

Sept. 12, 1961

G. S. BOTT ET AL

2,999,588

SIZE CLASSIFICATION OF SUTURES

Filed Aug. 29, 1960

4 Sheets-Sheet 1

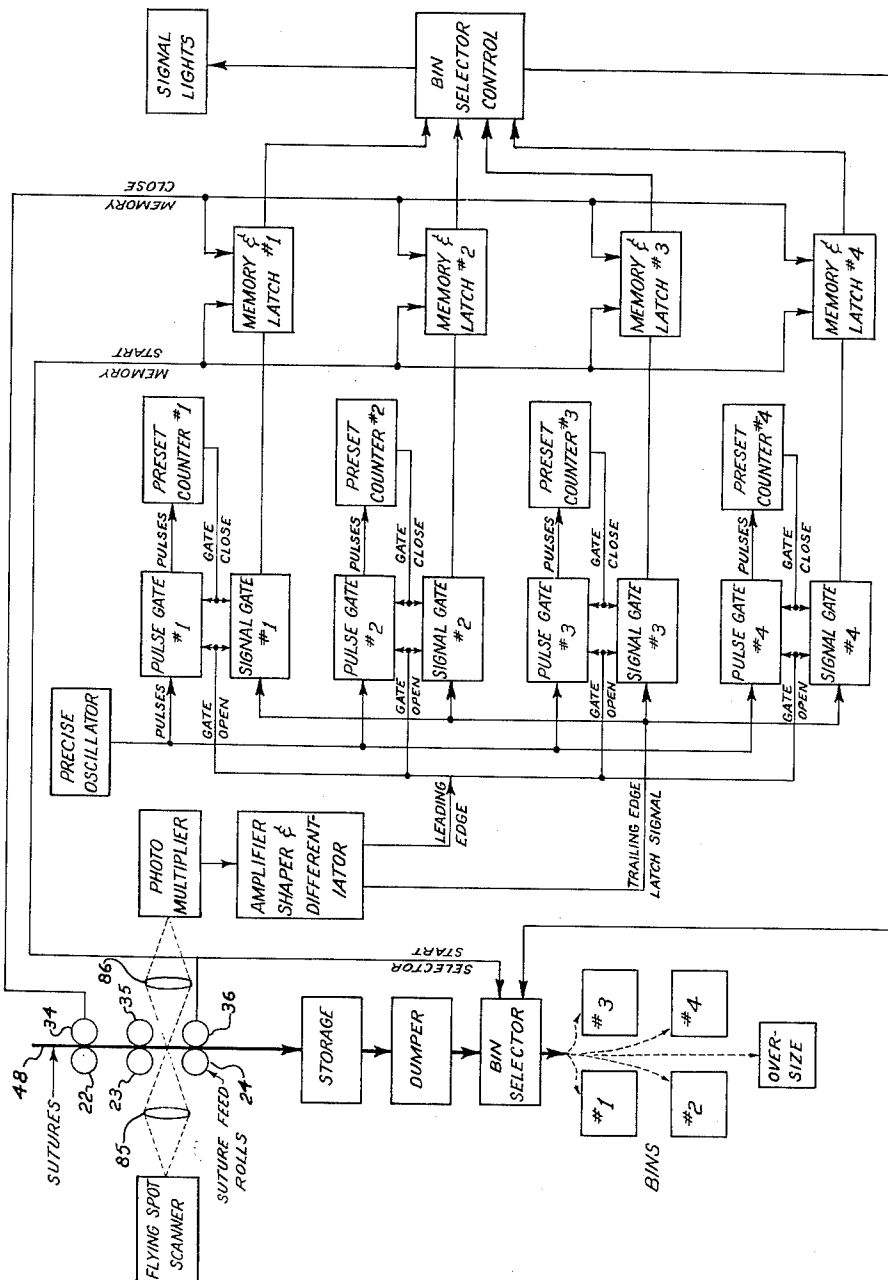


Fig. 1

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4 Sheets-Sheet 2

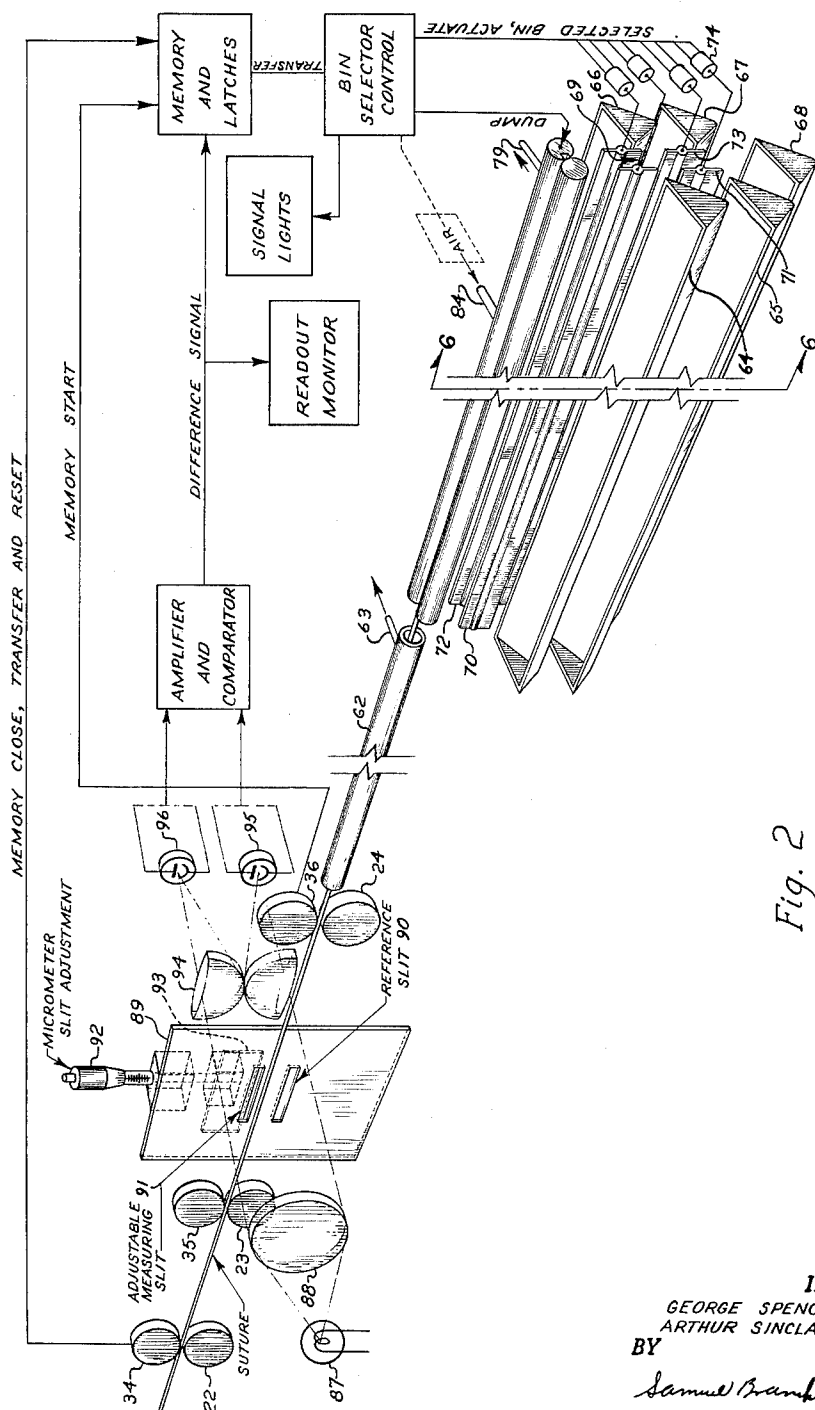


Fig. 2

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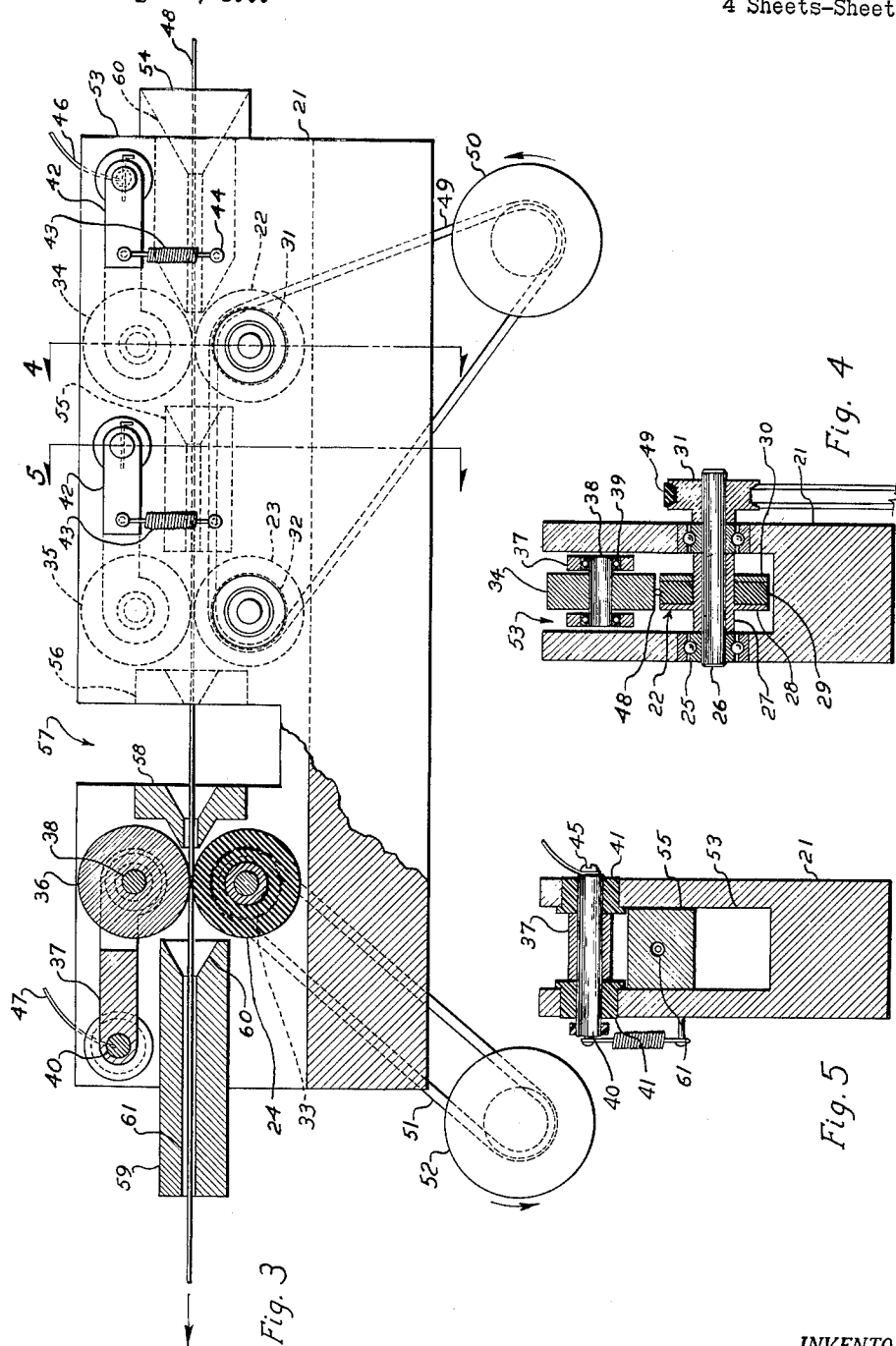
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4 Sheets-Sheet 4

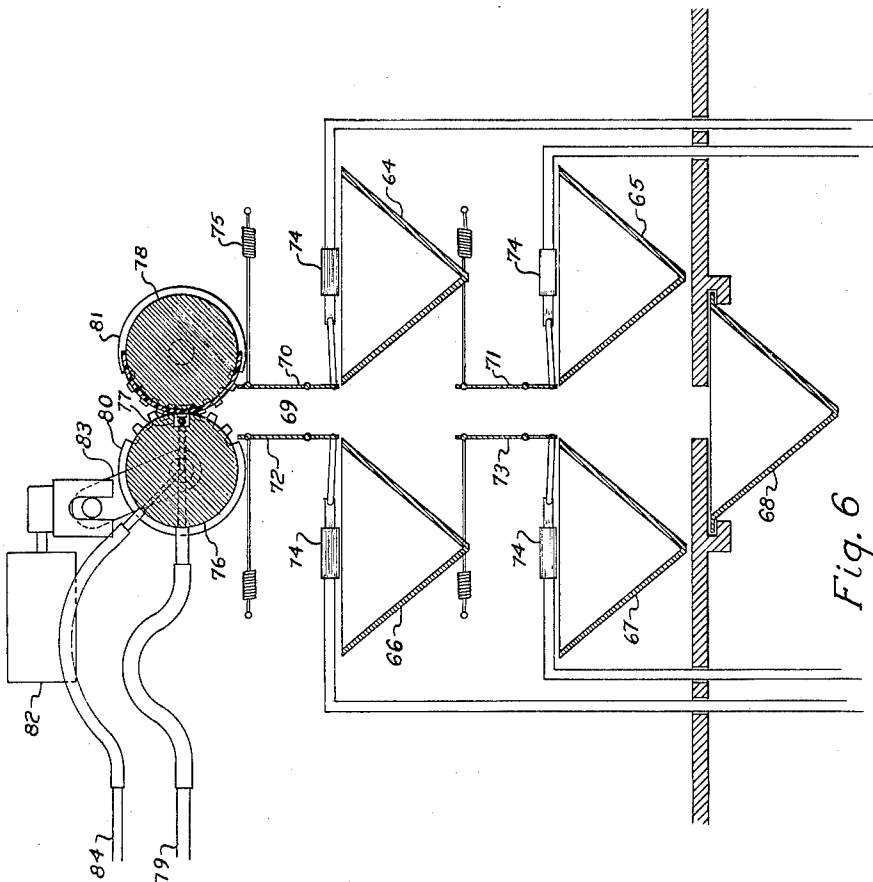


Fig. 6

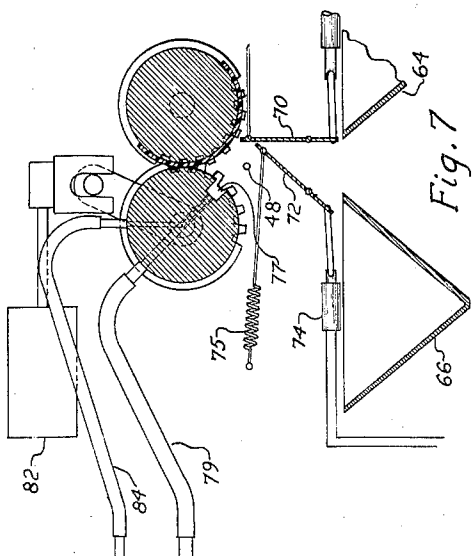


Fig. 7

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2,999,588

## SIZE CLASSIFICATION OF SUTURES

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Filed Aug. 29, 1960, Ser. No. 52,636

12 Claims. (Cl. 209-74)

This invention relates to an apparatus and method for the rapid, automatic sorting of surgical sutures, or other short lengths of strands or filaments, according to their diameter. The sutures, or filaments, are kept straight and free from whipping by measuring while stretched between two sets of feed rolls, one of which acts as a drag, and when measured are transferred to a long, thin groove by vacuum, which groove has a removable dumping seal.

In preparing surgical sutures, particularly from catgut, that is, treated split animal membranes, frequently called gut, the problem of size is important. The gut strands are formed by splitting various naturally occurring membranes into long, thin strings which are twisted together and dried. These strands, which will hereinafter be called sutures, whether finished or unfinished, are necessarily somewhat uneven in diameter because the membranes are natural products and are subject to biological uncertainties. In general, the twisting is sufficient to insure that the cross section at any position is approximately circular so that any diameter measurement is sufficient to establish the size of the suture at that position. In the surgical field, the sutures are classified into diameters according to various Governmental standards. In the United States, the standard is the United States Pharmacopoeia. The maximum diameter at any position along the suture determines the size classification. For a homogeneous material, the minimum diameter determines the strength. Inasmuch as it is desired to have each suture as strong as possible within the diameter limits, it is desirable to have a suture of uniform diameter so that the strength will be uniform, and of a diameter which is as large as possible to remain within the size classification.

In the past, it has been customary to gauge the sutures by hand, passing them over an anvil under the measuring block of an indicator dial. The sutures have been hand sorted as to size, and then ground so that the diameter is uniform. In each instance, the suture is placed in the group such that the larger diameter sutures are reduced to not more than the measured minimum, and usually the suture is sufficiently ground that it is just within a size classification. For instance, all sutures whose minimum diameter gauges between the maximum for a size No. 0 suture, 0.0195 inches, and 0.0230, the maximum for a size No. 1 suture, are ground to a uniform diameter just under 0.0195 inches. Those with a minimum diameter over 0.0230 inches, are used for a size No. 1 or larger suture. Those with a minimum diameter of less than 0.0195 inches are used for a size No. 00 or smaller suture.

The measuring of a diameter at various positions along the length of the suture by hand is a tedious and expensive operation.

We have now found it possible to mechanically, rapidly and accurately classify the sutures into groups based upon diameter measurements. It is obvious that the present apparatus could be adapted for classifying by average or maximum diameters, but the usual desire is to classify by the minimum diameter at any position along the length of the sutures and hence this preferred embodiment is described. In general, the classification is in two groups, such that the minimum measured diameter at

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any position along the length of the suture is not less than the desired diameter of the suture to be produced from the group, and the oversize is ground off in suture grinding machines. The grinding machines are not part of the present invention.

In the classification of sutures by diameter, the sutures in general are of the order of five feet long. It is necessary to gauge each individual suture separately for size classification. In the past, devices have been perfected for measuring continuous wires, for instance, a patent to G. E. Chilton et al., Continuous Reading Electronic Micrometer, 2,850,645, September 2, 1958, describes one method of measuring the running diameter of a wire. Some measuring devices incorporating choppers, which are suitable for measuring the diameters of continuous strands, are disclosed in such patents as C. A. Vossberg et al., 2,548,755, Optical Area Measuring System, April 10, 1951. The apparatus, in general useful for measuring a continuous wire, is not satisfactory for measuring the diameter of sutures because the feed mechanisms to pass the suture must be such that lengths of about five feet can be conveniently measured, and the diameter measuring system must distinguish between the diameter being measured and the zero diameter which would be recorded in the interval between sutures.

In feeding continuous wires, the problem of whipping is usually not particularly serious because the position of the wire stabilizes after a few feet are fed. In feeding the lengths of sutures, it is necessary that the position of the suture be stabilized to minimize whipping during the measuring operation, and the actual measuring operation is preferably such that a minor degree of whipping is not unduly deleterious, and does not give false measurements.

We have found that the sutures may be conveniently measured for size by passing the sutures separately and sequentially through a guide tube into the bite of an entrance feed roll, through this feed roll, past an optical measuring position to a faster feed roll; the drives being arranged such that as soon as the faster feed rolls pick up the sutures, the suture is stretched to avoid whipping; and mechanically or electrically the entrance feed roll is allowed to act as a drag on the suture to keep it straight, but without permanently stretching the suture; and the suture is propelled by the faster feed rolls to a sorting mechanism which conveniently is a groove sufficiently large to receive the maximum size suture, in which vacuum applied to the groove draws the suture into the groove. After the suture is completely gauged, and the entire length of the suture lies within the groove, one side of the groove opens and dumps the sutures. Meanwhile, the diameter of the suture at a plurality of positions is measured optically between the two sets of rolls, and the appropriate classification information is used to actuate bins or deflectors such that the suture, when dumped, falls into a bin for sutures of that size. The size classification may be accomplished by either an analog measurement in which the suture interrupts part of the light passing to a photodetector, and the reduction in incident light controls the size classification, or a flying spot scanner may be used in which the spot is interrupted by the suture, the period of interruption is ascertained by a photodetector which converts the interruption to an electric signal, which signal is converted to diameter information used to control the classifying circuit. Conveniently, the period of spot interception can be used to control gating circuits which pass a high frequency signal and, by counting the number of cycles or pulses passed, a digital measurement of diameter may be made. Such a digital measurement is frequently particularly convenient because the stability of electric cir-

cuits in a digital system is less critical than in analog systems.

The above, and other objects, advantages and novel features of the present invention, which is defined in the appended claims, are better understood in conjunction with the detailed description of certain embodiments of our invention which are set forth in greater detail in conjunction with the accompanying drawings in which:

FIGURE 1 is a diagrammatic view of a flying spot scanner, in conjunction with the suture feeding and sorting apparatus.

FIGURE 2 is a view of an analog gauging system in conjunction with the feeding and sorting apparatus.

FIGURE 3 is a front view, in partial section, of the suture feed frame and gauging block assembly.

FIGURE 4 is a section along line 4—4 of FIGURE 3 showing the entrance feed rolls.

FIGURE 5 is a section along line 5—5 of FIGURE 3 showing the insulated, mounted system for the guide idler roll.

FIGURE 6 is a view along line 6—6 of FIGURE 2 showing a deflection vane sorting system.

FIGURE 7 is a partial view in the same position as FIGURE 6 showing the deflection vane sorting system in operation.

The apparatus has several sections that operate concurrently. For convenience in description, the feed section is described first, followed by the mechanical phase of the storage and dump sections, and the bin selector, and then the descriptions of the optical systems and electrical circuits in two alternate embodiments, a digital system and an analog gauging system.

The feed system is symbolically shown in FIGURES 1 and 2. The details of the suture feed subassembly are shown in FIGURES 3, 4 and 5.

#### *Suture feed*

The suture feed system consists of a suture feed frame and gauge block 21 which acts as an electrical conductor for the ground side of the circuits and supports the rolls. Mounted in the suture feed frame and gauge block is a fixed entrance feed roll 22, and along the path of suture travel a fixed guide roll 23, and a fixed faster feed roll 24. Each of these rolls is supported on fixed roll bearings 25. The mounting system for each of these three fixed rolls is the same. As shown in FIGURE 4 and as typical, the fixed entrance feed roll is mounted on the fixed entrance feed roll shaft 26, and consists of a conductive hub 27 having an integral flange 28, on which is mounted a resilient annular center 29, which in turn is held in position by a retaining flange 30. Each of the fixed rolls is ground to size so that the surfaces of the resilient annular center and the flanges are concentric and of the same diameter. The resilient annular center is preferably of a material such as rubber or a plastic which has a high coefficient of friction and thus prevents the suture from sliding. A polyurethane rubber is particularly satisfactory as it has both a high coefficient of friction and an extremely tough surface which gives long wearing life. On one end of the fixed entrance feed roll shaft 26 is a fixed entrance feed roll drive pulley 31. Similarly positioned is a fixed guide roll drive pulley 32 and a fixed faster feed roll drive pulley 33.

Above the respective fixed rolls is an entrance feed idler roll 34, a guide idler roll 35, and a faster feed idler roll 36. These rolls are substantially the same, and are each mounted in an idler roll fork 37 on an idler roll shaft 38 which is supported in idler roll bearings 39. Each fork is mounted on a fork shaft 40 which is mounted in insulating bushings 41, which bushings have shoulders to keep the fork centered and to keep the fork insulated from the suture feed frame and gauge block 21. Each fork is mounted so that it turns with the fork shaft. At one end of the fork shaft is mounted the idler fork shaft tension arm 42, which is of an insulating ma-

terial such as a fabric-reinforced plastic, which arm is approximately parallel to the idler roll fork 37. A tension arm spring 43, in cooperation with a tension arm spring pin 44, spring loads the idler roll fork so that each idler roll is pressed against its cooperating fixed roll. The fork shafts have at their end an idler roll connector 45 to give an electrical contact through the fork to the respective idler rolls. The entrance feed roll lead 46 and the faster feed roll lead 47 extend to the electrical circuits which actuate the start and finish of gauging operations and start the dumping operations, as later described. The surface of the respective idler rolls is in contact with the metal flanges of the respective fixed rolls when there is no suture 48 therebetween. As shown in FIGURE 4, the suture 48 separates the respective pair of rolls as the suture is fed therebetween breaking contact and giving electrical notice of the presence of the suture.

The fixed entrance feed roll drive pulley 31 and fixed guide roll drive pulley 32 are driven by a first belt 49 which in turn is driven by a drag electric motor 50. A second belt 51, in turn driven by a principal electric motor 52, drives the faster feed roll. Located in the same longitudinal slot 53 in the suture feed frame and gauge block 21, as are the respective roll pairs, are a group of suture guides. The suture 48 is fed into a first suture guide 54 from which it is fed to the bite of the entrance feed rolls. As the suture emerges from the entrance feed rolls, the suture is picked up and directed by a second suture guide 55, which directs the suture to the guide roll pair. As the suture emerges from the guide roll pair, it is picked up by a third suture guide 56 which controls its path as it enters the gauging zone 57. The gauging zone 57 is a cross slot in the suture feed frame and gauge block through which the light beams of the gauging system operate, as described below. As the suture emerges from the gauging zone, it is picked up by a fourth suture guide 58 which directs it to the bite of the faster feed roll pair from which it is picked up by the fifth suture guide 59, from which it is directed towards a transfer and/or sorting system, described below. Each of the suture guides has a conical entrance 60 and a directing bore 61. The conical entrance is big enough that the suture is easily directed into the conical entrance, and the conical entrance guides its path to the directing bore. The directing bore is preferably just larger than the largest diameter of the largest suture, which may be fed into the system, so that the suture is directed with a minimum of whipping or lost motion along its path to the next working position.

#### *Operation of suture feed*

A suture is fed into the conical entrance of the first suture guide which directs it towards the entrance feed rolls. Once the end of the suture is fed into the bite or nip of these entrance feed rolls, the suture is mechanically propelled and may be released by the operator who is then free to select the next suture to be engaged. As the suture emerges from the entrance feed rolls, it is directed through the second suture guide to the guide rolls, and by them through the third suture gauge to the gauging zone, in which the optical gauging occurs. From this gauging zone, the suture is directed through the fourth suture guide and into the bite of the faster feed rolls.

The faster feed rolls are driven at a surface speed preferably of about 5% to 10% greater than the surface speed of the entrance feed rolls and the guide rolls. The suture is thus picked up and accelerated by the faster feed rolls, which immediately removes any slack in the suture between the faster feed rolls and the guide rolls and entrance feed rolls. The guide feed rolls and entrance feed rolls are driven by a common drag electric motor 50 and have the same surface speed. Whereas, it would be possible to adjust the spring loading so as to permit the rolls to slide on the suture when the speeds are not identical, such sliding would cause rapid wear

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of the resilient annular centers and would tend to contribute to a lateral whipping action of the suture. It is therefore preferred that the drag electric motor be an induction-type motor which can be accelerated by the tension on the suture so that as soon as the principal electric motor 52 takes over control of the feed motion of the suture, the drag electric motor no longer acts to propel, but thus acts to drag on the suture, thus keeping the suture straight and reducing whipping. It is a characteristic of an induction motor that the rotor lags behind its inductive field when operating as a motor. As the rotor of the drag electric motor is speeded up, the current consumption drops and the rotor begins to gain on its magnetic field. Actually, the rotor can be overspeeded so that it is driven faster than its magnetic field, in which case the motor functions as a generator. If both the principal electric motor and the drag electric motor are small induction motors with a comparatively high slippage, as is usually common in small induction motors, the drag on the drag motor straightens out the suture while the inertia of the system is small enough not to unduly jar smooth conveyance. The principal electric motor has an increased slippage, and the drag motor a reduced slippage.

The breaking of contact between the faster feed rolls acts to start a gauging operation, which operation is electrically delayed enough that the suture is drawn tight before the first effective diameter measurements are made. The contacting of the faster feed rolls and closing of the circuit between them also actuates the bin selector system. The initial breaking of contact as the suture is feed into the entrance feed rolls is normally not used as a signal, but the closing of the entrance feed rolls and the establishing of contact is used to close the diameter memory latches, transfer the stored information as to diameter size to a bin selector control, and then reset the memory latch system. Inasmuch as the end of the suture starts to whip as soon as it passes the entrance feed rolls, the guide feed rolls are interposed to control the path of the suture and prevent any whipping from occurring until after the memory system is closed, so that erroneous diameter measurements, which might be induced by the free end of the suture whipping as it passes through the gauging zone, have no effect on the classification.

#### *Storage, bin selection and dump*

As seen in FIGURE 2, the suture passes from the fifth suture guide 59, above described, to a holding chamber 62 which acts as a storage for the suture. The holding chamber 62 has a vacuum bleed 63 which reduces the pressure at the discharge end of the holding chamber. The air flowing through the holding chamber picks up the suture as it emerges from the fifth suture guide and draws it into the storage chamber.

The function of the storage chamber is to permit accelerated operation. The gauging operation itself is comparatively slow and may require from about one to four seconds for a five-foot length of suture. The dumping operation, later described, is also comparatively slow. It may require a second or two for dumping to occur, and the dumper to be reset to receive the next suture. If the dumping system is placed right next to the fifth suture guide, it is necessary to wait until one suture has cleared the dumping operation and the receiving groove is reset before the next suture may be fed. To expedite operations, the holding chamber is interposed. The holding chamber is long enough to hold a suture and the suture is fed into the holding chamber and is stored there until gauging is completed. At this time, the suture is ready for immediate transfer to the groove in the dumping mechanism and is rapidly drawn, in a fraction of a second, into the groove which frees the holding chamber for a following suture and the dumping mechanism dumps one suture concurrently with the gauging of the

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following suture. By thus having a holding chamber which permits a fast transfer, the two comparatively slow operations of gauging and dumping do not delay one another.

The comparative length of the holding chamber and the dumping mechanism in FIGURE 2 is markedly reduced as is illustrated by the broken lines, inasmuch as the holding chamber must be long enough to receive the longest suture to be gauged, normally about six feet, and preferably has a diameter not greatly in excess of the largest diameter of the largest suture to be gauged, which may be as much as about  $\frac{1}{16}$  of an inch. If in correct proportion without a break, the diameter would be so slight as to obscure detail.

As shown in FIGURES 2, 6, and 7, the sutures are sorted into a group of bins. Although the number of bins which are selected varies with the size variation in the fed stock, for purposes of convenience the present invention is illustrated as classifying the sutures into five groups. These are designated as a bin for size #1, 64, a bin for size #2, 65, a bin for size #3, 66, a bin for size #4, 67, and a bin for oversize, 68. The bins are arranged with sizes #1 and #2 on one side, sizes #3 and #4 on the other side, and the oversize bin at the bottom of a suture drop pathway 69. Adjacent to the suture drop pathway are a plurality of deflection vanes, one for each of the four suture sizes, a size #1 deflection vane, 70, a size #2 deflection vane, 71, a size #3 deflection vane, 72, and a size #4, deflection vane, 73. The deflection vanes are rotatably pivoted and swing from a vertical inactive position to a sloped active position. The pivoting of the vanes is controlled by vane solenoids 74, one for each deflection vane. The vanes are biased back to a vertical position by vane springs 75. The proper solenoid is selected by the bin selector control described further in connection with the electrical circuits according to size data from the gauge system. As shown in FIGURE 7, in the dumping operation the suture is deflected by one of the deflection vanes to the proper one of the bins for sizes #1, #2, #3 or #4. If the suture is not of such size that the suture belongs in one of these four classes, but instead is oversized, none of the vanes are actuated, and the suture falls through the suture drop pathway 69 between the vanes and into the bin for oversized sutures 68.

Above the suture drop pathway is the dumper. The dumper consists of a grooved rotatable bar 76 having a rectangular groove 77 therein. In the suture loading position, the rectangular groove faces and is closed by a rubber-faced rotatable bar 78. These two bars are stiff enough to avoid undue flexure or are positioned by suitable clamp rolls so that in the suture loading position, shown in FIGURE 6, the rectangular groove 77 is sealed by the rubber-faced rotatable bar, with the groove end open towards the holding chamber 62 and is in alignment therewith. A groove vacuum line 79 adjacent the second and closed end of the groove acts through an air exhaust port and reduces the pressure in the groove near the end opposed to the holding chamber. Thus, a suture in the holding chamber is drawn by the groove vacuum into the groove. The groove vacuum line should have a higher vacuum than the vacuum bleed 63 so that a suture is drawn from the holding chamber 62 into the groove by the vacuum acting through the groove vacuum line 79, which effectively overpowers the effect of the vacuum bleed to the holding chamber. A screen or foraminous area may be used to prevent the end of the suture being drawn into the vacuum line. The grooved rotatable bar and the rubber-faced rotatable bar are connected together by a drive gear 80 and a driven gear 81. An air cylinder 82 is mounted to rotate the grooved rotatable bar 76 through a rotating linkage 83. The air cylinder is controlled by the bin selector control and at the appropriate time air is admitted to the air cylinder which rotates the grooved rotatable bar, and through the drive gear and the driven gear also rotates the rubber-faced

rotatable bar. As the two bars rotate, the vacuum is broken, and the rectangular groove 77 is rotated downward so that a suture 48, therein, is dumped out of the groove and down towards the suture drop pathway. The suture falls into the oversize bin unless one of the deflection vanes deflects the suture into a bin for sutures of an appropriate size.

The bin selector control system is described below.

The suture is automatically drawn from the holding chamber 62 as the rotatable grooved bar realigns the groove 77 with the end of the holding chamber 62, hence, no special operation is required. If the gauging operation is not complete, the suture is not released from the faster feed rolls and, accordingly, the bin selector control is not actuated and the dumping system remains inactive until gauging is completed.

For small sized sutures, which may not fall out of the groove sufficiently rapidly, an air line 84 is provided with an opening into the groove, and mechanically or electrically after the grooved rotatable bar has rotated to dumping position, a short air blast is fed through the air line to assist in disengaging the suture. Usually, such auxiliary dumping air is not required.

#### Digital classification

A block digital classification electrical circuit is shown in FIGURE 1. The flying spot scanner may use a flying spot electrically scanned on the face of a cathode ray tube, or a flying spot produced by a multiple-sided rotating mirror. Conveniently, the suture is gauged in a horizontal position so that the scanning spot moves vertically. An image of the flying spot is formed by a focusing lens 85 on the suture 48 in the gauging zone 57. Preferably, the light from the spot has substantially parallel rays and is in sharp focus as it passes the suture. The light which passes the suture is picked up by a collector lens 86 and forms an image on a photoelectric device, preferably a photomultiplier tube. The output of this photomultiplier thus shows as an electrical signal whether the spot is passing or is intercepted by the suture. The size of the spot in the gauging zone should be small as compared with the size of the suture so that the electrical output from the photomultiplier will be a comparatively sharp-edged signal. The number of scans per second is such that the suture is gauged by a scan at appropriate longitudinal positions. If the spot moves at a frequency of 500 scans per second, the suture can move at a speed of 50 inches per second and still give a scan signal every tenth of an inch of length.

The scan signal passes to an amplifier, shaper and differentiator where the scan signal is amplified, extraneous noise and false signals due to the spot passing the edge of the gauging zone removed, and the signal split into a leading edge signal corresponding to the spot first contacting the suture, and a trailing edge latch signal, corresponding to the suture just clearing the edge of the spot. These two signals are spaced apart in time proportional to the width of the suture, with due reference to the rate of scan.

As shown in FIGURE 1, there are four different size control systems for the four different sizes of bins. For purposes of convenience, only one will be described, the others operating identically. A precise oscillator generates an electrical signal consisting of a number of electrical signals or pulses. A 1,000 kilocycle, crystal-controlled oscillator gives good results. The pulses are passed to pulse gate #1 which may be a conventional pentode in which the pulses are passed to the signal grid. The leading edge signal, conveniently through a multi-vibrator, is connected to the control grid, usually the third grid of the pentode. Thus, the leading edge signal opens the gate. The pulses pass through the pulse gate to a preset counter which is set to be actuated at the end of a certain number of pulses, which number is adjusted to correspond to the size information desired. Thus,

if the flying spot moves across the suture at a speed of 100 inches per second, each pulse from a 1 megacycle oscillator would correspond to a dimension of one 10,000th of an inch and a count of 195 would be set to distinguish sutures which had a minimum diameter of 0.0195 inch, which corresponds to a size No. 0 suture. At the end of the count, the counter gives a count completed signal which is used to close the pulse gate and reset the counter. A set of three 6,700 magnetic beam switching tubes may be used as the counters, or any conventional electronic counter system may be used. The leading edge signal and the output signal from the counter are also used to open and close the signal gate which electrically is parallel with the pulse gate, and is open for the same length of time.

The trailing edge latch signal from the amplifier, shaper and differentiator is directed to the signal gate. If the suture is smaller than the preset size, the trailing edge signal hits the signal gate before the gate is closed. If the diameter of the suture is larger than the preset size, the signal gate is closed before the trailing edge latch signal arrives and hence the signal does not pass the gate. Thus, the output from the signal gate indicates that a particular diameter is smaller than a preset size.

This information is fed to the memory and latch #1. This conveniently is a thyatron tube. The thyatron may be controlled by a relay opening its cathode return. The cathode return is open until the suture opens the faster feed roll pair 24 and 36 as previously mentioned. The relay conveniently uses an electronic circuit so a very small current through the rolls can be used. The relay should be slow enough in operation to permit the suture to be stretched before the cathode return is closed. An ordinary magnetic relay is satisfactory. When the suture breaks the connection between these rolls, the memory start signal operates the relay to close the cathode return and any signal which passes the signal gate to the memory latch fires the thyatron. Once the thyatron is fired, it remains conductive until the cathode circuit is opened and thus the thyatron memory retains or remembers that the suture in one position has a diameter of less than the set size.

Each memory and latch #1, #2, #3 and #4, stores the data for a different suture size.

When the end of the suture passes the entrance feed rolls 22 and 34, a signal is given which closes the memory circuit, and first transfers information as to which thyatrons have been fired to the bin selector control, and then opens the cathode return to reset the thyatrons. The bin selector control is conveniently a group of relays which are arranged to each inactivate the relays for any larger size classification, and the smallest size classification relay also operates the bin selector which starts to operate as soon as the end of the suture passes the faster feed rolls 24 and 36, and which bin selector activates the appropriate deflector vane for the size as measured and simultaneously activates the air cylinder 82 which starts the rotation of the grooved rotatable bar and the dumping of the suture. The appropriate vane thus deflects the suture into bins #1, #2, #3 or #4, or if none of the memory and latches have been activated all vanes remain stationary and the suture falls into the oversize bin. The mechanical delay inherent in the relays and air cylinder 82 is sufficient for the suture to be transferred to the groove 77 before the bars start to rotate.

Although the particular description is in connection with certain types of pulse gates, signal gates and preset counters, it is to be understood that appropriate transistor circuits or other types of counters and circuits may be used to correlate the information from the flying spot to actuate the bin selector to cause the dumping of the suture into an appropriate bin. Signal lights are also connected to the bin selector control to indicate visually the size of each suture.

*Analog classification*

An analog classifier is shown in FIGURE 2.

The digital classifier has the advantage of using a precise oscillator as the circuit control, and the flying spot, through the photomultiplier, gives only an off-and-on signal corresponding to the interception of the flying spot by the suture. The size is indicated as a function of the number of pulses. Such a system is largely independent of circuit variations and, accordingly, a considerable variation in any of the circuit values with time, temperature or supply voltage, such as in a resistor or a condenser or the amplification of a tube does not have an adverse effect on the size classification. By the same token, the circuits are comparatively complex.

An analog system has the advantage of greater simplicity, but with the disadvantages that the system is more subject to drift from aging, voltage variations and temperature variations as the size of a signal is the controlling factor. With voltage control on the electric circuits and a temperature-controlled room, and using high-grade components which are comparatively free from drift, an analog classifier has the advantages of simplicity and ease of checking. The feeding and dumping may be the same as with the digital device previously described.

On one side of the gauging zone 57 is mounted a lamp 87, as a light source, the light from which passes through a collimator lens 88 which focuses the light passing to give parallel light rays and uniform illumination on two slits.

The slits are mounted on the other side of the suture path. In the optical gauge plate 89 is a reference slit 90. This reference slit is of standard size and is used as a basis for comparison. Behind the suture is an adjustable measuring slit 91. The width of the adjustable measuring slit is controlled by a micrometer spindle 92 which moves a blade 93 which opens and closes the adjustable measuring slit. A double lens 94 focuses the light passing each slit on its own photocell. The reference photocell 95 receives the beam through the reference slit and the measuring photocell 96 receives the beam through the adjustable measuring slit. The relative intensity of the light on the reference photocell and the measuring photocell controls the gauging. The reference photocell serves as a null value giving compensation for variation in lamp characteristics, voltage supply and/or other variables. The difference signal amplitude is a function of suture size, and controls the sorting systems.

One convenient system of utilizing the signals from the photocells includes feeding the signals from each to the respective grids of an amplifier, conveniently a twin triode such as a 6SN7, which can be wired with a common plate potential and duplicate grid resistors of about 5.6 megohms and with condensers to the cathodes to blank out high frequency variations. The cathodes can be connected through cathode return resistors to ground of about 560 kilohms, and the cathodes wired to the grids of a second stage, conveniently also a 6SN7, with separate cathode resistors of about 1,500 ohms. As so wired, by using matched components the photocell output from cells such as a CE34Q, or other photocells, are sufficiently amplified to be easily measured. Conveniently, a meter may be wired across the two cathodes and calibrated to give an absolute size measurement as a read-out monitor. For automatic sorting, the cathodes are connected together through a resistor and twin diodes, and a multi-vibrator signal fed to the conjunction of the diodes and to one side of the resistor. A multi-vibrator signal is fed to the diode junction point, and the cathode side of the resistor, through suitable isolating resistors of about 330,000 ohms. Such a circuit causes the difference in the photocell outputs, now acting as an amplified signal at the cathodes of the second amplified stage, to act as a clamp across the multi-vibrator output and give a square wave signal which is proportional to the

difference in the cathode potentials and in one direction only. Such a parametric amplifier is a particularly convenient method of converting a D.C. signal to an A.C. signal. As is well known, amplification is easier with A.C. signals and drift problems are reduced. The parametrically clamped square wave signal can be used to feed a group of variable amplification stages which each control a thyratron. The amplifier for each thyratron is set by controlling its amplification so that the thyratron fires at a signal corresponding to a desired size. Thus, the signal system is individually calibrated. The meter across the cathodes of the second amplifier serves as a readout monitor to inform the operator of the size of the suture at each and every position along its length. An ordinary D'Arsonval meter responds sufficiently rapidly for most purposes. A cathode ray oscilloscope can be used for faster response. The memory and latches and bin selector systems are conveniently essentially the same as described in connection with the digital classifier, although as shown in FIGURE 2 the memory close, transfer and reset are actuated by the entrance feed roll, with the electric circuits providing for sufficient delay that the transfer, dumping, and vane actuation, occur in proper sequence.

In operation, after the analog system has had an opportunity to warm up and stabilize, the micrometer slit adjustment is closed until the reference photocell and measuring photocell balance. This is taken as a zero point. The slit is then opened a distance corresponding to the first minimum diameter measurement, and the amplifier to the first memory thyratron is set to fire the thyratron at this value. The slit is then opened to the second minimum size value, and the second thyratron set to fire. This sequence is followed for each thyratron. Wires of known size can be placed by hand in the feed system to check the uniformity of response. The monitor meter may have a shunt or series resistor to control its sensitivity or provide calibration. In use from time to time, the drift of the circuits can be checked by resetting the micrometer slit adjustment to appropriate values to see if the thyratrons still fire at the desired values.

It is frequently convenient to include signal lights in parallel with the bin selector controls so that the operator can see the size indicated for each suture. If desired, counters can be installed with the signal lights to count the number of sutures which are sorted into each bin.

As is obvious to those skilled in the art, the exact construction shown is exemplary rather than definitive. For example, the bins themselves may be moved instead of the vanes. The number of classified sizes may be chosen for particular operations. Should it be desirable, the sutures or other strands could be classified by maximum rather than minimum sizes. Additionally, transistor or other circuits may be used. If sufficiently stable circuits are chosen, but a single light beam may be used in an analog system. Two pair of rolls can be used if the memory circuits are very rapidly closed after the end of the suture passes the entrance feed rolls, and before the suture has time to whip. Other modifications and variations within the scope of the appended claims are part of the present invention.

We claim:

1. Apparatus for classifying sutures according to predetermined diameter classification limits which comprises, in combination: guide means to control the path of a suture, at least a pair of entrance feed rolls and a pair of faster feed rolls, the rolls of each pair having parallel axes, and having at least a circular part of each of the four rolls of an electrically conductive material, means to hold each pair of rolls in juxtaposition under sufficient loading to be in electrical contact when the rolls of the pair are not separated by a suture between them, the said pairs of rolls being mounted with all rolls tangent to the

path of the suture, means to determine when each pair of rolls is in electrical contact and when each pair of rolls is separated by a suture, means to drive the entrance feed rolls, means to drive the faster feed rolls at a faster surface speed than the driven speed of the entrance feed rolls and to thereby keep the suture stretched while between the two pair of rolls, at least one of said drive means permitting slippage with respect to the suture; a gauging zone between the entrance feed rolls and the faster feed rolls, gauging means functioning through said gauging zone; a holding chamber, said guide means being coaxial with and serving to direct the suture into the holding chamber after the suture has passed the said rolls and gauging zone; a rotatable bar having a groove therein parallel to the axis of the bar, a resilient faced rotatable bar parallel and adjacent to and in sealing engagement with said grooved bar and sealing the groove when said groove is in a suture-receiving position, when in said suture-receiving position said groove being coaxial with said holding chamber and in position to receive a suture therefrom, a plurality of suture bins, and means controlled by the gauging means and the electric contact between the rolls of each pair of rolls to disengage the groove from engagement with the resilient faced bar, and to dump the suture from the groove, and means controlled by the gauging means to direct the suture into a suture bin selected on the basis of the gauged size characteristics of the suture.

2. In an apparatus for classifying sutures according to predetermined diameter classification limits which comprises, in combination: guide means to control the path of a suture, and direct it to at least a pair of entrance feed rolls and a pair of faster feed rolls, the rolls of each pair having parallel axes, means to sense when a suture is between the rolls, means to drive the entrance feed rolls, means to drive the faster feed rolls at a faster surface speed, to thereby keep the suture stretched while between the two pair of rolls; a gauging zone between the entrance feed rolls and the faster feed rolls, gauging means functioning through said gauging zone to determine size characteristics of a suture; a dumping means having a groove parallel to the axis of the suture travel, and coaxial therewith, to receive a suture; suture bins; means controlled by the gauging means and electric contact between the rolls of each pair to actuate the dumping of a suture from the groove, and means controlled by the gauging means to direct the suture into a suture bin selected on the basis of the gauged size characteristics of the suture.

3. In an apparatus for classifying sutures into groups based on the minimum of many single diameter measurements at a plurality of positions along the axis of the suture, the improvement comprising: a pair of entrance feed rolls, a pair of guide rolls, and a pair of faster feed rolls, the axes of both rolls of all pairs being parallel, each of the entrance feed rolls and faster feed roll pair comprising a driving roll having electrically conductive flanges and a resilient annular center of a composition having a high coefficient of friction with a suture, and an idler roll having at least the part contacting said flanges of an electrically conductive material, resilient means to press the rolls of all pairs towards each other, with part of the gap between the guide rolls and the faster feed rolls forming a gauging zone; a first suture guide to direct a suture towards the bite of the entrance feed rolls, a second suture guide to receive the suture from the entrance feed rolls and direct the suture towards the guide rolls, a third suture guide to receive the suture from the guide rolls and direct the suture towards and control the suture path approaching the gauging zone, a fourth suture guide to receive the suture from the gauging zone and direct the suture towards the faster feed rolls, and a fifth suture guide to receive the suture from the faster feed rolls, and direct the suture towards a suture sorting means; a gauging means functioning through said gauging

zone; means for passing a first electric current through the entrance feed rolls, which first current is interrupted by the passage of a suture, means for passing a second electric current through the faster feed rolls, which second current is interrupted by the passage of a suture, means to limit the effective operation of the gauging means to that time when both said electric currents are interrupted by a suture; means to drive the entrance feed rolls and the guide rolls, including means to drive the faster feed rolls at a faster surface speed than the entrance feed rolls, and to permit slippage in the drive means to thereby keep the suture stretched while between the entrance feed rolls and the faster feed rolls; and means to receive the suture from said fifth suture guide, and means to direct the suture into a size bin based on intelligence from said gauging means.

4. An apparatus for classifying sutures into size groups based on single diameter measurements at a plurality of positions along the axis of the suture, the improvement comprising: a pair of entrance feed rolls, and a pair of faster feed rolls, the axes of all rolls being parallel, means to press the rolls of both pair towards each other, part of the gap between the entrance feed rolls and the faster feed rolls forming a gauging zone; suture guide means to direct a suture towards the bite of the entrance feed rolls, thence through the gauging zone, the faster feed rolls, and then towards a suture sorting means, a gauging means functioning through said gauging zone, means to determine when both pair of feed rolls have a suture between them; means to limit the effective operation of the gauging means to that time when a suture is between both pair of rolls; means to drive the entrance feed rolls, means to drive the faster feed rolls at a faster surface speed than the entrance feed rolls, and to permit slippage to thereby keep the suture stretched while between the entrance feed rolls and the faster feed rolls, means to receive the suture from said suture guide means, and means to direct the suture into a size bin based on intelligence from said gauging means.

5. In an apparatus for classifying sutures into size groups, the improvement comprising: a pair of entrance feed rolls, and a pair of faster feed rolls, the axes of all rolls being parallel, means to press the rolls of each pair towards each other, part of the gap between the guide rolls and the faster feed rolls forming a gauging zone, suture guide means to direct a suture towards the bite of the entrance feed rolls, thence through the gauging zone, the faster feed rolls and then towards a suture sorting means, a gauging means functioning through said gauge zone, means to determine when both pair of feed rolls have a suture between them, means to limit the effective operation of the gauging means to that time when a suture is between both pair of rolls; and means to drive the entrance feed rolls and the faster feed rolls at such relative speeds that a suture between them is kept stretched enough to avoid whipping.

6. An apparatus for classifying sutures according to predetermined diameter measurements, which comprises: three pairs of rolls having a peripheral portion of metal, the rolls of each pair being held in juxtaposition to one another under sufficient loading to make electrical contact when no suture is therebetween, but insufficient to block their separation by a suture passing between them, the said pairs of rolls being mounted in a support so that the points of contact between the rolls of each pair all fall in a line, the said pairs of rolls being cooperatively rotated mechanically so that respective tangential edges of each roll of said pairs and of each pair in respect to the other move in the same direction, an optical scanning means positioned to scan continuously a zone between the second and third of said pairs of rolls and designed to issue after a suture has been scanned one of a series of electrical signals corresponding to a predetermined series of limits in the diameter of the said suture, the first two of said pairs of rolls acting to feed

a length of suture into said zone and the third pair of rolls acting to withdraw it from said zone, the said third pair of rolls having a greater peripheral velocity than the said first two pairs; two rotatable parallel tangentially contacting cylinders, one of which has a slot along the line of tangency, which is closed by the other cylinder when in the suture-receiving position, the said cylinders being positioned with the said slot lying along the line joining the point of tangency of the three said pairs of rolls, a series of storage bins corresponding to said predetermined series of limits and rigidly mounted such that one is directly below said cylinders and the others are below and to one or the other side of said cylinders, a series of long, independently rotatable vanes corresponding to said side bins mounted below the said rotatable cylinders in such fashion that in the normal vertical position of said vanes there is an unobstructed drop from said cylinders to said lower bin, each of said vanes when in a rotated position diverting the drop of a suture to the bin to which it corresponds, means for rotating said cylinders to a position wherein the said longitudinal slot is exposed over the said drop, means for rotating said vanes individually to obstruct, and divert the suture drop upon actuation by the said signal from said scanning means, in correspondence to size intelligence, the said means for rotating said cylinders being actuated by the electrical contacts formed by the closing of said rolls.

7. An alternatively vacuum loaded and pressure ejection mechanism for sutures which comprises a pair of solid parallel rotatable cylinders touching along one side; the first of said cylinders having a longitudinal slot down the line of tangency, the said longitudinal slot being open at one end and having an air exhaust port at the other; a resilient coating around the arc of tangency of the second of said cylinders such that in the normal position when the said slot is at the point of tangency said resilient material forms an air-tight seal along the length of the said slot, means for partially rotating said cylinders cooperatively so as to expose said slot and discharge a suture therefrom, and means for exhausting air through said exhaust port when said slot is in the normal position.

8. An alternatively vacuum loaded and pressure ejection mechanism for sutures which comprises a pair of solid parallel rotatable cylinders touching along one side; the first of said cylinders having a longitudinal slot down the line of tangency, the said longitudinal slot being open at one end and having an air exhaust port at the other; a resilient coating around the arc of tangency of the second of said cylinders such that in the normal position when the said slot is at the point of tangency, said resilient material forms an air-tight seal along the length of the said slot, means for partially rotating said cylinders cooperatively so as to expose said slot and discharge a suture therefrom, and means for exhausting air through said exhaust port when said slot is in the normal position, and means for applying air pressure into said slot when said cylinders are in the rotated position.

9. In an apparatus for classifying sutures, the improvement in dumping means which comprises: a bar having therein a long, thin groove having one open end and an open face, means to seal the open face of the groove when the bar is in a loading position, means to change the position of said bar with respect to said seal means

to a discharge position in which discharge position the contents of the groove are released, evacuating means adjacent the second and closed end of the groove to draw a suture into the groove when the groove is closed, and a guide means adjacent to and coaxial with said one open end of said groove to direct a suture axially into the groove.

10. In an apparatus for classifying sutures, the improvement in dumping means which comprises: a rotatable bar having therein a long, thin groove having one open end and an open face, a second parallel rotatable bar to seal the open face of the groove when the bar is in a loading position, resilient seal means between said bars, means to move said rotatable bar relative to said second bar to a discharge position, in which discharge position the contents of the groove are released, evacuating means adjacent the second and closed end of the groove to draw a suture into the groove when the groove is closed, and a guide means adjacent to and coaxial with said one open end of said groove to direct a suture axially into the groove.

11. A method of classifying sutures into groups based upon the minimum diameter at any position along the strand, based upon single diameter measurements at a plurality of positions along the axis of the suture which comprises: feeding each suture axially along a limited path, past an optical diameter sensing position, optically sensing the suture diameter repeatedly, sensing the presence of the suture in said path before and after the diameter sensing position, maintaining the suture in tension to reduce whip between said suture sensing positions, utilizing only those measurements which are taken while the presence of the suture is sensed both ahead of and behind the diameter sensing position, determining the minimum of all utilized diameter measurements, moving the suture to a storage position by reducing the pressure in a dumping position and thereby transferring the suture from storage position to dumping position, discharging the suture from the dumping position, and passing the suture along a path controlled by the said minimum diameter measurement to a bin appropriate to said minimum measurement.

12. A method of classifying sutures into groups based upon the minimum diameter at any position along the strand, based upon single diameter measurements at a plurality of positions along the axis of the suture which comprises: feeding each suture axially along the limited path, past a diameter sensing position, sensing the suture diameter repeatedly, sensing the presence of the suture in said path before and after the diameter sensing position, maintaining the suture in tension to reduce whip between said suture sensing positions, utilizing only those measurements which are taken while the presence of the suture is sensed both ahead of and behind the diameter sensing position, determining the minimum of all utilized diameter measurements, moving the suture to a dumping position, discharging the suture from the dumping position, and passing the suture along a path controlled by the said minimum diameter measurement to a bin appropriate to said minimum measurement.

No references cited.