

Oct. 20, 1970

R. W. CROOK III

3,535,588

APPARATUS FOR CHARGING FIBROUS MATERIAL

Filed April 6, 1967

2 Sheets-Sheet 1

Fig. 1.

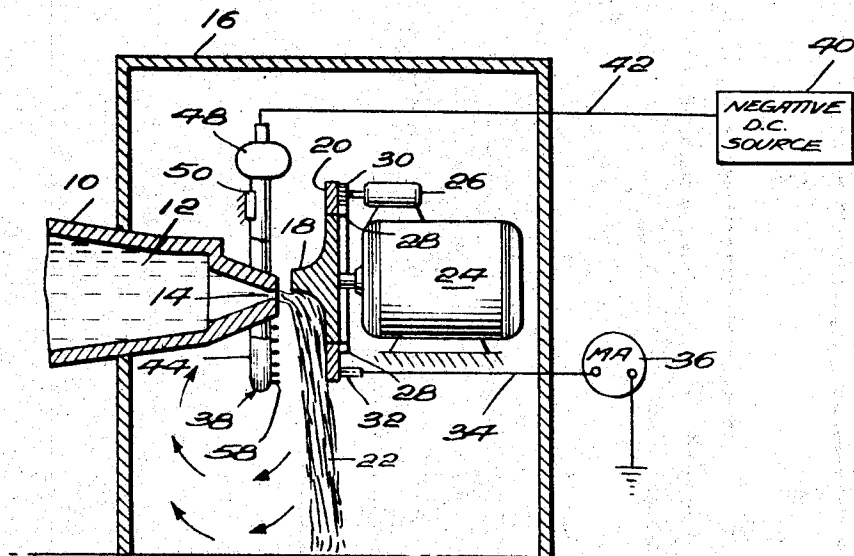


Fig. 2.

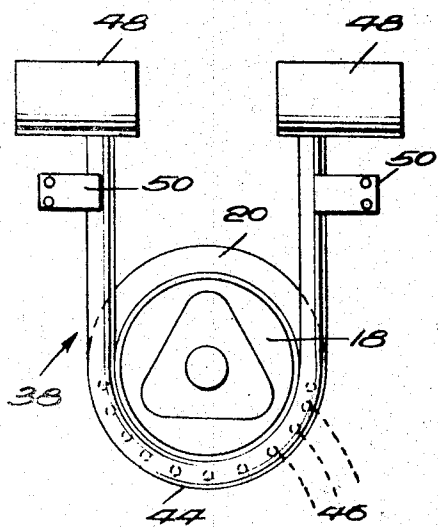
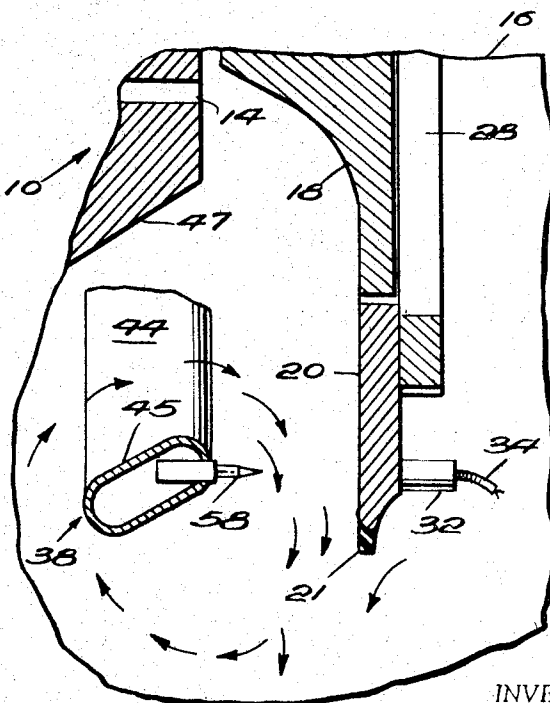


Fig. 3.



INVENTOR
RAPP WALLACE CROOK III,

BY *Howard P. West Jr.*

ATTORNEY

Oct. 20, 1970

R. W. CROOK III

3,535,588

APPARATUS FOR CHARGING FIBROUS MATERIAL

Filed April 6, 1967

2 Sheets-Sheet 2

Fig. 4.

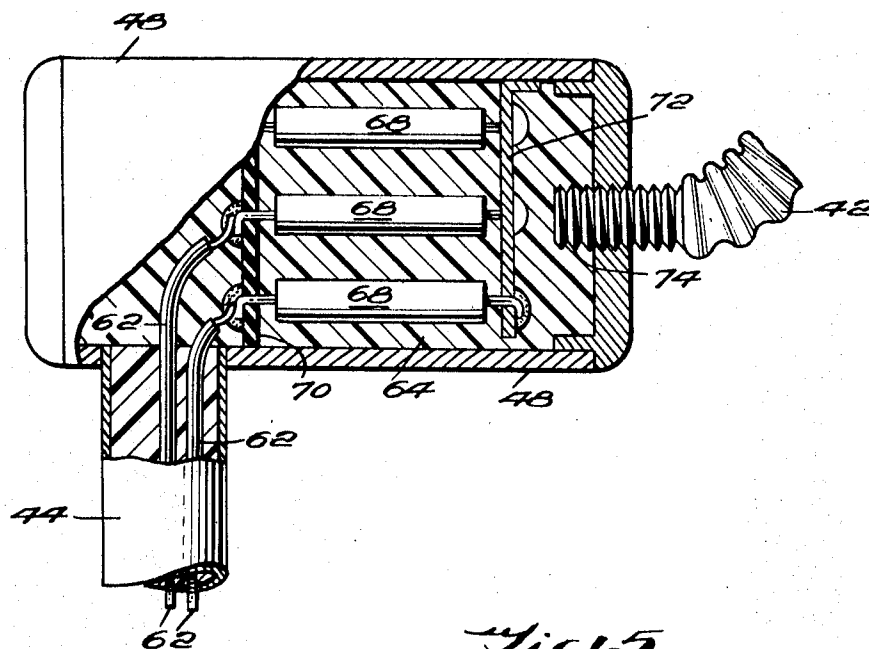
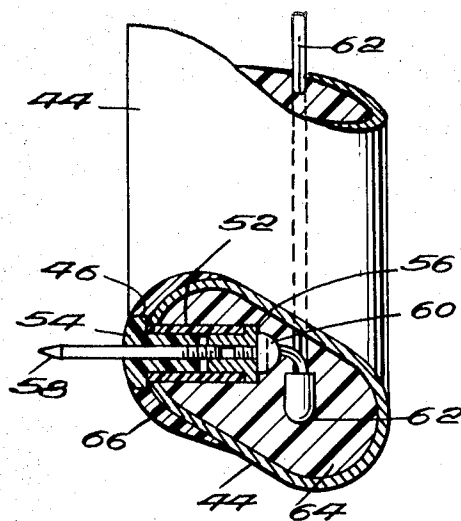


Fig. 5.



INVENTOR
RAPP WALLACE CROOK III,

BY *Howard P. West Jr.*

ATTORNEY

1

3,535,588

APPARATUS FOR CHARGING FIBROUS MATERIAL

Rapp Wallace Crook III, Newark, Del., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

Filed Apr. 6, 1967, Ser. No. 628,983

Int. Cl. H01j 3/04

U.S. Cl. 317—4

7 Claims

ABSTRACT OF THE DISCLOSURE

A corona charging device consisting of an ion gun and a grounded target electrode. The ion gun includes a plurality of corona generating points, each being connected in series through a resistor to a high voltage source. A conductive sheath connected to the high voltage source encloses the resistors and connections to the corona generating points to protect the insulating materials in the ion gun from degradation due to high voltage environment.

BACKGROUND OF THE INVENTION

This invention concerns an apparatus for applying a uniform electrostatic charge to a wide swath of moving fibrous material.

In the Steuber patent U.S. 3,169,899 a process is described for making a non-woven sheet from flash-spun fibrous material. In the flash spinning technique, a solution of an organic polymer, which is under pressure and at a temperature far above the boiling point of the solvent is extruded into an area of substantially atmospheric pressure. As the material issues from the orifice, the solvent expands rapidly and a plexifilamentary strand is formed. The plexifilamentary strand is composed of very thin film-fibril elements which are interconnected in a three-dimensional network as described in detail in Blades and White, U.S. Pat. 3,081,519. The three-dimensional network is preferably spread into a wide web by causing it to impinge on a curved surface whereupon the expanding solvent gas spreads the material. The control of the collection of this network by aerodynamic and electrostatic means has been the subject of much research. The problem is particularly difficult because of the extremely fine nature of the fibrils and because of the high volume and high velocity of the gas in the system.

Electrostatic charging of the fibers has been used to promote mutual repulsion (better dispersion) of fibers and to promote better adherence of fibers to a collecting roll or belt. In the Steuber patent, for example, a rake-like electrode is shown. While this device improves the tendency of the fiber to be attracted to a grounded or oppositely charged collection surface, it has deficiencies particularly with respect to uniform charging and deposit of the web.

Some of the problems in uniformity have been eliminated by use of a particular multi-needled electrode described in copending U.S. application Ser. No. 372,623 of Hollberg and Owens, filed June 4, 1964, now U.S. Pat. No. 3,387,326, wherein each needle is connected in series to a high impedance resistor which is, in turn, connected to a source of high voltage direct current power. While this type of apparatus greatly improves the control of the laydown process, the life of the apparatus is less than desirable for commercial operation. The resistors in this system are located remotely from the spinning area to provide a low cross-sectional area in the gas stream and the lowest possible resistance to flow of gases. Unfortunately, the relatively fine wires which connect the needles of the ion gun to the resistors are themselves sources of corona discharge, especially whenever break-

2

down of the insulating materials occur because of solvent or high voltage attack. Likewise, the connecting terminals between the wires and the needles or between the wires and the resistors are sources for corona discharge. As a result, the insulating materials are degraded, and with the degradation increasing exposure to corona discharge occurs. Eventually, the insulating materials become ineffective, excessive power losses occur, and the ion gun must be replaced.

SUMMARY OF THE INVENTION

The purpose of the present invention is to provide an ion gun which has low resistance to gas flow, provides uniform charging across a wide web of fibrous materials in a gaseous stream and has low susceptibility to degradation by a high voltage environment, or solvents.

The apparatus of the present invention is an ion gun for use in conjunction with a grounded target electrode to apply a uniform electrostatic charge to a web of moving fibrous material advancing between the ion gun and the target electrode. The ion gun comprises a conductive tubular housing with ports substantially equi-spaced along its length and with a conductive resistor enclosure joined to at least one end of the tubular housing. The ports along the length of the tubular housing are provided with individual conducting needles which extend from the tube. Needles are sealed in the ports and are electrically insulated from the tubular housing. Each needle is connected through an insulated conductor of small diameter to one terminal of an insulated resistor located in the conductive resistor enclosure. Means are provided to connect the tubular housing, the resistor enclosure and the second terminal of each resistor to a common source of high voltage direct current power to provide a charged sheath enclosing the connecting means and the resistors.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration indicating the arrangement of various elements in a system wherein the corona charging device of this invention is useful.

FIG. 2 is a front elevation of the U-shaped ion gun shown in FIG. 1.

FIG. 3 is an enlarged partially sectioned fragmentary view of FIG. 1, showing the relationship of the conducting needles of the ion gun to the target electrode.

FIG. 4 is a partially sectioned front view of the resistor housing.

FIG. 5 is a cross section through the ion gun shown in FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1 a spinneret 10 is connected to a source of polymer dissolved in an organic solvent. Polymer solution 12 is extruded through orifice 14 in spinneret 10 into chamber 16 which is substantially at atmospheric pressure. Due to the pressure drop at spinning orifice 14 the solvent expands greatly and is carried around the curved surface of a lobed deflector 18 onto the surface of an annular target electrode 20. From the outer circular edge of the target electrode the solvent gas and the film fibril material 22 are carried downward in a linear path toward a moving collection surface not shown. Deflector 18 is connected to motor 24 which continuously rotates the deflector and thereby imparts oscillatory movement to the network of film-fibril material as it is deflected from the lobed surface. Annular target electrode 20 is coupled, for rotary movement about deflector 18, to motor 26 through ring 28 and pinion gear 30 attached to the shaft of motor 26. Target electrode 20 is connected to ground through a contracting carbon brush 32, lead 34 and microammeter 36. An ion gun 38 is positioned on the opposite

side of the path of advance of the film fibril material 22 from the target electrode and is connected to a high voltage source of direct current (D.C.) power 40 through lead 42. Preferably, a negative D.C. source in the range of from 45 to 70 kilovolts is used. The electrical potential which is provided between ion gun 38 and target electrode 20 ionizes the solvent gas between the two and the ionized gas molecules attach themselves or deposit a charge on the moving fibrous material 22.

Referring now to FIGS. 2-5, the arrangement of a U-shaped ion gun 38 opposite annular target electrode 20 with the deflector 18 centered within electrode 20 is shown in FIG. 2. In the U-shaped embodiment, the ion gun 38 includes a conductive tubular housing 44 with numerous ports 46 along its length. Connected to each end of housing 44 is a conductive resistor enclosure 48. Housing 44 and enclosure 48 are joined in such a manner to form a good electrical connection between them, thereby providing a conductive sheath surrounding the internal components of ion gun 38. The entire ion gun structure is supported by support arms 50 which are composed of electrical insulating material and are cemented to housing 44. The lower portion of U-shaped housing 44 is generally oval in cross section (FIGS. 3 and 5) and fabrication is accomplished by selecting a straight length of tubing, e.g., aluminum, flattening a portion of the tubing to the desired oval shape then bending the flattened portion into a U-shape.

The oval shape may be obtained by inserting a flat bar having rounded-edges into the undeformed tube then hammering or pressing portions of the tube so as to deform it to the desired cross-section. The step of bending the tube into a U-shape is best carried out by temporarily filling the entire interior of the tube with a soft, easily bent metal alloy having a very low melting point such as "Cerroband," by carrying out the bending operation on a conventional three-roll former or in a press and, finally, by heating the tube to melt and remove the temporary metal filling. In the lower portion of the tubular housing 44, spaced from each other with a chordal distance of about 0.965 cm. (or 7°10' angular spacing), are holes 46 (FIG. 2). As best shown in FIG. 5 each hole 46 is occupied by an insulative tubular insert 52 in the outer end of which is a close-fitting insulating jacket 54 and in the inner end of which is a close-fitting conductive metal bushing 56, which carries a screw thread on its interior surface. Extending through the center of the insulating jacket 54 is a corona generating needle 58 which is threadedly engaged in the metal bushing 56. Engaged in the other end of bushing 56 is a round head screw 60 to which is soldered a wire 62. Inserts 52 are, e.g., Teflon (registered trademark) fluorocarbon resin. The surface of the inserts (inside ion gun) has been chemically etched to allow adhesion to epoxy. The entire inside of the tubular housing 44 is potted with an insulative resin 64 which holds inserts in position. The axes of the needles 58 are generally at a right angle to a plane running through the left-hand face of the housing 44 as well as perpendicular to the planar surface of the target electrode 20 (FIG. 3). The needles 58 are adjusted, so that their sharp, conical points are equidistant from the surface of the target electrode 20 being spaced therefrom by about 1.3 cm. As shown in FIG. 5 a portion of the exterior surface of the housing 44 is coated with a thin layer 66 of epoxy resin, an insulating material used to reduce the tendency for corona discharge to occur between the needles 58 and the outer surface of the sheath 44.

Each wire 62 connects a needle 58 and a resistor 68 and is electrically insulated along its length from the corona generating point to the resistor. The wires 62 pass upwardly through the legs of housing 44 into the confines of one of the aluminum resistor enclosures 48 where each wire 62 is joined to one terminal of its respective resistor 68 (FIGS. 4 and 5), the resistance of these being substantially equal and being in the range of 1 to 1000

megohm. The ends of the wires 62 are insulated from each other where attached to the resistors 68 by means of insulating perforated partition 70, connected to enclosure 48. The resistors are also protected by insulative materials to prevent shorting to resistor enclosures 48 or to one another; the opposite ends of the resistors are joined to a brass bus bar 72, which along with partitions 70 supports the resistors in enclosure 48. The bus bar 72 is conductively secured to enclosure 48 which is provided with a threaded hole to receive a stud 74 connected to lead 42 which is in turn connected to D.C. source 40. Wires 62 are preferably pre-coated with insulating materials and may be further insulated by pouring insulative resins 64 or other insulating materials into the tubular housing 44 while the wires are held in position. In a completely sealed ion gun the resistor housings 48 as well as tubular housing 44 are filled with resins. A resin particularly suited for this use is Dow Corning "Dielectric Gel."

It can be readily seen from the above described structure that a charge equivalent to the D.C. source 40 (45-70 kilovolts) is placed on resistor housing 48 and tubular housing 44 by means of the electrical continuity between source 40, lead 42, stud 74 and housings 48 and 44, thus providing a charged sheath around the internal components of ion gun 38. The needles 58 are also connected to D.C. source 40 through leads 62, resistors 68, bus bar 72, housing 48, stud 74 and lead 42. The needles are charged to a somewhat lower voltage, this being equivalent to the D.C. source potential of from about 45 to 70 kilovolts minus the voltage drop in the resistors.

It can be readily appreciated that the charge placed on housings 44, 48 electrically shields the components inside these housings from ground and greatly reduces the voltage stress placed on these components which in turn minimizes degradation of insulative materials within the housings resulting in extended life for the ion gun.

In operation of the charging apparatus, a corona current at each needle 58 from about 5 to about 30 microamps is adequate, with between 10 and 20 microamps per needle being preferred for charging a film-fibril network. At these low currents of 5 to 30 microamperes per point and in the absence of the resistors 68 the effect of fluctuations in the dynamic resistance between electrodes would be magnified. The ion gun described herein, however, provides a high impedance circuit to each point so that normal fluctuations in the effective dynamic resistance of corona discharge have little effect on emitted current. This is done by using a resistance 68 of sufficient magnitude in series with each needle 58 to provide a voltage drop of at least about 3,000 volts. In a typical ion gun target configuration the effective dynamic resistance of corona discharge is about 60 megohms, whereas the resistance placed in series with each needle 58 to provide a corona current of at least 5 microamps is typically 600 megohms and for 12 to 20 microamps is typically 270 megohms. Use of the resistors 68 makes the needle-to-needle current variations much less sensitive to such factors as point/target spacing.

The position of corona generating needles 58 with reference to target electrode 20 is important for efficient operation. It will be apparent that the clearance between the needles and the target electrode should be as small as efficient operation will permit. Generally, a clearance of from about 1 cm. to about 2.5 cm. is satisfactory although this will vary with the design and capacity of the particular equipment.

It should be noted that as the distance between the needle points and the target electrode is reduced, the total applied voltage across the resistor and the gap should be reduced to keep the current per point in the 5-30 microampere range. In addition, as the needle point-to-electrode distance is decreased it is desirable to increase the number of points per inch in order to deposit a uniform charge on all parts of the web of fibrous elements, provided the diameter of the inserts 52 is maintained large enough to prevent discharge from the nee-

5

dles to the conductive sheath or an insulating layer 66 is applied to the exterior of housing 44 (FIG. 5). On the other hand, when increasing the distance between the needle points and the target electrode the voltage should be increased and/or the number of points per cm. decreased. For optimum operation, the points should be equally spaced along the tubular housing 44. It has been found convenient in developing dimensions for the ion gun and target electrode to create a carbon black deposit on target electrode 20 by spraying powdered carbon black into the operating area between the plate and the gun. An oval pattern is outlined by carbon deposits opposite each needle indicating the area of electrostatic influence of each needle under the particular conditions employed. The pattern laid down by single points are centered the same distance apart as the needles. The shape and size of the oval varies depending on needle to target spacing.

Making the circle diameter for the needles smaller (at the same current level and same target plate diameter) results in pinning or clinging of the web to the target electrode. This results in bunching for an instant, an uneven discharge across the web width, and a falling free of the bunched web to give a non-uniform sheet. On the other hand, if the ion gun is aimed too near the outer edge of the target electrode, secondary ionization will develop at the edge of the target electrode 20 generating ions of opposite polarity which will tend to discharge the web. Thin layer 21 of epoxy resin at the outer peripheral edge of target electrode 20 (FIG. 3) is useful in reducing secondary ionization at the edge of the target electrode by eliminating a sharp conductive edge. Smooth operation of this equipment with uniform laydown on the collection surface was readily obtained. In the optimum arrangement the outside diameter of the target electrode 20 was 19.2 cm., the inside diameter of the epoxy layer 21 on the face of the target electrode was 18.4 cm. and the diameter of the circular ring of needles 58 in the ion gun was 16.5 cm.

Considering again FIGS. 1 and 3 the flow of solvent gases tends to aspirate additional gases indicated by the arrows over the tubular portion 44 of the ion gun 38 on the side nearest the spinneret 10. It is to be noted that the inner surface 45 (FIG. 3) of the ion gun is conical and generally concentric with the conical surface 47 of the spinneret 10. Thus there is smooth flow of the atmospheric gases over the U-shaped ion gun into the flow line provided by the solvent escaping from the orifice 14. In a similar manner, gas is aspirated along the bottom surface of the target electrode 20 and is carried toward and past the back surface of the thin outer epoxy-covered edge 21 of target electrode 20. Because of the aerodynamic design, turbulence is minimized and the formation of the low pressure area along the face of the target electrode 20 is maximized. This permits the fibrous web 22 to ride close close to the target electrode surface in a zone of high voltage gradient and maximum charging efficiency.

This invention has been described in detail with reference to a U-shaped apparatus, other shapes are equally suitable. For example, the tubular housing of the apparatus may be perfectly straight. Likewise it may have resistor housings on either one or both ends. However, it is obvious that the shape of the ion gun should conform to the shape of the target electrode edge, since the gun should be aimed close to the outer edge of the target electrode, e.g., in the U-shaped embodiment the gun is positioned so that the outer circular edge of the target electrode is concentric with the curved portion of the U-shaped housing of the gun.

An important consideration in the design of the tubular part of the apparatus is the need for maintaining minimum resistance to flow of the flash-spinning solvent and of the entrained atmosphere. This is facilitated by the concentricity between the proximal surfaces of the spinneret and the tubular housing of the ion gun and the remote location of the resistor enclosures 48 relative to the path

6

of the gas stream flowing over the lower part of the U-shaped tube.

While the ion gun has been shown in connection with flash spinning, it obviously is useful with other modes of spinning such as, melt spinning and dry spinning.

It is apparent that many modifications may be made in the disclosed apparatus without departing from the spirit of my invention which is, therefore, intended to be limited only by the scope of the appended claims.

What is claimed is:

1. In an apparatus for applying an electrostatic charge to fibrous elements forwarded along a path, an ion gun comprising:

- (a) a plurality of needles in fixed parallel spacial relationship disposed across one side of said path;
- (b) a direct current source of high voltage power;
- (c) means connecting each needle to said source of high voltage power; and
- (d) a conductive sheath connected to said high voltage source, said sheath enclosing and reducing the voltage stress on said connecting means.

2. The apparatus of claim 1 wherein each connecting means includes a high impedance resistor.

3. The apparatus of claim 2 wherein said conductive sheath includes a U-shaped tubular housing and an enclosure joined to at least one end of the tubular housing, said enclosure being connected to said high voltage source, said resistors being mounted in said enclosure and having one end connected thereto, the other end of said resistors being connected to said needles, said needles projecting from said tubular housing and being electrically insulated therefrom.

4. An apparatus for applying an electrostatic charge to fibrous elements forwarded along a path, said apparatus comprising:

- (a) a grounded target electrode disposed on one side of said path;
- (b) a plurality of needles in fixed parallel spacial relationship disposed completely across the opposite side of said path, said needles having points directed toward said target electrode;
- (c) a direct current source of high voltage power;
- (d) means connecting each needle to said source of high voltage power, each connecting means including a high impedance resistor; and
- (e) a conductive sheath connected to said high voltage source, said sheath enclosing and reducing the voltage stress on said connecting means.

5. The apparatus of claim 4 wherein said conductive sheath includes a U-shaped tubular housing and an enclosure joined to each end of the tubular housing, the interiors of said enclosure and said tubular housing being in communication, said enclosure being connected to said high voltage source, said resistors being mounted in said enclosure and having one end connected thereto, the other end of said resistors being insulated from said enclosure and said housing and being connected to said needles, said needles projecting from said tubular housing and being electrically insulated therefrom.

6. The apparatus of claim 5, said target electrode having an outer circular edge concentric with the curved portion of the U-shaped housing.

7. The apparatus of claim 5, said tubular U-shaped housing and said enclosure being filled with an insulative resin.

References Cited

UNITED STATES PATENTS

3,387,326 6/1968 Hollberg et al. ----- 264—24 X

J D MILLER, Primary Examiner

A. D. PELLINEN, Assistant Examiner

U.S. Cl. X.R.

18—8; 317—262