This invention relates to the manufacture of grid electrodes for electron discharge devices and, more particularly, to a method and apparatus for making these grid electrodes.

In the manufacture of grid electrodes, it is customary to provide a plurality of spaced support members around which a wire is wound to provide the grid laterals. The wire which forms the grid laterals is supplied from some suitable source, usually a spool, and is directed onto the support members to form the grid laterals. The manner in which the grid laterals are formed is customarily achieved by directing the grid wire through a suitable guide and providing between this guide and the spaced support members both relative rotational and longitudinal movements. Perhaps the most usual way of winding a grid electrode is to have a stationary wire source and moving guide, and providing both rotational and longitudinal movements of the support members.

However, it is also quite usual to provide that the support members are stationary and that the winding head is provided with both rotational and longitudinal motion with respect to the support members. It is also possible that combinations of these movements be utilized.

Grid electrodes are commonly wound in strips; that is, several grids are wound successively and after being wound are separated to form the individual electrodes. A grid is normally comprised of two areas, namely, the active area in which it is necessary to have grid laterals and a leg portion in which there are no lateral wires. In order to conserve lateral wire and time customarily achieved by one of two methods. Either of these two methods may be utilized regardless of the manner in which the relative longitudinal motion between the support rods and the winding guide is achieved. The first of these methods provides that the winding is continuous but that in the leg portion of the grid strip the rate of longitudinal advancement is greatly increased so that the adjacent turns of grid lateral wire are spaced a greater distance apart. The second method customarily used is to break the wire at the end of one active grid portion, shift the mechanism over the leg portion of the grid, and commence winding with the next active grid portion. In either method, the demand upon the grid wire is subject to very rapid changes.

The continuously winding method is commonly used on frame grids; that is, grids having a pair of spaced support rods and cross bars extending between the support rods to hold them in their spaced relationship. In these cases, the wire customarily used is extremely fine and has, therefore, a very low tensile strength. Thus, when the demand upon the wire is suddenly increased by the greater spacing between adjacent turns, the wire often breaks. The break

method is commonly used on notch and peen type grids where the grid laterals serve to maintain the support members in their spaced relationship. In this latter method, the grid wire is often much heavier than that used in the case of frame grids. However, upon the initiation of the winding of a new grid, the demand on the wire rises at an almost infinite rate from zero demand to full demand. Thus, even though the wire of this method is generally of greater size, this extremely rapid rise in demand can easily result in a breaking of the grid wire.

While various tensioning devices are known in the art which satisfactorily serve to adjust for fluctuations in the demand occasioned by the non-symmetry of the grid about its rotational axis, these tensioning devices normally depend upon the change in tension of the wire to make the proper adjustment. Because the demand in the above-illustrated cases changes so rapidly, conventional type of tensioning devices are not sufficiently responsive to adjust to this extremely rapid change and the result is a broken grid wire.

It is, therefore, an object of this invention to provide an improved grid winding machine.

Another object is to provide improved means for use in the manufacture of grid wires.

A still further object is to provide improved means to compensate for sudden changes in demand for grid lateral wire in the manufacture of grids for use in electron discharge devices.

Stated briefly, the present invention provides that sudden changes in demand for grid lateral wire are anticipated. This anticipation permits the reduction of fluctuation in tension between the grid wire source and the support members to provide a more constant tension between the elements. Thus, upon a sudden change in demand, the amount of wire necessary to supply the demand is readily available without increasing the tension upon the grid wire to limits which exceed the tensile strength of the wire. By the utilization of the present invention, the ability to rapidly wind grids and yet take advantage of a reduction in lateral wire in non-active grid areas is readily achievable.

Further objects and advantages of the invention will become apparent as the following description proceeds and features of novelty which characterize the invention will be pointed out in particularity in the claims annexed to and forming a part of this specification.

For a better understanding of the invention, reference may be had to the accompanying drawings, in which:

FIGURE 1 shows a diagrammatic front view of a grid machine embodying the present invention;

FIGS. 2A and 2B are diagrammatic views of, respectively, conventional and frame grid strips illustrating the areas of the winding process in which the present invention is necessary;

FIG. 3 is a perspective view of the present invention in its preferred embodiment as applied to the winding of grids having no turns in the leg portion; and

FIG. 4 is a perspective view of the present invention in its preferred embodiment as applied to the winding of grids having a very few turns in the leg portion.

The invention comprises, in general, a system which takes the form of an attachment which can be easily added to a standard grid making machine such as a rotary grid lathe as illustrated in FIG. 1. With specific reference
to FIG. 1, the machine is constructed similar to a lathe and comprises a bed plate 10 upon which is supported, at one end a head stock 11 and at the other a tail stock 12. The head stock 11 includes a main rotary spindle which is driven by suitable means 7. A tubular draw bar 14 is provided at one end with a strip clamp 13 and on its other end with a half nut or split nut 16. The half nut 16 may be opened and closed by means of a handle 18. A lead screw 20 is provided having one end rotatedly mounted in the tail stock 12 and the other end positioned to engage the half nut 16.

The apparatus illustrated in FIG. 1 is designed to wind so-called conventional grids by the notch and peen process. In this embodiment, each support member or side rod wire 15 is automatically fed in a continuous length from a spool 17 carried in a yoke 19 positioned on the outer end of a spindle 22. The support members 15 pass through channels extending longitudinally through the spindle 22. A mandrel 21 is secured to the spindle 22 and grooves are provided in the mandrel for the support members 15. A notching wheel 26 and a peening wheel 25 are supported by suitable means from the head stock 11 and are positioned adjacent the mandrel 21. A grid wire 52 is directed onto the rotating support members 15 from a suitable source, for example a spool 51. The grid lateral wire 52 is supplied to the members 15 by means of the tensioning device of the present invention which is described generally at 50 and by which a tensioning device may be supported by the head stock 11.

The winding operation is started by securing the support members 15 by means of the clamp 13 on the draw bar 14. The half nut 16 is closed on the lead screw 20 so that as the draw bar 14 retreats due to the relative rotation between lead screw 20 and the draw bar 14, the support members 15 are drawn through the channels in the head spindle 22 and along opposite edges of the mandrel 21. The notching wheel 26 is mounted in a position such that its periphery cuts a notch in each support member 15 as that member is carried under the notching wheel 26 by the rotation of the mandrel 21. The grid wire 52 is then disposed within these notches and is secured therein by a peening wheel 25 as the support member 15 and grid wire 52 are carried under the peening wheel 25 by the rotation of the mandrel 21. This operation is continued throughout that portion of the grid strip where it is desired to have grid laterals.

With reference now to FIG. 2A, there is shown a portion of a grid strip having areas A which include grid turns and areas B which do not have turns thereon. Areas A may be designated as the active grid portions while areas B are the respective leg portions of adjacent grid structures. After the grid strip has been wound, the side rods 15 are severed at approximately the midpoints between adjacent active areas A to form individual grid electrodes as is customary in the art. A grid strip such as is illustrated in FIG. 2A may be formed by breaking the grid wire at the end of a first active grid portion, advancing the support members 15 longitudinally to the point where it is desired to start the next active grid portion and at that time commencing once again the winding of the grid laterals. The method and mechanism by which this so-called "wire break" is achieved is more fully set forth in U.S. Patent 3,121,448, filed November 4, 1960, entitled Grid Manufacturing Apparatus, by Douglas G. Noiles et al., which application is assigned to the assignee of the present invention. However, stated briefly, this patent sets forth that having wound one active grid portion A, the grid wire is grasped between a pair of jaws to prevent further movement of the grid wire. Upon continuing operation of the support members 15, the grid wire is caused to break at a point where last peened and the machine is then advanced to the next successive active grid portion where the grid wire is again pickuped and wound around the support members 15. By this method, no turns are wound in the leg portion B of the grid strip.

It may also be provided that the longitudinal movement of the members 15 in the leg portion B is more rapid than the longitudinal movement when the active grid portion A is being wound.

While the described wire break method effects a substantial savings in time and grid wire certain difficulties are prevalent in the operation of the device in that the grid wire has a tendency to break at the initiation of a new active grid portion. In the winding of conventional notch and peen grids, the wire diameters range customarily from approximately 0.005 inch to 0.0006 inch. Winding tensions are desired in the 250 to 50 gram range. Winding speeds, that is the rotational speed of the support members, range up to 1500 revolutions per minute. It is readily apparent that after the wire has been broken its rate of feed is zero. Once the wire is attached to the rotating support members at the initiation of a new active grid portion it must rise at an almost infinite rate to a speed sufficient to supply the demand of the support members which, as has been stated, may be rotated at speeds up to 5000 r.p.m. of the system when the wire break mechanism is operated. This over-run produces some slack in the wire between the source and the jaws which clamp the wire further complicating the breaking problem in that when the wire is once more picked up to be wound upon the support members, the slack results in a snap in the wire which further increases its propensity to break. Some prior art systems have attempted to reduce this slack by rotating the wire source in the reverse direction. While this system has some merit it often results in the grid wire being pulled from the retaining jaws of the break mechanism so that the wire cannot once again be automatically picked up. Thus, the machine must be re-threaded by hand.

With reference now to FIG. 3, there is shown the tensioning device of the present invention as it is applied to the winding of conventional grids by the notch and peen process and which may be incorporated with the wire break system. The device includes a source of wire in the form of a spool 30 which is secured to a shaft 32 of a motor 34. The wire 52 is taken from the top of the spool, looped around a pulley 38, brought back once again around the spool 30, from the underneath side, and from the top of the spool taken to the support members 15. The pulley 38 is rotatably mounted on a resilient member 49 which may be secured to a suitable fixed reference for example the bed plate 10 of the device of FIG. 1. Thus, the pulley 38 is provided not only with rotary motion but also with an arcuate reciprocating motion towards and away from the spool 30. Intermediate the spool 30 and the support members 15 are a pair of blocks 42 which represent the gripper jaws of the wire break system. The jaws also act as a guide means for directing wire onto the support members 15. The device as a whole is supported by a suitable housing 36 which may be supported from the bed plate 10 and head stock 11 of the device of FIG. 1.

In the winding operation, the grid wire 52 is fixed to one of the support members 15 and the members 15 are then caused to rotate and move longitudinally. These movements of the support members 15 draw wire from the spool which wire passes around the pulley 38 and from the pulley 38 back around the spool 30 and then to the support members 15. The normal direction of rotation of the spool 30 as, viewed in FIG. 3, is in the counterclockwise direction. During the winding of the active grid portion A (FIG. 2A), the motor 34 is de-activated and acts as a spindle for the spool 30. The
requisite tension on the grid wire 52 during the normal winding operation is provided by any suitable friction or hysteresis tensioning device. In FIG. 3 this tensioning device is shown to be of a frictional nature and is illustrated by a resilient member 45 which is in frictional contact with a wheel 44 which is also secured to the motor shaft 32.

After an active grid portion A has been wound, the wire break jaws 42 clamp on the wire 52 and thus prevent the rotated members 15 from drawing additional wire from the spool 30. These results in a breakage of the wire at the support members 15. As the system has a whole a certain amount of rotational inertia, the sudden stoppage of the wire 52 results in some over-run of the system. If and when desirable, this over-run can be reduced or eliminated by the addition of a suitable second brake on the motor spindle which is momentarily actuated at the instant the wire breaks. This second brake and actuating means are not shown. However, in view of the nature in which the wire is wound, near normal winding tension is maintained in the wire between the spool and the pulley 56, and the bulk of the reduction in tension is taken up in the wire between the jaws 42 and the spool 30. This reduction in tension is not harmful.

The critical time of tensioning, however, is when the lateral wire 52 is picked up to start winding the next active grid portion A. At this time member 45 is drawn away from zero to full speed in virtually zero time—the rate of change approaching infinity. No servo device, responsive to an increase in tension of the lateral wire 52, is sufficiently fast to respond to this high rate of change; and the forces occasioned by this rapid rate of change may often be sufficient to break the wire 52.

In the present invention, however, there is connected to the spool 30 a driving means which is shown as a small electric motor 34. The motor 34 is connected to a suitable source of voltage 48 through an adjustable impedance 46 and a switch 47. The switch 47 may be actuated by the same mechanism which initiates the action of the wire break jaws 42 as described in the previously mentioned U.S. Patent 3,121,448 and/or the rapid longitudinal advancement of the support members 15. This mechanism is curiously a rotatable cam mounted on the apparatus of FIG. 1. Any suitable means, for example a cam follower linking the cam and the switch 47 will serve to actuate the latter. The cam and cam follower mechanism is illustrated as Item 8 and is described in U.S. Patent 3,121,448. The direction of rotation of the cam is determined when energized or when the spooling. Thus, by utilizing the actuating mechanism of the wire break jaws 42 to control the switch 47, and by adjusting the potential applied to the motor 34 through the impedance 46, it is seen that this actuating mechanism may cause the energization of the motor 34 an amount and for a proper period of time to overcome the inertia of the spool by turning the spool in the direction of normal rotation, to compensate for the sudden increase in wire demand. The motor 34 is energized at a time which is closely coincident with the initiation of the winding of an active grid portion. A ready indication of the proper adjustment of time and amount of input torque of the motor 34 is by observing the action of the pulley 28. When these parameters are properly adjusted the pulley 28 has very little arcuate motion on the resilient member 40 thus indicating a nearly constant tension being maintained on the wire 52. If these parameters are improperly adjusted, the amount of arcuate motion of the pulley 28 will be considerable.

A second method of reducing the number of grid turns in the leg portion of the grid is illustrated in FIG. 2B. In FIG. 2B there is shown a grid strip having a pair of spaced support members 23 which are held in tandem spaced relationship by a plurality of cross members 23. As in the case of FIG. 2A the active grid portion is designated as A and the leg portion is designated as B. In this example, however, a very limited number of widely spaced turns are placed in the leg portion of the grid strip. This wide spacing of grid turns in the leg portion is achieved by rapidly advancing the leg portion with respect to the winding head. The mechanism (herein designated as "skip" or "skip turn") by which this is accomplished is more fully set forth in U.S. Patent No. 3,029,844, filed May 22, 1959, entitled Grid Making Machine by William H. Simmons and which is assigned to the assignee of the present invention. Although this skip method of winding the leg turns will work equally well in the notch and peen process of conventional grids it is explained with respect to frame grids where it finds a greater application.

In the winding of frame type grids the lateral wires are normally held onto the support rods by their own tension and the wires are of a smaller diameter than those usually found in grids of the conventional notch and peen process. A typical example of a frame grid would utilize wire in a diameter of approximately 0.0004 inch and winding would be at a rotational speed of about 700 r.p.m.

The embodiment of the present invention as it is applied to the winding in the skip turn process is shown in FIG. 4. In that figure, there is shown a source or spool 30 of wire 52 which is attached to a shaft 32 of a motor 34. As in the embodiment of FIG. 3, the assembly of this embodiment is supported by a housing 53. The rotary and longitudinal movements of the support members 15 draw wire from the spool 30 so as to cause the spool 30 to rotate, as viewed in FIG. 4, in the clockwise direction. After leaving the spool 30 the lateral wire 52 is caused to pass over a rotating pulley 66, from the pulley 60 to a second pulley 62 and from there through a guide member 64 onto the support members 15. The pulley 62 and the guide member 64 may be supported by a suitable member 66 which is affixed to a fixed reference point such as the lathe bed 10 (FIG. 1). The pulley 60 is rotatably supported on a resilient member 68 which in turn is supported by the housing 36. A member 70 limits the upward movement of the resilient member 68. Normal winding tension in the present embodiment is provided by a strap 71, of a suitable material such as canvas, which is passed around and in frictional engagement with a pulley 72 which may also be located on the shaft 32. One end of the strap 71 is connected to a spring 74 which in turn is connected to the resilient member 68 near the pulley 60. The other end of the strap 71 is connected to a screw 76 which in turn passes through a bracket 78. The screw 76 is provided with a wing nut 80 at its upper portion to provide fine adjustment of the strap 71 on the pulley 72. The bracket 78 is supported by the housing 36 and means including a screw 82 and slot 84 may be provided for coarse adjustment of the tensioning means.

As the tension on the grid lateral wire 52 increases, pulley 60 is caused to move in the downward direction which in turn reduces the pressure of the strap 71 on the pulley 72. Hence the frictional restraint on the rotation of the spool is lessened and the spool 30 is permitted to more freely rotate to relieve the increased wire tension. Conversely, as the tension on the lateral wire 52 decreases the pulley 60 moves in the upward direction and hence increases the amount of tension on the lateral wire 52. The device thus described is self regulating and even through the lateral wire 52 very thin this system adequately compensates for variations in tensions occasioned by the winding of the active grid portion where the turns are evenly spaced or have only a small variance. The above is old in the art.

However, once the grid strip reaches the end of an active grid portion and it is desired to wind the turns on the leg portion, which turns are more greatly spaced apart, it is apparent that the demand for wire rapidly increases. As an illustration, normal distance between ad-
acent grid laterals in the active portion of the grid may be approximately 0.0025 inch while the spacing between adjacent turns in the leg portion approaches 0.25 inch. The sudden increase in wire demand occasioned by the greater spacing often places stresses upon the lateral wire for which the normal tensioning device just described cannot compensate. Although a wire of this diameter normally has a breaking strength of about 30 grams, it has been found that measurable winding tensions above 15 grams often produce wire breakage, even in uniform practice.

The active area of the frame grid is wound with tension produced only by the tensioning device described. Here, as in the case of the embodiment of FIG. 3, the motor is not energized and serves as a spindle for the spool 30. At the time the support members 15 are rapidly advanced, resulting in a rapid increase in wire demand, the motor 34 is pulsed from a source 48 through the adjustable impedance 46 and the switch 47. Here again, as in the embodiment of FIG. 3, the voltage applied to the motor 34 may be adjusted by the impedance 46 and the duration of the pulse adjusted through the actuation of the switch 47. The mechanism, for example a rotating cam, which effects the rapid advancement of the support members 15 may be utilized to actuate the switch 47 as was done in the case of the previous embodiment. As before, the direction of rotation of the motor is such to provide an unspooling of the wire (in FIG. 4 the motor runs to effect a clockwise motion of the spool 30). A ready indication of proper adjustment of time and amount of the torque supplied by the motor 34 is easily discernible by observation of the action of pulley 60. With the proper adjustment there is very little movement of the pulley 60 during the skip period thus indicating a relatively constant wire tension. That is, the pulley 60 is relatively stationary even though the skip mechanism is operated and the wire demand is greatly increased.

It is thus seen that by the present invention there is provided an improved means for maintaining a grid lateral wire under the proper tension between its source and the support members even though the demand upon this supply varies between very great limits. By the present invention, there is provided a device which is readily adaptable to standard grid making machines and which greatly facilitates the use of various methods for conserving time and material in the grid making process.

While there have been shown and described what are at present considered to be the most preferred embodiments of the invention, modifications thereto will readily occur to those skilled in the art. For example, the invention is not limited to use in systems as have been described, namely, the wire break and skip turn mechanisms, but is equally applicable to any system in which there is a very rapid change in demand upon a strand such that there may be occasioned a breakage of that strand.

It is not desired, therefore, that the invention be limited to the specific arrangements shown and described and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

We claim as our invention:

1. A grid winding machine comprising a spindle, a first means for rotating said spindle, a plurality of spaced support members held by and rotated with said spindle, a second means for advancing said support members longitudinally, a source of grid wire, a third means for supplying said grid wire to said support members whereby upon said rotative and longitudinal movements thereof said grid wire is drawn from said source and is wound about said support members, said third means including a fourth means for maintaining said wire under tension between said grid wire source and said support members, a fifth means operatively associated with said first means to cause a periodic increase in demand of said grid wire from said source of grid wire, and a sixth means independent of said fourth means for maintaining said wire under tension and operatively associated with said fifth means for supplementally drawing said grid wire from said source.

2. A grid winding machine comprising a spindle, a first means for rotating said spindle, a plurality of spaced support members held by and rotated with said spindle, a second means for advancing said support members longitudinally, a source of grid wire, a third means for supplying said grid wire to said support members whereby upon said rotative and longitudinal movements thereof said grid wire is drawn from said source and is wound about said support members, said third means comprising a fourth means for maintaining said wire under a predetermined tension between said source and said support members, a fifth means operatively associated with said first means to cause a periodic increase in demand for grid wire from said source, and a sixth means independent of said fourth means and operatively associated with said fifth means for supplementing the action of said support members in drawing said grid wire from said source in response to said periodic increase in demand for said grid wire.

3. A grid winding machine comprising a spindle, a first means for rotating said spindle, a plurality of spaced support members held by and rotated with said spindle, a second means for advancing said support members longitudinally at a first speed, a spool of grid wire, a third means for supplying said grid wire to said support members wherein upon said rotative and longitudinal movements of said support members said wire is drawn from said spool and wound about said support members, a fourth means operatively associated with said first means to cause a periodic increase in demand for grid wire from said source, and a fifth means adapted to drive said spool and operatively associated with said fourth means for supplementing the action of said support members in removing wire from said spool simultaneously with said periodic increase in demand.

4. A grid winding machine comprising a spindle, a first means for rotating said spindle, a plurality of spaced support members held by and rotated with said spindle, a second means for advancing said support members longitudinally, a spool of grid wire, a third means for supplying said grid wire from said spool to said support members whereby upon said rotative and longitudinal movements thereof said grid wire is wound about said support members, said third means comprising a fourth means for maintaining said grid wire under tension between said spool and said support members, a fifth means operatively associated with said first means to cause a periodic increase in demand for grid wire from said spool, a motor means operatively associated with said fifth means, said spool adapted to be driven by said motor means in the direction of unspooling simultaneously with said periodic increase in demand for said grid wire by said support members.

5. A grid winding machine comprising a spindle, a first means for rotating said spindle, a plurality of spaced support members held by and rotated with said spindle, a second means for advancing said support members longitudinally, a source of grid wire, a third means for supplying said grid wire to said support members whereby upon said rotative and longitudinal movements thereof said grid wire is wound about said support members, said movements acting to draw wire from said source, a fourth means operatively associated with said first means to cause a periodic increase in demand for said grid wire from said source, a fifth means for maintaining said wire under a uniform tension between said source and said support member, motor means operatively associated with said source of grid wire, and a sixth means independent of said fifth means for maintaining said wire under tension
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Operatively associated with said fourth means and said motor means to supplement the action of said support members in drawing wire from said source simultaneously with said periodic increase in demand of grid wire.

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