed-cam that it shall rotate with said shaft and at the same time be shiftable laterally thereof, said cam has at its under face a slide 66, which is fitted for sliding movement in a slideway formed in the upper face of the hub of the bevel-gear d^2, which gear is fixedly secured to the shaft D^2, as will be understood by reference to Fig. 4 of the drawings.

The adjusting device G for the wedge 62, in the form thereof herein shown, is in the nature of a stud journaled for rotary movement in a bearing 67, formed in the side wall of the upright or column of the frame, and said stud has a crank-pin 68 the inner end of which engages in the peripheral groove 69 in the collar or head 63 of the sliding wedge 62, as will be seen by reference to Fig. 4 of the drawings. This adjusting device is removably secured in the bearing 67 by means of a detent-catch 70, seated in a transverse opening 71, formed in the stud or adjusting device G and engaging in an annular groove 72, formed in the inner face of said bearing 67, the detent-catch being normally held in its interlocked engagement with the faces of the said groove 72 by means of a spring 73, seated in the transverse opening 71 and bearing against the inner end of said detent-catch, as clearly shown in said Fig. 4. For convenience in rotating the adjusting device and for determining the extent of said rotation with accuracy, said adjusting device is provided at its outer end with a knurled head 75, and is also provided at a point contiguous to the outer face of the bearing 67 or outer face of the end wall of the upright 4 with a graduated indicator plate or dial 76, adapted to be read in connection with a pointer 77, secured to said end wall with its point in close proximity to the graduated periphery of said dial. (See Figs. 1 and 4.)

By means of the construction and organization of feed mechanism, and of regulating means therefor, as hereinbefore described, it will be seen that the throw or effective horizontal movement of the feed-lever may be increased or decreased to a limited extent by simply turning the adjusting device G to the right or left, as the case may be, which operation will raise or lower the cam-shifting wedge 62 relatively to the feed-cam 54 and shift said feed-cam laterally relatively to the axis of the shaft D^2, causing the same to describe a larger or smaller circle during its rotation, and thereby increasing or decreasing the throw of the feed-lever, as will be readily understood by a comparison of Figs. 8, 9, and 10 of the drawings.

As a means for securing the proper tension to the upper and lower threads W and W′, respectively, I have provided two tension devices, (designated in a general way by T and T^3, respectively.) The tension device T is supported, preferably, in close proximity to the source of supply of the upper thread W, and is adapted for regulating the tension thereof, whereas the tension device T^3 is carried by the cap or thread-guiding member 10 of the shuttle, as clearly shown in Figs. 21 to 30, inclusive, and is adapted for regulating the tension of the lower thread W′. As a means for preventing the accidental retraction or premature taking up of the needle-thread W (after the loop L has been formed by the descent of the needle and prior to its

engagement by one of the loop-engaging hooks of the shuttle and during the earlier part of the upward stroke of the needle-bar) I have provided an automatic resistance device T^2, which is shown carried by the needle-bar, preferably in close proximity to the extreme lower end thereof, which resistance device is of a construction and organization adapted for exerting a resistance upon the upper thread or needle-thread W sufficient to prevent a retracting movement or backward slipping of said needle-thread during the very earliest part of the upward stroke of the needle-bar, and for maintaining said resistance until the proper hook of the shuttle engages the loop of the needle-thread, and as a means for exerting an upward or drawing stress upon the needle-thread in excess of the normal resistance of said thread during the latter part of the ascending movement of the needle-bar, so as to quickly take up the loop end of the needle-thread after it has passed completely around and is released from the shuttle, and to draw said loop into close proximity with the fabric and out of the path of movement of the hook from which said loop was released, so as to prevent said hook from accidentally reëngaging this loop, I have provided, in connection with the upper end of the needle-bar, a retracting device T', which engages the needle-thread at a point intermediate to the tension device T and the resistance device T^2 and acts during the latter stages of the upward stroke of the needle-bar to draw said loop end above the path of movement of the loop-engaging hooks, as will be hereinafter more particularly described in connection with the description of the operation of the machine in forming the stitches.

Briefly stated, the tension device T, in the form thereof herein shown, consists of the axially-recessed carrying member 22, removably secured to the upper wall of the arm 5 of the machine with its axis in vertical alinement with the cam-face of the arm 46 of the presser-bar-lifting shaft 40; a thread-carrying disk 23, carried upon said member 22, near the upper end thereof; a friction-plate or tension-spring stop 24 in normal bearing contact with the thread-carrying disk 23; a lifting-pin 25 for said friction-plate; a tension-spring 26, carried upon said member 22 and bearing against said friction-plate, and an adjusting-nut screwed upon the upper end of said member 22 and adapted for regulating the tension of said spring. The carrying member 22 preferably has its lower end extended into the interior of the arm 5 of the machine and has its upper end diametrically reduced to form a bearing or spindle 57 for the thread-carrying disk, as more clearly shown in Figs. 4, 5, 6, and 7 of the drawings. The upper end or spindle 57 of the carrying member 22 is slotted longitudinally, as shown at 58, to form a guideway for the central portion or bridge 24' of the friction-plate 24, which plate extends through said slot, as shown in Figs. 6 and 7. The axial recess through the carrying member 22 is diametrically enlarged at the upper end thereof to form a stop-face at 22' for the head of the lifting-pin 25 to limit the downward movement thereof. This lifting-pin 25, as shown in Figs. 6 and 7, projects at its lower end beyond the extreme lower end of the carrying member 22 and bears upon and is adapted to be operated by the cam-face 46' of the arm 46.

As will be understood by reference to Figs. 3, 4, 5, 6, and 7 of the drawings, the tension device T is controlled, in so far as its effective or ineffective operation is concerned, by the operation of the presser-bar-lifting shaft 40. It will be observed that when the presser-bar is depressed the lifting-pin of the tension device T is in its lowest position and the spring of said tension device presses the friction-plate in close contact with the thread-carrying disk 23, increasing the resistance to rotation of said disk and consequently rendering the tension device operative for the purpose intended, whereas when the presser-bar of the machine is elevated the lifting-pin 25 of the tension device T is lifted by the arm 46 upon the presser-bar-lifting shaft, which, as shown in Fig. 7, carries the friction-plate 24 away from and leaves the thread-carrying disk 23 free to rotate without resistance. This construction and organization of the tension device, whereby it is controlled by the operation of the presser-bar, is of considerable importance, as it enables the operator to withdraw the work after lifting the presser-bar without regard to the tension of the thread and without the necessity of drawing off a considerable length of the upper thread W from the spool by hand, as is customary with sewing-machines of ordinary construction, to prevent breaking of the thread in the vicinity of the needle.

The tension device T^3 for the lower thread W' is in the nature of a disk slit from the periphery thereof inwardly, as shown most clearly in Fig. 36 of the drawings, to form a thread-receiving groove 80 and a resilient thread-impinging arm 81. This tension device, as before stated, is carried by the cap or thread-guiding member 10 of the shuttle, it being removably secured to the outer face thereof by means of a set-screw 82, as shown most clearly in Fig. 35. The lower thread W', which is carried by the bobbin of the shuttle in the usual manner, is threaded through the transverse opening 83 in the cap 10 of the shuttle and is carried over and under the resilient arm 81 of the tension device T^3 in the manner shown in Figs. 22 to 30, inclusively. This tension disk or device T^3 will preferably be somewhat "dished" or be convexed relatively to the face of the cap 10, upon which it bears, so that for the purposes of increasing or decreasing the tension of the lower thread W' it is only necessary to adjust the set-screw 82 inward or outward, so that the resilient arm 81 of said disk will bear with

a greater or less pressure upon the lower thread, as will be seen by reference to Figs. 22 to 30, inclusively, and to the detail views of said devices shown in Figs. 34 to 37, inclusively. This tension device, however, is "automatic" in its action within certain limits, since the larger size of thread bends outward the said arm to a greater extent, thereby producing a greater friction on the thread. Hence when properly constructed the device seldom needs to be adjusted.

The resistance device T^2, which is connected with the needle-bar at the lower end thereof, as before described, and which is adapted for holding the upper thread against premature retractive movement, is somewhat similar in general construction to the tension device T', it consisting of a thread-carrying disk or peripherally-grooved roller 85, carried for rotary movement upon a stud 86 at the outer end of a bracket or arm 87, secured to the lower end of the needle-bar, as illustrated most clearly in Figs. 31, 32, and 33; an adjusting-nut 88 screwed upon the outer end of said stud, and a spiral spring 89, carried upon said stud between the thread-carrying disk and adjusting-nut. This spring 89, as will be seen by a comparison of Figs. 6, 7, 31, 32, and 33 of the drawings, is relatively small as compared to the spring 26 of the tension device T, and will consequently have no material effect upon the normal tension of the upper thread W, which is wholly governed by the main holdback or tension device T. The function of the resistance device, as before stated, is to prevent accidental retraction of the needle-thread or upper thread during the very first part of the upward stroke of the needle-bar and at a point below the eye of the needle and to prevent accidental drawing up of the loop L before the same is engaged by the hook of the loop-taker, which drawing up of the loop might be occasioned by the extreme tautness of the upper thread, which is always more or less elastic, this elasticity of the needle-thread having a tendency to retract or draw back the slack created by the descent of the needle in forming the loop L to be engaged by a hook of the loop-taker or shuttle. In practice the resistance device T^2 will be so regulated in its effective operation relatively to the main tension device T as to hold the upper thread against retractive movement caused by its own elasticity, but will not have sufficient power to interfere with the feed or forward movement of said thread. This will be readily understood by reference to Fig. 4 of the drawings.

The retracting device T', which, as before stated, is adapted for taking up the increment of the loop end immediately preceding the final drawing up of the same to form the stitch and for drawing said loop end out of the path of movement of and preventing the reëngagement thereof by the hook of the loop-taker or shuttle, is, in the form thereof herein shown, in the nature of a projecting arm carried by the needle-bar at the upper end thereof and provided with an eye 90 at the outer end thereof for engaging the upper thread W, as shown in Figs. 1 and 2 of the drawings. This retracting device is so disposed and operative relatively to the tension device T that the thread-engaging end of said retracting device will, when the needle-bar is in its depressed position, be located somewhat below the horizontal path of the upper thread W or below a horizontal line drawn through the periphery of the thread-carrying disk of the tension device T, and in consequence thereof the retracting device will, during the first part of the upward stroke of the needle-bar, have no retracting effect upon the needle-thread and will only be effective for this purpose during the latter part of its upward stroke, at which part of its upward stroke it will, owing to the increased distance of the thread-engaging eye from the tension device T, draw upon the upper thread, and owing to the effective resistance of the tension device T the entire retractive movement of the upper thread must necessarily take place at a point below the retracting device and adjacent to the needle, the resultant effect being to reduce the size of the loop released from the shuttle and draw the same into close proximity with the fabric and out of the path of movement of the hooks of the loop-taker or shuttle. This peculiar taking up or in-drawing of the loop end of the needle-thread is accomplished with great rapidity owing to the peculiar connection of the needle-bar-actuating shaft with the needle-bar, to wit, at one side of the longitudinal axis thereof, as before stated and as shown most clearly in Figs. 11, 12, and 13 of the drawings, which connection secures to the needle-bar an upward and downward movement of relatively varying velocities, the upward movement thereof being accelerated, as will be understood by reference to Fig. 39 of the drawings, which is a graphical diagram illustrating certain successive and relative positions of the needle and shuttle and also illustrating the ratio of variation in the velocity of the needle during its upward and downward stroke.

Referring to Figs. 22 to 30, inclusively, which figures illustrate nine successive positions assumed by the shuttle, needle, needle-bar, and a portion of the needle-bar-actuating mechanism in the operation of forming a stitch, it is desired to state that while the successive positions of the end portion of the needle-thread loop are substantially correct the configuration of the intermediate portion is slightly modified to more clearly show opposite portions of said loop.

The machine herein shown and described is especially designed for forming what is known as a "lock-stitch;" but it will be understood that by reversing the movement of the shuttle or feed mechanism a chain-stitch might be formed. For this purpose the shuttle S is shown having the loop-receiving openings e,

f, and *g* of such conformation that the opposing walls of each opening will constitute opposite loop-engaging hooks adapted one for engagement with the loop of the needle-thread when the shuttle is driven in one direction, and the other is adapted for engagement with said loop when the shuttle is driven in the opposite direction, and as a means for reversing the movement of the shuttle I have shown, partially in dotted and partially in full lines in Fig. 4 of the drawings, a pair of oppositely-disposed reversing-gears, which in practice will be connected together and supported for a shifting movement upon and longitudinally of the shuttle-actuating shaft D′ and adapted for alternately meshing with the bevel-gear d^2 at the lower end of the intermediate shaft D^2. Suitable shifting means (not shown) will be provided in connection with said shiftable gears for throwing one or the other of them into or out from working mesh with the gear of the intermediate shaft, as will be readily understood by reference to said Fig. 4. It will be understood, however, that my present invention is not limited to the particular organization of mechanism above described for reversing the shuttle to form the chain-stitch, as other means might be employed in connection with the shuttle-actuating mechanism for accomplishing this end. It is also desired to state, in this connection, that the form of loop-engaging hooks of the loop-taker might also be variously modified (especially where the machine is designed only for forming a lock-stitch) without departure from my present invention.

As a preamble to the description of the operation of the machine in forming a lock-stitch it is deemed desirable to state that with the organization of shuttle and needle actuating mechanism herein shown and described the shuttle and needle-bar are so timed in their movements relatively to one another that the ratio of movement thereof is as two to three, the shuttle making two complete revolutions to three complete reciprocations of the needle-bar. Thus it will be seen that at each complete upward or downward stroke of the needle-bar the peripheral travel of the shuttle is substantially equal to one-third of the length of the circumference of said shuttle, and in consequence of the equidistant peripheral disposition of the three loop-receiving openings or spaces *e*, *f*, and *g* relatively to each other and their peculiar operative arrangement relatively to the reciprocations of the needle, as represented in Figs. 22 to 30 of the drawings, the needle will at each descent or complete downward stroke of the needle-bar come in close proximity to, but slightly in advance of, a needle-thread-loop-engaging space or opening and in position to insure the engagement of the loop formed by said downward stroke of the needle by the hook of said adjacent loop-receiving space, and it will be further observed that at each complete reciprocation of the needle one of the loop-receiving spaces of the shuttle will be carried past the loop-engaging position, and the successive loops formed by the needle will be successively engaged by the several hooks in the alternating order of their rotation.

Referring to the diagram Fig. 38, the dotted circle R represents the circuit or path of movement of the needle-bar-actuating crank. The parallel vertical lines R′ and R^2, respectively, represent the paths of movement of the needle and its connection, and the large dotted circle R^3 represents the circuit or path of movement of the loop-engaging hooks of the loop-taker or shuttle. The dotted circle R, which represents the circuit of the crank, is shown divided by dots *h*, *i*, *j*, *k*, *l*, *m*, *n*, *o*, *p*, *q*, *r*, *s*, *t*, *u*, *v*, and *w*, respectively, into sixteen aliquot parts, which represent sixteen successive positions of the crank during one complete rotation thereof, and upon the vertical line R′ is a series of indicating-marks which coincide in number with the dots of the circle R, which marks are designated *h*′, *i*′, *j*′, *k*′, *l*′, *m*′, *n*′, *o*′, *p*′, *q*′, *r*′, *s*′, *t*′, *u*′, *v*′, and *w*′, respectively, and represent sixteen successive positions of the needle, corresponding to the aforesaid sixteen successive positions of the crank, and the large circle R^3, which represents the periphery of the shuttle, is divided by radial lines h^2, i^2, j^2, k^2, l^2, m^2, n^2, o^2, p^2, q^2, r^2, s^2, t^2, u^2, v^2, and w^2, and h^3, i^3, j^3, k^3, l^3, m^3, n^3, and o^3, respectively, into twenty-four aliquot parts, representing twenty-four successive positions of a loop-engaging hook of the shuttle during one and one-half reciprocations of the needle, the sum of the spaces between the lines designated by h^2 to w^2, alphabetically and inclusively, expressing the distance traversed by one of the loop-engaging hooks of the shuttle at each complete reciprocation of the needle, and the sum of the spaces between the lines designated by h^3 to o^3, alphabetically and inclusively, expressing the distance traversed by one of the hooks of said shuttle during one-half of a complete reciprocation of the needle, that is, during one complete upward or downward stroke thereof.

Referring to the graphical diagram, Fig. 39, the full horizontal line O and the full curvilinear line O′ represent, respectively, the ordinates or the respective paths of movement of the shuttle and needle-bar, said diagram representing the relative positions of the shuttle and needle-bar during one complete reciprocation of the latter. The vertical division-lines (designated by O^2 in said figure) represent sixteen successive positions of the shuttle and needle-bar, corresponding with the sixteen successive positions thereof represented in Fig. 38. The points of intersection of the vertical division-lines O^2 with the curvilinear line O′ are designated by *h*′, *i*′, *j*′, *k*′, *l*′, *m*′, *n*′, *o*′, *p*′, *q*′, *r*′, *s*′, *t*′, *u*′, *v*′, and *w*′, respectively, and the distances of these points of intersection above or below the horizontal dotted line O^3 represent the successive posi-

tions of the eye of the needle above and below the throat-plate of the machine, which throat-plate is represented by said dotted horizontal line O^3. By a comparison of these two diagrams, Figs. 38 and 39, the relative movements of the shuttle and needle during one complete reciprocation of the needle-bar can be readily understood. In Fig. 39 the difference in the velocity between the upward and the downward strokes of the needle is defined by the dotted curvilinear line O^4.

In Fig. 40, which is a graphical diagram upon a relatively reduced but somewhat extended scale as compared with Fig. 39, I have shown the successive relative positions of the shuttle and needle during a plurality of cycles of movements thereof, or a sufficient number to denote the entire series of movements necessary for inaugurating and completing one stitch. This figure is intended as a companion figure to and it is intended to be read in connection with Figs. 22 to 30, inclusively, which latter figures illustrate in a different manner from Fig. 40 a series of cycles of movements of said shuttle and needle and a portion of the actuating mechanism necessary in the operation of inaugurating and completing one stitch, each figure representing one step in the operation of forming the stitch. For convenience the successive positions of the stitch-forming mechanisms will be referred to in the chronological order shown in said Figs. 22 to 30, respectively and inclusively, and as also represented in Fig. 40 as first, second, third, fourth, fifth, sixth, seventh, eighth, and ninth positions, respectively.

In the series of cycles of movements in the operation of inaugurating and completing a stitch illustrated in Figs. 22 to 30, inclusively, the shuttle and needle are shown in several of the figures in coinciding positions, certain successive cycles of movements being practically repetitions of certain preceding cycles of movements, although each figure, *i. e.*, Figs. 22 to 30, inclusive, illustrates a separate and distinct step in the process of forming the stitch, and for the purpose of designating without confusion the relative positions assumed by the needle and shuttle at each step in the operation of forming a stitch I have shown in the graphical diagram Fig. 40 the successive positions of the needle and shuttle in their progressive order, said positions being represented by the vertical lines marked "1st," "2d," "3d," "4th," "5th," "6th," "7th," "8th," and "9th," respectively, which will be readily understood by a comparison of the graphical diagram Fig. 40 with Figs. 22 to 30, inclusive.

In the operation of forming a stitch, assuming the shuttle and needle to be in the first position, (illustrated in Figs. 22 and 40,) with the needle and needle-bar in their extreme retracted or upper "dead-center" positions (designated by p', Figs. 38, 39, and 40) and the hooks of the loop-receiving openings e, f, and g of the shuttle in the positions designated by h^2, p^2, and h^3, respectively, and the upper and lower thread in the positions they occupy preparatory to the formation of a loop, a movement imparted to the needle-bar-actuating crank in the direction of the arrow in Fig. 22 and a simultaneous rotative movement imparted to the shuttle in the direction of the arrow in said figure will carry the needle downward with a variable descending movement to the second or lower dead-center position (designated by h', Figs. 38 and 40) and the shuttle will be rotated one-third of a complete rotation, the needle during this operation forming the loop, and a hook, as 15, (see Fig. 23,) coming into position at this operation to engage the loop. During the lower stages of this downward movement of the needle, or in its travel from v' to w' and thence to h', (see Fig. 38) the velocity of said needle is, owing to the peculiar disposition of the crank-and-link connector, greatly decreased, as compared with the middle portion of the descending movement thereof. This results in the holding of the loop formed by the descent of the needle practically without movement for a considerable length of time in position to be engaged by the hook of the loop-taker, thus avoiding the accidental non-engagement of the hook with the loop, as might occur if the needle were not materially retarded throughout the lower stages of its downward movement. This practically constitutes the first effective step in the inauguration of the stitch. After the loop has been formed, as illustrated in Fig. 23, by the descent of the needle from the position shown in Fig. 22 to that shown in Fig. 23 the resistance device T^2 at the lower end of the needle-bar becomes effective for holding the looped end of the needle-thread against accidental drawing up, relatively to the needle, during the first stages of the ascending movement of the needle-bar. A continued movement of the shuttle and needle next brings said parts to the third position (shown in Figs. 24 and 40) with the eye of the needle slightly below the throat-plate and the hook 15 of the shuttle in its "loop-taking" position. After the loop L of the needle has been engaged by the hook of the shuttle, which occurs immediately after the needle-bar has reached its lower dead-center position and is on the ascendancy, the velocity of the needle, owing to the peculiar disposition of the crank-and-link connector (hereinbefore described) of the needle-bar, is greatly increased during the lower part of the ascending movement of the needle as compared with the decrease in the velocity of the needle during the corresponding lower part of the descending movement of said needle. This results in a comparatively sudden tightening of the loop on the hook of the shuttle, thereby holding the loop against accidental displacement relatively to, and after the same has been engaged by, the loop-taker, and also quickly carries the hook of the needle-bar

past its lower dead-center position. The needle and shuttle are next carried by the continued movement thereof to the fourth position, (shown in Figs. 25 and 40,) the first loop L of the needle-thread having at this time been carried approximately one-third way around the shuttle and the needle-bar at this point in the cycle of movement being again at its upper dead-center position. In the next or fifth position (illustrated in Figs. 26 and 40) the first loop L is shown in full lines carried by the hook of the shuttle approximately one-half way around said shuttle, at which point said loop has its greatest slack, and said loop being also shown in dotted lines in said figure in its "fully-drawn-out" position or midway between the positions thereof shown in Figs. 25 and 26.

In the sixth position of the parts (illustrated in Fig. 27) the first loop L is shown carried approximately two-thirds way around the shuttle, the slack of said loop having been taken up and the loop retightened by the downward stroke of the needle-point through and below the fabric in the formation of the second loop L', which second loop at this stage of operation in forming the stitch is in substantially the same position as that of the first loop, (shown in Fig. 23,) another hook, as 14, having arrived approximately at the loop-taking position.

In the seventh position of the parts (shown in Fig. 28) the first loop L is shown advanced but a short distance from the position shown in Fig. 27, and the second loop L' is shown engaged by the hook 14 of the shuttle. In this position the needle is on the ascendancy, and after the shuttle in its continued rotation carries the hook 14 past this loop-taking position the second loop L', as it is carried around by the shuttle, takes up the first loop L, the resistance device T^2 holding the needle side of the thread against slippage until the first loop L is fully drawn up, the resistance of this resistance device upon the needle side of the thread being, in practice, greater than the resistance of the fabric upon the drawing end of the first loop L. Thus it will be seen that before a succeeding loop in its course around the shuttle can exert sufficient strain upon the needle side of the thread to overcome the resistance of the resistance device T^2 the preceding loop must be nearly drawn fully up.

In the eighth position of the parts (shown in Fig. 29) the first loop L is shown drawn off from and out of the path of movement of the hook 15 and is shown in locked engagement with the lower or shuttle thread, and the second loop L' is shown advanced a distance equal to one-third of a rotation of the shuttle. During this eighth stage in the operation of forming the stitch the retractive device T' is effective, owing to the accelerated upward movement of the needle-bar, for drawing the second loop taut, and through it taking up the increment of the first loop to thereby draw said first loop off the hook carrying the same and out of the path of movement of the succeeding hooks of the shuttle, as will be understood by reference to Fig. 29 of the drawings. Owing to the relatively rapid velocity imparted to the needle during the earlier part of the ascending movement thereof, which effects a relatively rapid and proper drawing up of the first loop, the needle is brought to its upper dead-center position at a relatively early period in the operation of drawing out the second loop, and therefore the needle will begin its downward movement before the second loop is completely drawn out, which will materially prolong the latter portion of the stitch-forming operation and will draw up the preceding loop of the stitch with a reduced speed. This avoids a sudden tension on the thread while said loop is being entirely drawn out, and owing to this slower action subjects the thread to less strain than would otherwise accrue.

In the ninth and last stage in the operation of forming a stitch (illustrated in Fig. 30) the second loop L' is shown in dotted lines in said Fig. 30 fully drawn out and in the same position as the first-loop position, which is shown in dotted lines in Fig. 26, and is shown in full lines as carried one-half way around the shuttle. In this last operation of forming a stitch the second loop L', when it reaches the dotted-line position, as shown in Fig. 30, draws the first loop taut and in interlocked engagement with the lower thread and with the fabric, and thus completes the formation of the stitch.

From a comparison of the several operative views of the drawings, in connection with the foregoing description of the stitch-forming operation of the machine, it will be seen that the combined needle-bar and shuttle-actuating mechanism is so organized and timed as to impart such comparative and relatively-differential movements to the needle-bar and shuttle as will effect a retardation or decrease in the normal velocity of the needle-bar at the lower stages of its descending movement and just preceding the arrival of the hook of the loop-taker in position to take the loop, and will effect an augmented acceleration in the ascending movement of the needle-bar immediately succeeding the taking up of the loop by the hook of the loop-taker; or, in other words, the needle-bar and loop-taker will be so actuated that the hook of the loop-taker will be brought into position to take the loop simultaneously with a decrease in the descending velocity of the needle-bar, and said loop-taker will be advanced to take and draw out the loop simultaneously with an increase in the ascending velocity of the needle-bar.

From the foregoing it will be seen that the needle-bar has the normal velocity thereof retarded during the lower stages of the descending movement thereof and augmentatively accelerated during the corresponding stages of the ascending movement thereof, and that

the hook of the loop-taker arrives in position to and does take the loop, in point of time, practically between the retarded descending and accelerated ascending movements of the needle-bar.

In the organization of mechanism herein shown and described for carrying out the operation of forming a stitch after the manner described in the preceding paragraph the means for imparting the comparative and relatively-variable movements described to the needle-bar and shuttle, the retention device for preventing a retractive movement under limited stress of the needle-thread after the formation of the loop and preparatory to the engagement of said loop by the shuttle or loop-taker, and the retractive device carried by the needle-bar and adapted for retracting the needle-thread after release of the loop by the shuttle or loop-taker, so as to quickly draw the same out of the path of movement of the hooks of the shuttle or loop-taker, are important factors in the operation of the machine, and, in connection with the tension device T, constitute an operative combination of elements whose coaction materially contributes to the successful operation of said machine.

The particular organizations of the several elements comprising the sewing-machine and the successive positions of the stitch-forming devices being so fully illustrated in the several figures of the drawings, it is deemed unnecessary to a clear understanding of the operation of forming a stitch to enter into a detailed description of the operation of the minor parts of the machine, as this will be readily understood by those conversant with that branch of the sewing-machine art to which this invention appertains.

Certain of the elements herein shown and described, but not herein specifically claimed, constitute the subject-matter of separate applications for Letters Patents of the United States—to wit, the "loop-taker" or "shuttle," substantially in the form thereof herein shown and described, constitutes the subject-matter of my patent granted April 21, 1896, No. 558,662, and the "reversing driving mechanism" for the shuttle (shown in full and dotted lines in Fig. 4 of the drawings) constitutes the subject-matter of an application filed by me January 26, 1895, Serial No. 536,338, and the feed-lever, actuating mechanism therefor, the feed-dog, and means for maintaining said dog in parallelism with the line of its longitudinal movement are claimed in my application filed March 21, 1895, Serial No. 542,632.

Having thus described my invention, I claim—

1. In a sewing-machine, the combination with fabric holding and feeding devices, of stitch-forming mechanism comprising a vertically-reciprocating needle-bar; a revoluble three-hook loop-taker; a horizontally-disposed needle-bar-actuating shaft; a crank carried by said needle-bar-actuating shaft; a link pivotally connected at one end with said crank, and pivotally connected at its opposite end with the needle-bar, in the rear of the path of movement of said needle-bar; a horizontally-disposed loop-taker-actuating shaft; a driver carried by said loop-taker-actuating shaft and in operative connection with the loop-taker; a vertically-disposed feed-actuating shaft; a one-to-one train of gears operatively connecting the needle-bar-actuating shaft and feed-actuating shaft; a two-to-three train of gears operatively connecting the loop-taker-actuating shaft and feed-actuating shaft; a driver in connection with one of said shafts; and suitable tension devices for the thread, all constructed and organized, whereby the loop-taker and needle-bar will have a two-to-three ratio of movement, and whereby the needle will have a relatively slight retardation during the lower part of its downward stroke, and a relatively great acceleration during the corresponding lower part of its upward stroke.

2. In a sewing-machine, the combination of a reciprocatory needle-bar; a revoluble three-hook loop-taker; a feed-lever; a loop-taker-actuating shaft in operative connection with the loop-taker; a needle-bar-actuating shaft in operative connection with the needle-bar; a feed-lever-actuating shaft, having lever-actuating means thereon, located intermediate the loop-taker and needle-bar-actuating shafts; a two-to-three train of gears operatively connecting the loop-taker-actuating shaft and intermediate shaft; a one-to-one train of gears operatively connecting the intermediate shaft and needle-bar-actuating shaft; and means for actuating one of said shafts, whereby a two-to-three ratio of movement is effected between the loop-taker and needle-bar.

3. In a sewing-machine, the combination with fabric-holding and fabric-feeding devices; of stitch-forming mechanism comprising a revoluble loop-taker having three equidistantly-disposed peripheral loop-engaging hooks; a reciprocatory needle-bar carrying a needle; a loop-taker-actuating shaft; a needle-bar-actuating shaft; an actuating-connector between and connecting said loop-taker-actuating shaft and needle-bar-actuating shaft, and embodying a shaft and a one-to-one and a two-to-three train of gears for effecting a two-to-three ratio of movement between the loop-taker and needle-bar; and a connector between the needle-bar-actuating shaft and needle-bar, for effecting a retardation in the velocity of the needle-bar at that point in the descending movement thereof which corresponds with the loop-taking position of the loop-taker, and for effecting an acceleration in the velocity of the needle-bar at that point in the ascending movement which corresponds with the initial loop-drawing position of the loop-taker.

4. In a sewing-machine of the class speci-

fied, the combination with the frame of the machine and with the vertically-reciprocating needle-bar and its actuating-shaft; of a revoluble loop-taker peripherally supported at an inclination to the path of movement of and below the needle-bar, and having three relatively equidistant peripherally-disposed loop-engaging hooks, and having three pairs of relatively equidistantly-disposed driving-sockets in one side thereof, located, one pair between each two adjacent hooks; a loop-taker-actuating shaft; a driver carried by said shaft with its axis at an inclination to the axis of the loop-taker, and having equidistantly-disposed driving-pins in position and adapted for successively entering the successive pairs of driving-sockets in and for rotating the loop-taker, and also adapted for holding said loop-taker against movement relatively to said driving-pins; mechanism operatively connecting the needle-bar-actuating shaft and loop-taker-actuating shaft for reducing the speed of the latter; and means for actuating one of said shafts.

5. In a sewing-machine, the combination with the sewing-machine head and with suitable fabric-feeding devices, of a longitudinally-recessed presser-bar supported for vertical movement in, and locked as against rotary movement relatively to, said head; a presser-bar actuator in operative connection with said presser-bar; a needle-bar supported for reciprocatory movement in said presser-bar; a needle-bar-actuating shaft; an actuating-connector extending through the longitudinal recess in the presser-bar, and operatively connecting the needle-bar and needle-bar-actuating shaft, and providing means for holding the needle-bar against rotation relatively to the presser-bar; and complemental stitch-forming mechanism.

6. In a sewing-machine, the combination with a reciprocatory needle and a revoluble three-hook loop-taker; of needle-bar and shuttle actuating mechanism organized and timed to impart relatively slow and fast, downward and upward strokes, respectively, to the needle-bar, and retard the lower part of the slow, downward stroke, and accelerate the corresponding lower part of the fast, upward stroke of said needle-bar at predetermined points in the rotation of the shuttle, substantially as described, and comprising a needle-bar-actuating shaft having its axis in the plane of, and at right angles to, the axis of the needle-bar; a crank carried at the end of said shaft and having a link connection with the needle-bar; a loop-taker-actuating shaft located in the plane of, and parallel to, the needle-bar-actuating shaft; and an actuating-connector between and connecting the needle-bar and loop-taker actuating shafts, and embodying a one-to-one and a two-to-three train of gears, for effecting a two-to-three ratio of movement between the loop-taker and needle-bar actuating shafts.

7. In a sewing-machine, the combination with fabric holding and feeding devices, of stitch-forming mechanism comprising a reciprocating needle-bar; a revoluble three-hook loop-taker; a needle-bar-actuating shaft; a crank carried by said shaft; a link pivotally connected with said crank and needle-bar; a loop-taker-actuating shaft; a driver carried by said loop-taker-actuating shaft and in operative connection with the loop-taker; a feed-actuating shaft; a one-to-one train of gears connecting the needle-bar-actuating shaft and feed-actuating shaft; a two-to-three train of gears connecting the loop-taker-actuating shaft and feed-actuating shaft; and a driver in connection with one of said shafts; and the parts being so organized that the loop-taker and needle-bar will have a two-to-three ratio of movement, and the needle will have a relatively slight retardation during the lower part of its downward stroke and a relatively great acceleration during the corresponding lower part of its upward stroke.

8. The combination with a sewing-machine head, of combined presser-bar and needle-bar mechanism comprising a tubular, longitudinally-recessed presser-bar non-rotatively supported for vertical movement in said head; a needle-bar supported for reciprocatory movement within and concentric to the presser-bar; a needle-bar-actuating shaft carrying a crank adjacent to the needle-bar; a strap carried by the needle-bar and extending through the recess in the presser-bar, and holding the needle-bar against rotation relatively to the presser-bar; a link pivotally connected at one end to the strap and at the opposite end thereof to the crank on the needle-bar-actuating shaft; a presser-regulating device in adjustable connection with the presser-bar; means for actuating the presser-bar independently of the needle-bar; and complementary stitch-forming mechanism.

9. The combination with the sewing-machine head and with the tubular, longitudinally-recessed presser-bar non-rotatively supported for vertical movement in the said head; of a needle-bar supported for reciprocatory movement within and concentric to the presser-bar; a rotating needle-bar-actuating shaft carrying a crank adjacent to the needle-bar; a strap carried by the needle-bar and extending through the recess in the presser-bar and adapted for holding the needle-bar against rotation relatively to the presser-bar; and a link pivotally connected at one end to said strap and at the opposite end to the crank of the needle-bar-actuating shaft.

10. The combination with the sewing-machine head, of a presser-bar supported for vertical movement in said head; a laterally-projecting arm fixed to said presser-bar and having cam-faces on the outer end thereof; a rock-shaft supported for rocking movement in bearings in the sewing-machine head; and a crank carried at the outer end of said rock-shaft, and having a pin extended between the cam-faces of the laterally-projecting arm of

the presser-bar; and means for actuating the rock-shaft to raise and lower the presser-bar.

11. The combination with the sewing-machine head, of a presser-bar supported for vertical movement in bearings in said head; a pressure device in adjustable engagement with the upper end of said presser-bar; a laterally-projecting arm secured to said presser-bar and having oppositely-disposed cam-faces at the outer end thereof; a rock-shaft supported in bearings in said head; a crank carried at the outer end of said rock-shaft and having a crank-pin in movable engagement with and between the cam-faces of the laterally-projecting arm; and means for actuating the rock-shaft to raise and lower the presser-bar.

12. The combination with the sewing-machine head, of a presser-bar supported for vertical movement in said head, and having a laterally-projecting slotted arm; a crank engaging in the slot in said arm and having stop-faces in bearing engagement with the opposite sides of said arm, and holding the same against lateral movement; and a rock-shaft in connection with, and having means adapted for rocking, said crank to raise and lower the presser-bar.

13. In a sewing-machine, a vertically-reciprocating needle-bar; a revoluble three-hook shuttle peripherally supported below the needle-bar; a horizontally-disposed needle-bar-actuating shaft having means in connection with, and adapted for effecting a relatively slow downward movement and a relatively rapid upward movement of, the needle-bar at every two-thirds of a revolution of the shuttle; a shuttle-actuating shaft in vertical alinement and in horizontal parallelism with the needle-bar-actuating shaft; a vertical shaft intermediate to the two horizontal shafts; a one-to-one train of gears operatively connecting the needle-bar-actuating and vertical shafts; a two-to-three train of gears connecting the shuttle-actuating and vertical shafts, whereby a two-to-three ratio of movement is maintained between the shuttle-actuating shaft and needle-bar-actuating shaft; and feed mechanism in direct operative connection with, and actuated by, the vertical shaft.

14. In a sewing-machine, cöoperative stitch-forcing and fabric-feeding mechanism comprising a reciprocating needle-bar; a revoluble three-hook loop-taker; a universally oscillatory feed-lever carrying a feed-dog; and combined needle-bar, loop-taker, and feed-actuating mechanism constructed, organized, and timed to actuate the loop-taker and needle-bar with a two-to-three ratio of movement, and effect a slow downward and a relatively rapid upward movement of the needle-bar at every two-thirds of a rotation of the loop-taker, and also to impart a feed movement to the feed-lever subsequently to each downward stroke of the needle-bar, and comprising a loop-taker-actuating shaft and needle-bar-actuating shaft located in the plane of the axis of the needle-bar and at right angles thereto; a feed-lever-actuating shaft; a one-to-one and a two-to-three train of gears operatively connecting the feed-lever-actuating shaft with the needle-bar and loop-taker actuating shafts, respectively; and means for actuating one of said shafts.

15. In a sewing-machine of the class specified having a suitable frame, a vertically-reciprocatory needle-bar, a revoluble multihook shuttle, and a feed-dog supported for reciprocatory movement intermediate to the needle-bar and shuttle; in combination with a horizontally-disposed needle-bar-actuating shaft in operative connection with the needle-bar; a horizontally-disposed shuttle-actuating shaft operatively connected with the shuttle; a vertical shaft having means in operative connection with the feed-dog and adapted for directly controlling the movements of said feed-dog; a one-to-one train of gears directly connecting the needle-bar-actuating shaft and vertical shaft; and a two-to-three train of gears directly connecting the vertical shaft and the shuttle-actuating shaft.

16. In a sewing-machine, the combination with two horizontally-disposed shafts and a vertically-disposed shaft, of actuating mechanism for synchronously rotating the two horizontal shafts with a two-to-three ratio of movement; a reciprocatory needle-bar in operative connection with one of said horizontal shafts; a revoluble three-hook shuttle operated by the other horizontal shaft; a feed mechanism in operative connection with the vertical shaft between the two horizontal shafts, and actuated by said vertical shaft; means in direct connection with, and adapted for rotating, one of said shafts, to effect a simultaneous movement of all of said shafts; and means in position and adapted for effecting a relatively slow downward and a relatively rapid upward movement of the needle-bar at every two-thirds of a revolution of the shuttle.

17. In a sewing-machine, a reciprocatory needle-bar; a revoluble multihook shuttle; a feed-dog supported for reciprocatory movement intermediate to said needle-bar and shuttle; and a feed-lever supported for oscillatory movements and carrying said feed-dog; in combination with a horizontally-disposed needle-bar-actuating shaft in operative connection with the needle-bar; a horizontally-disposed shuttle-actuating shaft in operative connection with the shuttle; a vertically-disposed feed-lever-actuating shaft; a feed-lever-actuating cam adjustably carried by said shaft in operative connection with the feed-lever; a one-to-one train of gears directly connecting the feed-lever-actuating shaft and needle-bar-actuating shaft; a two-to-three train of gears directly connecting the feed-lever-actuating shaft and shuttle-actuating shaft; means for directly actuating one of said horizontally-disposed shafts to rotate

both of said shafts at comparative speeds of relatively-varying velocities; and means for maintaining the feed-dog in parallelism with the line of its longitudinal movement.

18. In a sewing-machine, the combination with a reciprocatory needle-bar and its horizontal actuating-shaft, and with the revoluble shuttle and its horizontal actuating-shaft; of a feed mechanism comprising a vertical shaft intermediate to, and in direct geared connection with, the two aforesaid horizontal shafts; a feed-cam shiftably carried by, and adapted for movement transversely of, the vertical shaft, and having means for imparting both vertical and horizontal oscillations to a feed-lever; a feed-lever supported midway of its length for vertical and horizontal oscillations, and having cam-engaging arms at one end thereof in engagement with opposite sides of the feed-cam; a regulating device in sliding connection with, and adapted for changing the transverse relations of, the feed-cam and vertical shaft; a feed-dog pivotally carried for longitudinal reciprocation by the feed-lever; and means for actuating the three shafts in synchronism.

19. In a sewing-machine having a suitable frame and a revoluble shuttle, the combination therewith of a combined cloth-clamp and needle-carrier comprising two axially-coincident members locked as against rotation and supported for longitudinal movement relatively to each other, and the outer member of which has an outwardly-extended cam-faced arm; and actuating mechanism for said members which consist of two horizontally-disposed shafts, one of which is supported for rotation and has a crank operatively connected by means of a link with the inner member at one side of and remote from the axis of said inner member, and is adapted for imparting a relatively slow advancing and a relatively rapid retracting movement to said inner member, and the other shaft of which carries a crank in operative connection with the cam-faced arm, and is adapted to be operated to lift the outer member independently, of the inner member; means for continuously rotating that shaft which is operatively connected with the inner member, to effect a continuous reciprocation of said inner member; and means for operating that shaft which is in operative connection with the outer member, to raise and lower said outer member relatively to the inner member.

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