

United States Patent

Flournoy et al.

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[54] FILAMENT PLATING SYSTEM

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[51] Int. Cl. C23c 13/10

[58] Field of Search 118/48-49.5, 47, 118/235; 277/135; 117/113-115, 107.1, 107.2; 28/1.6; 148/188; 242/155 M, 156, 25

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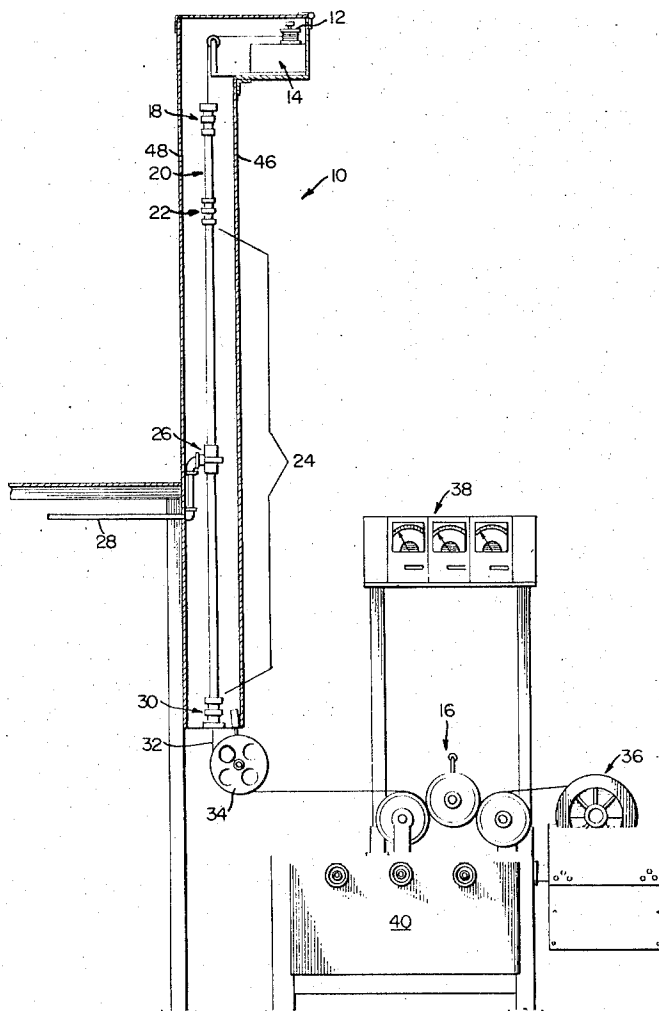
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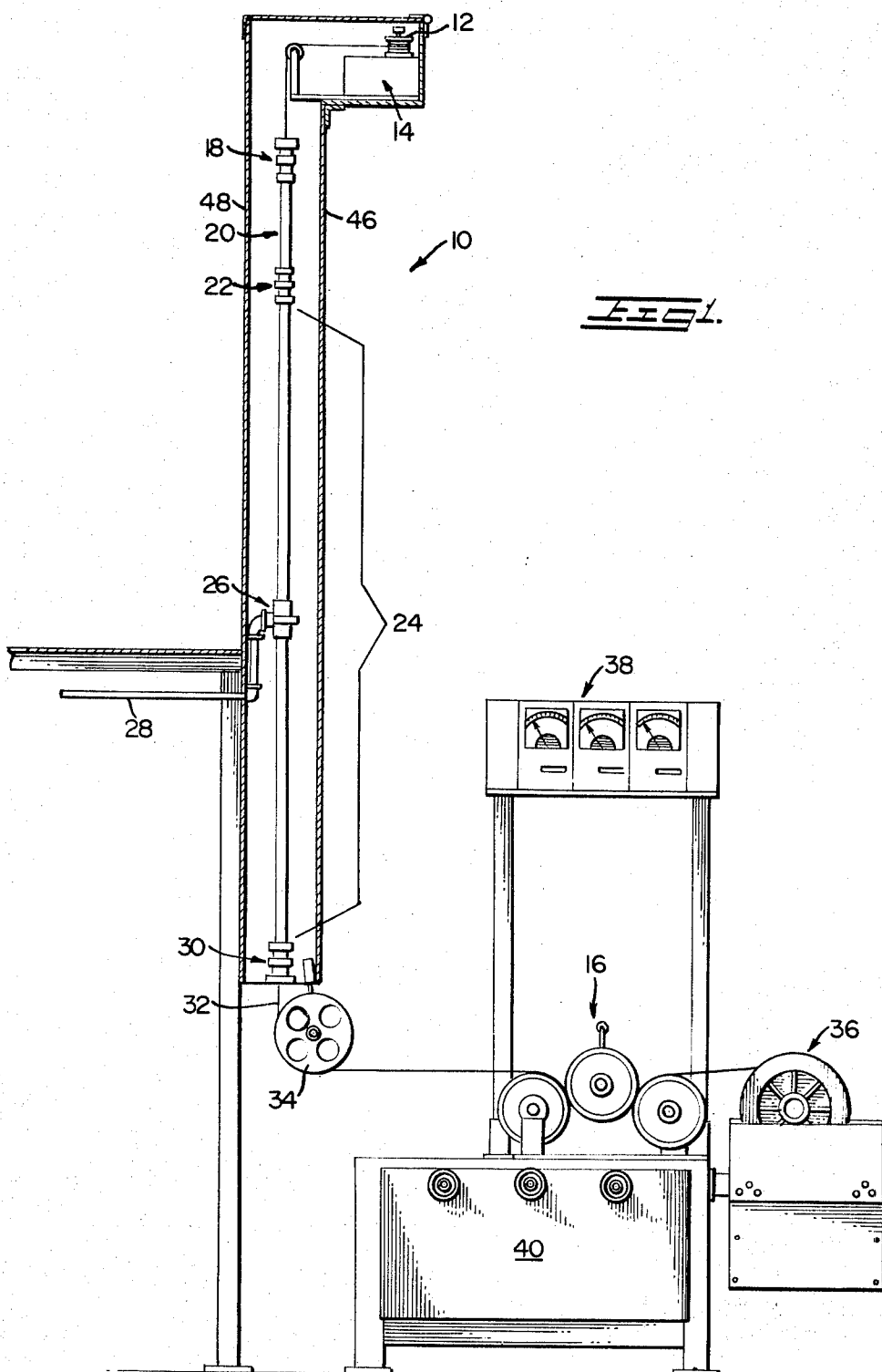
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[57] ABSTRACT

A plating system for a fine conductive substrate is provided wherein the substrate is pulled from an eddy-current brake type letoff unit through combination gas seals and electrical contact units to and through a plating chamber and outlet gas seals and electrical contacts by a capstan-drive speed regulating mechanism. After leaving the capstan-drive unit the plated filament is random wound on a spool which is friction driven via its rim so that tension in the plating chamber is independent of spool tension and which drive automatically compensates for changes in diameter as spooling progresses.

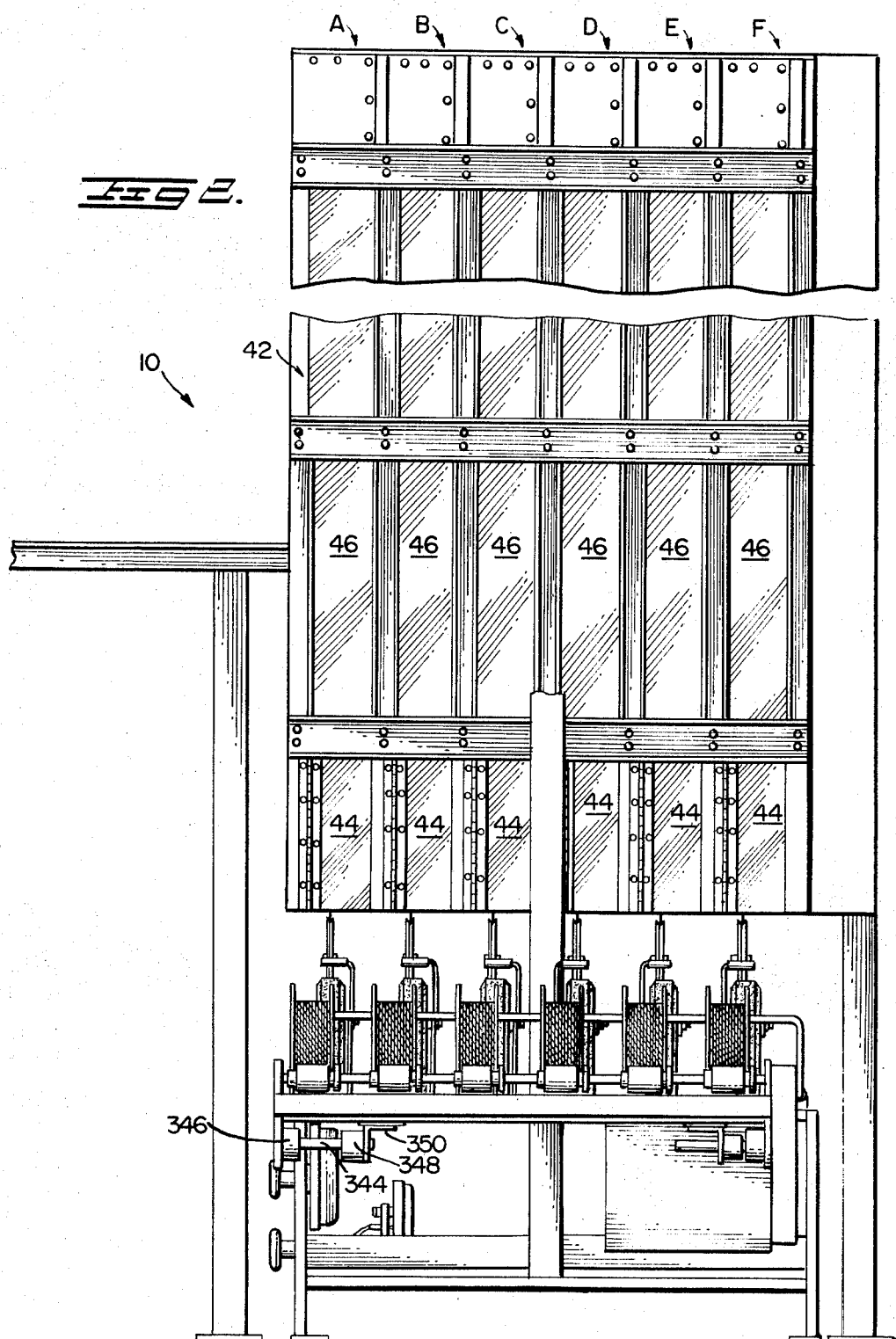
14 Claims, 22 Drawing Figures





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FIG 3.

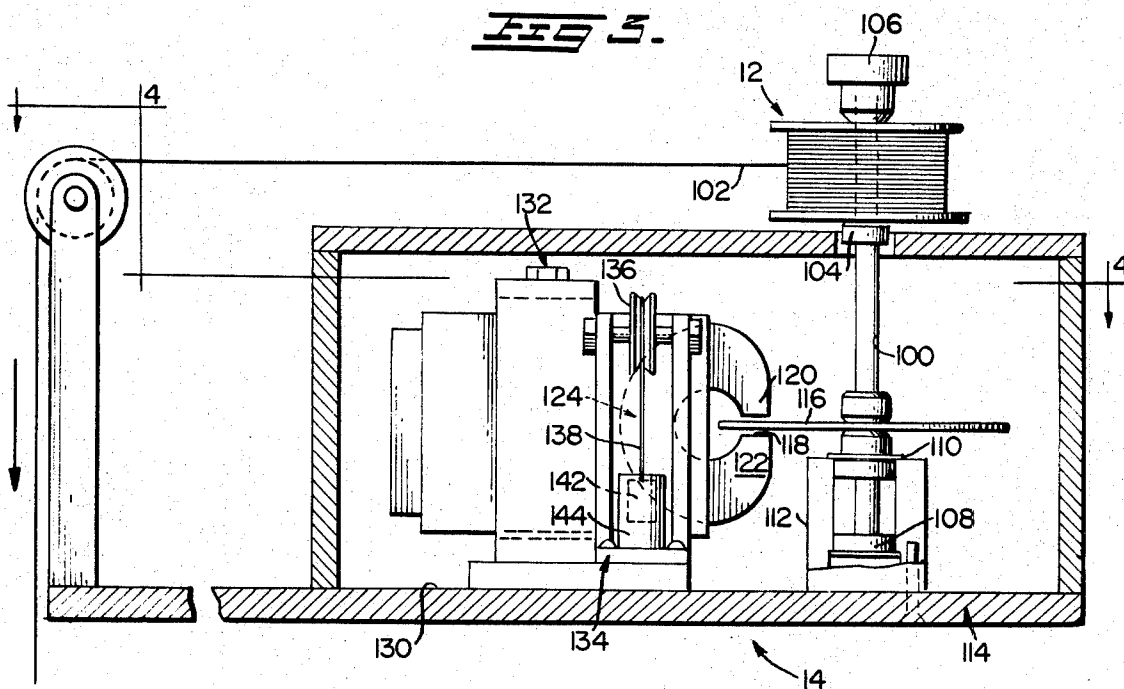
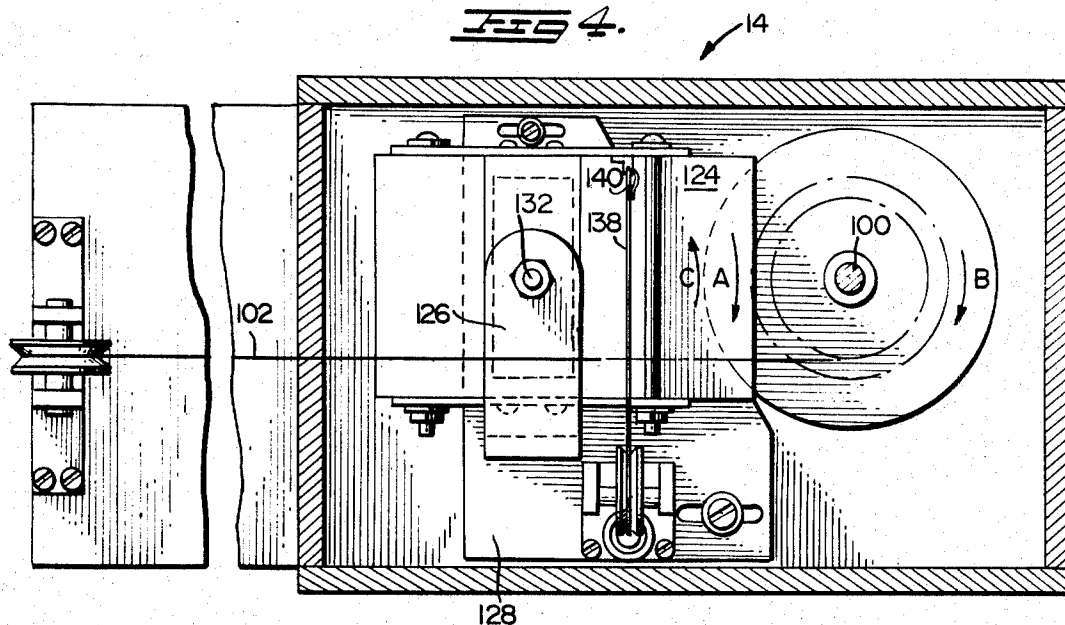


FIG 4.



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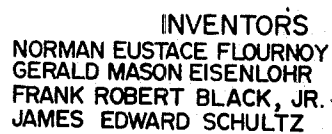
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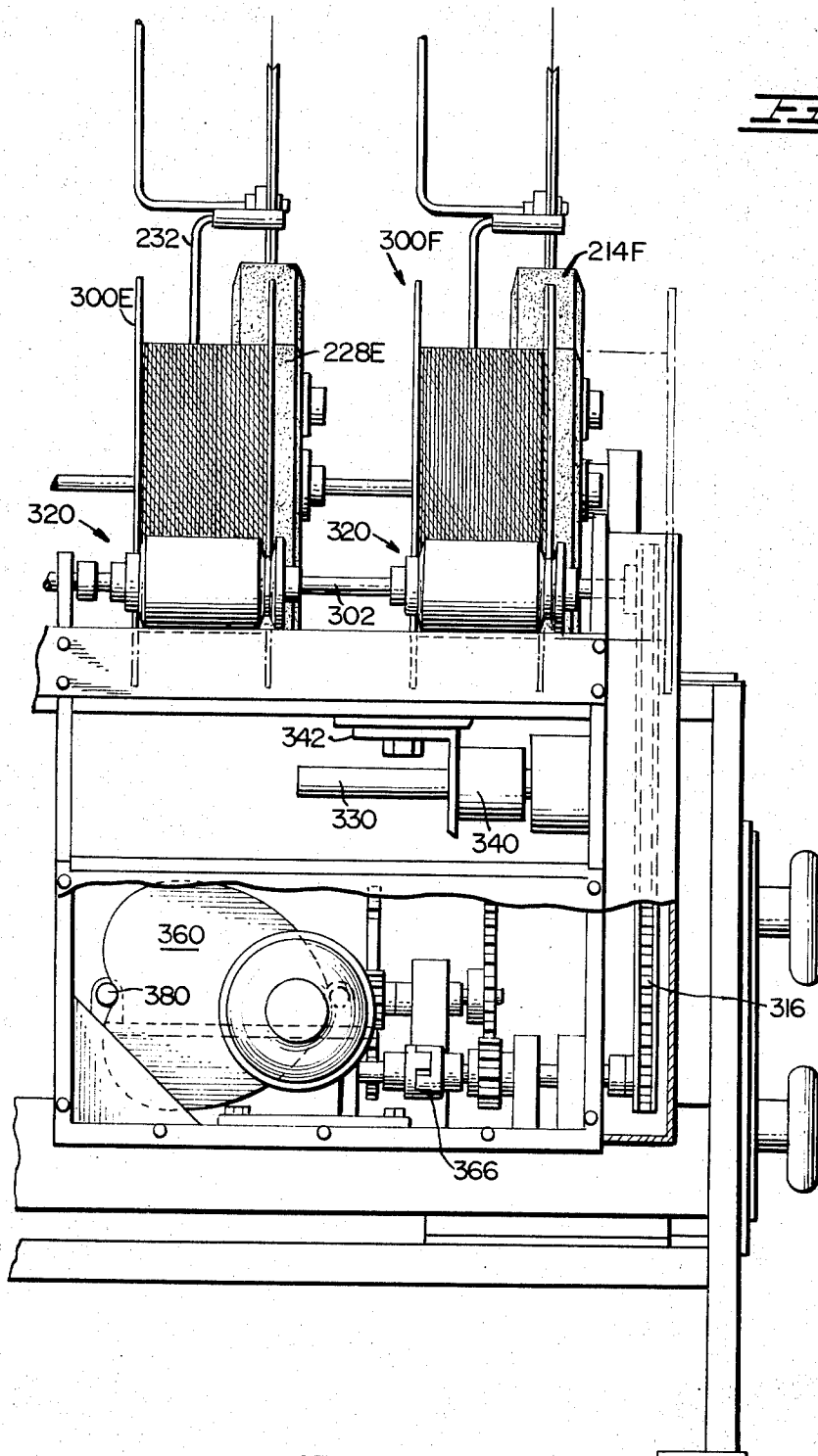
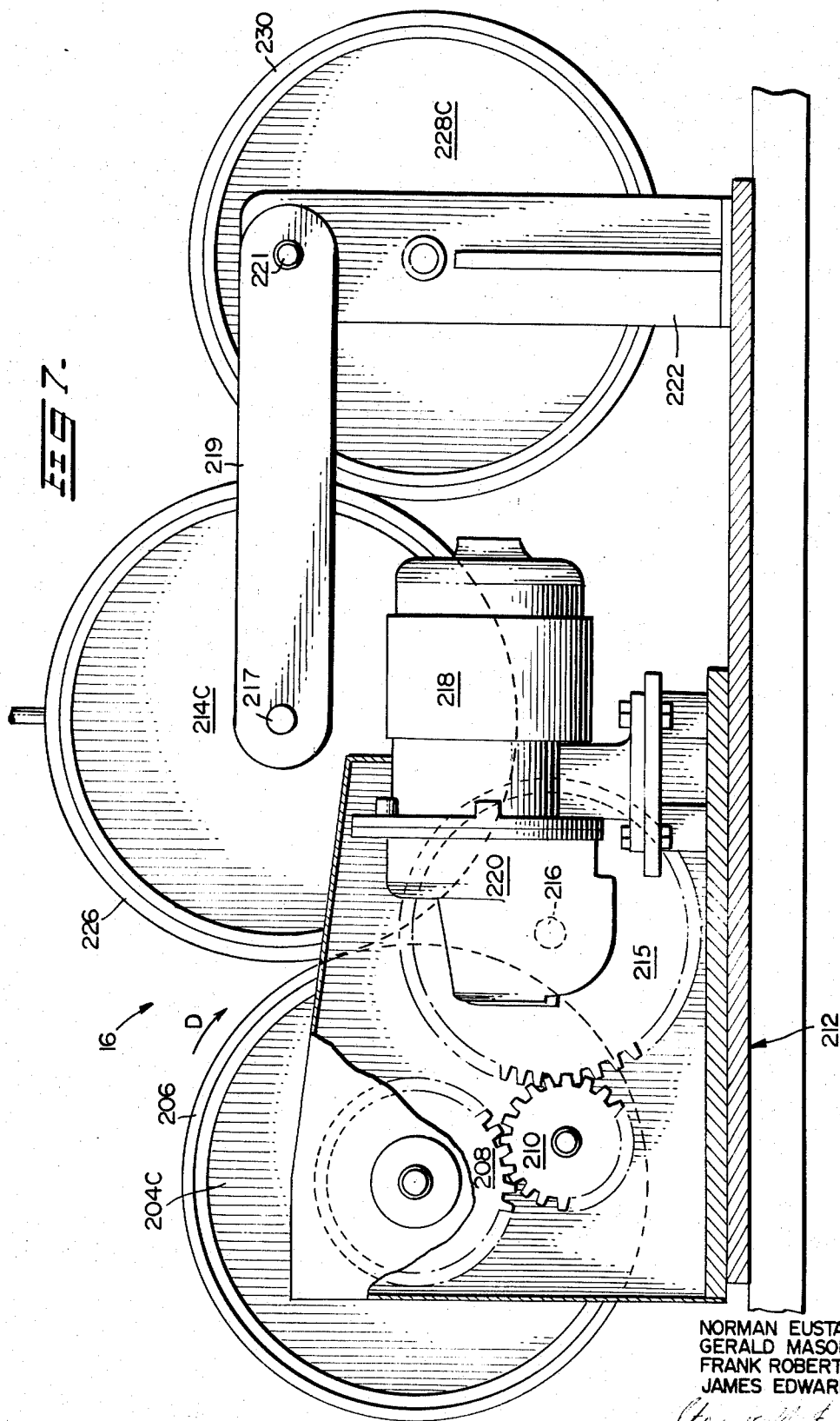


FIG. 6.

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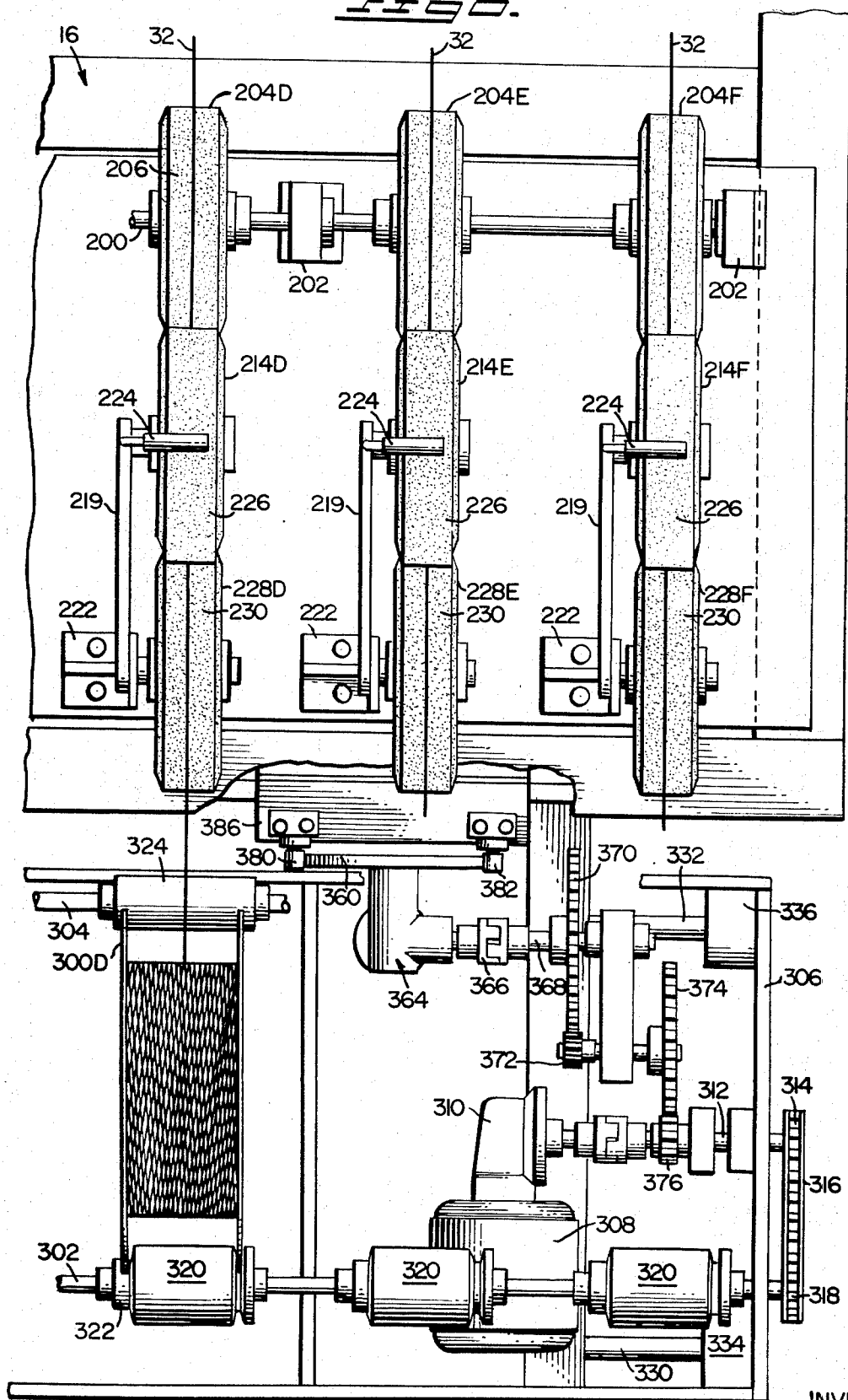
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FIG. 8.



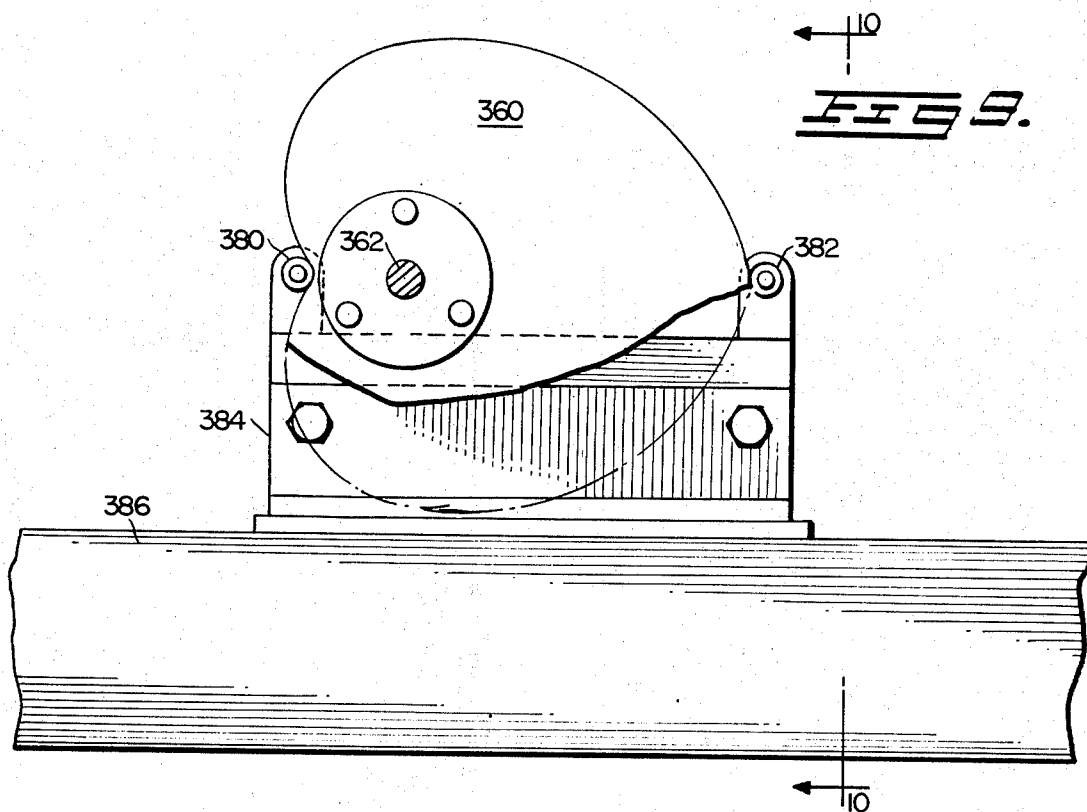
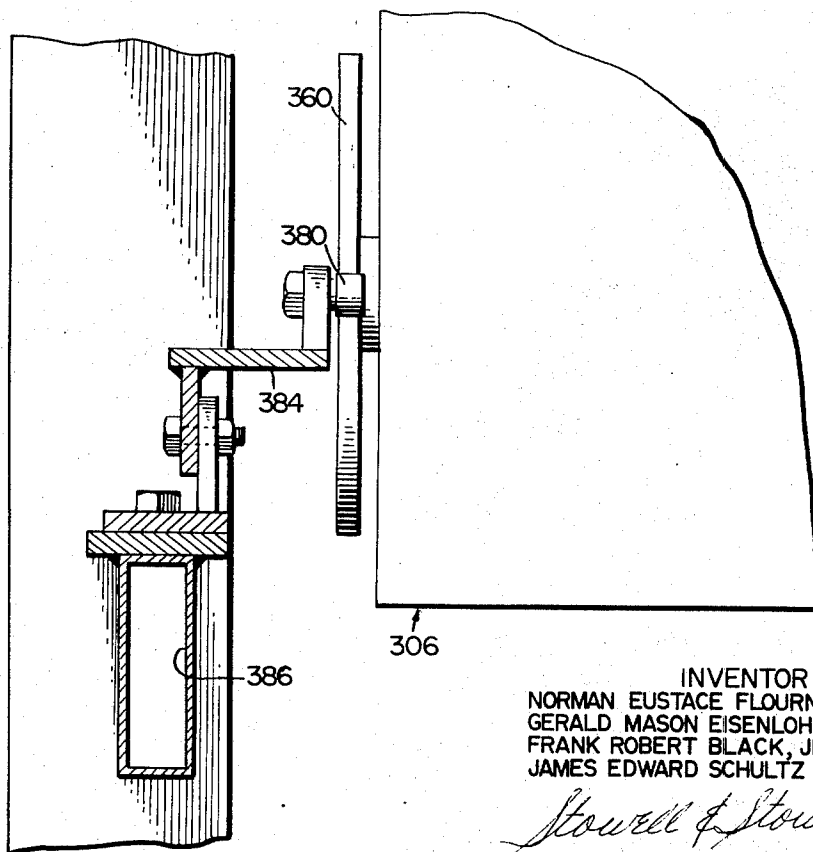


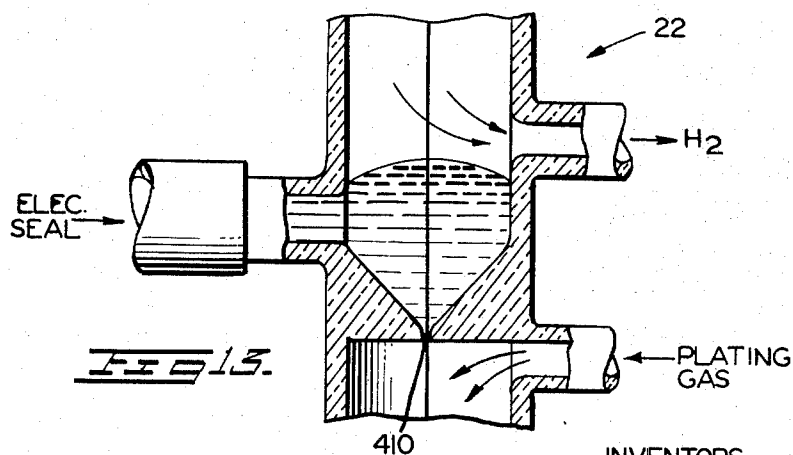
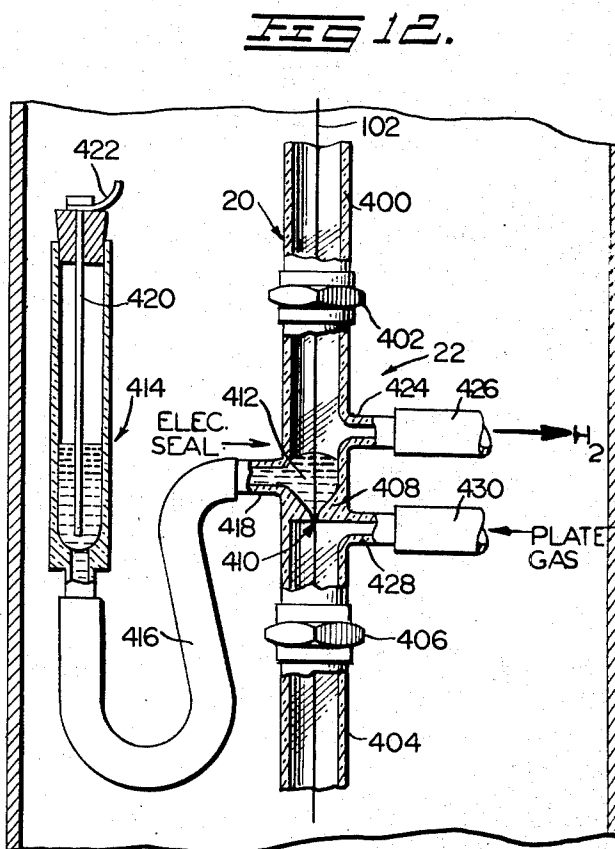
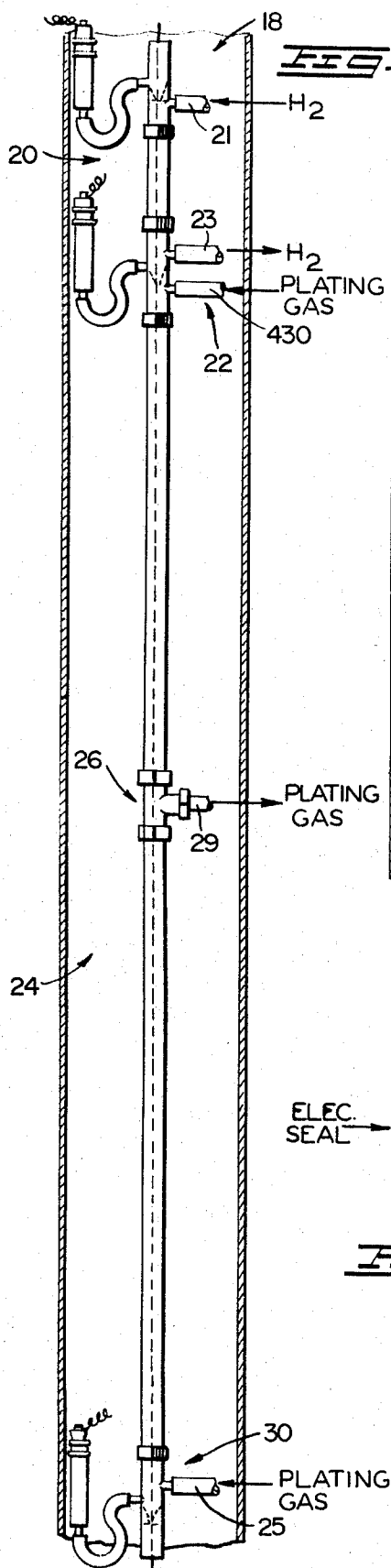
FIG. 10.



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FIG 14.

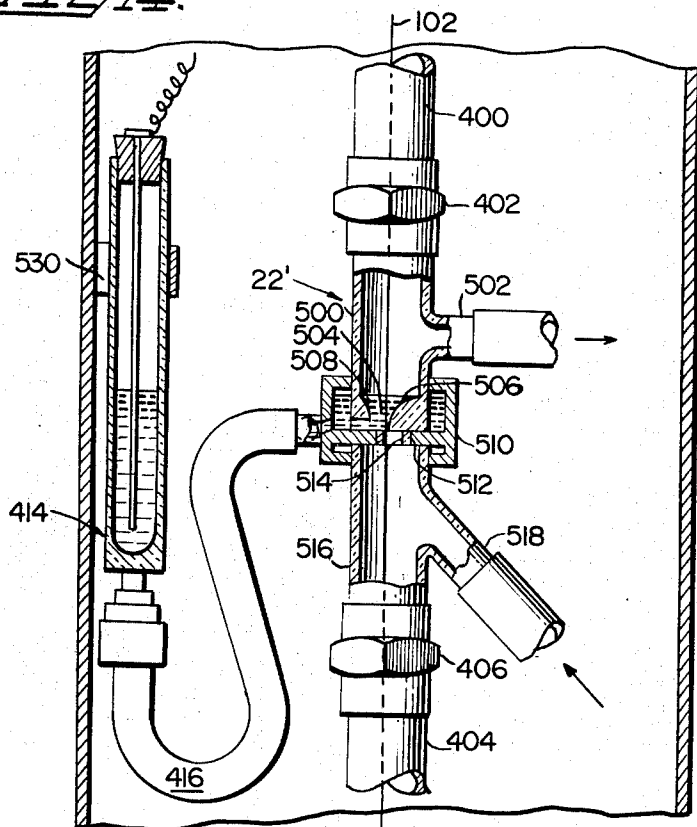


FIG 15.

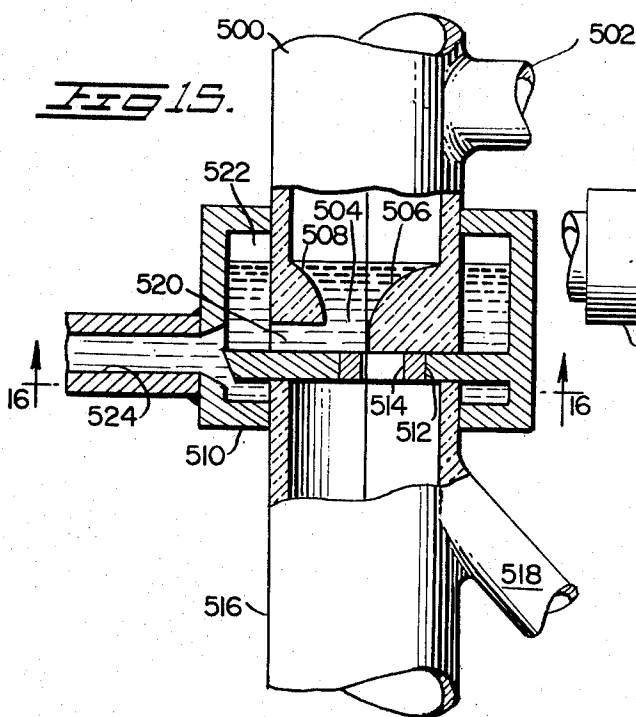
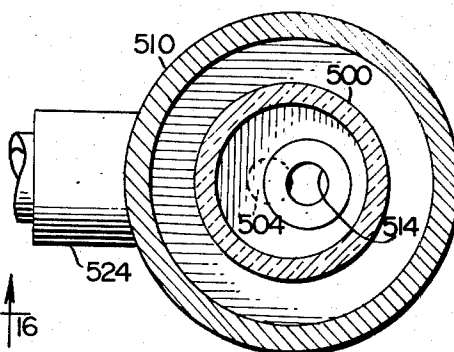


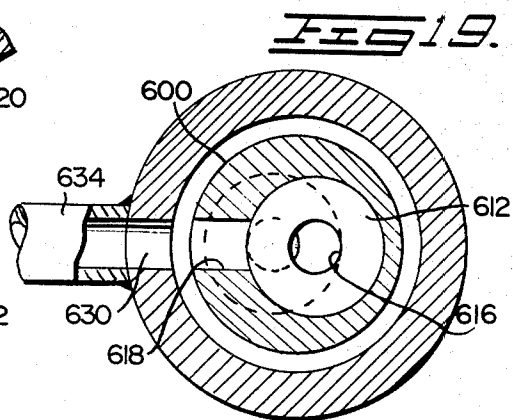
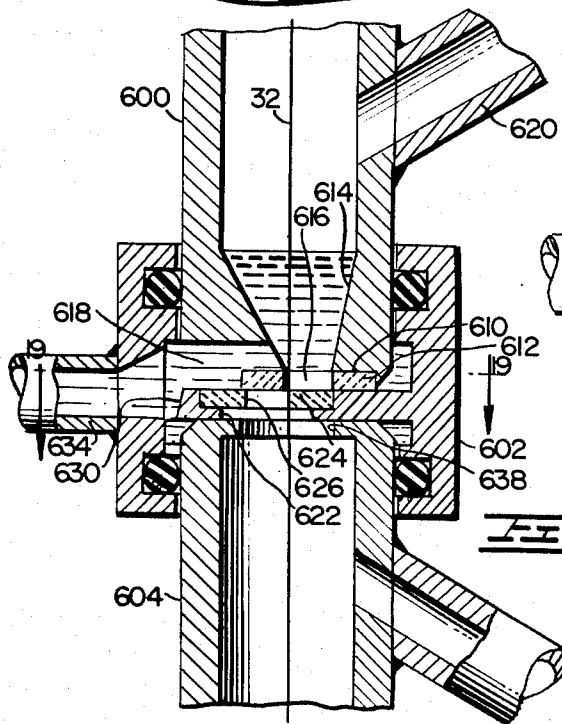
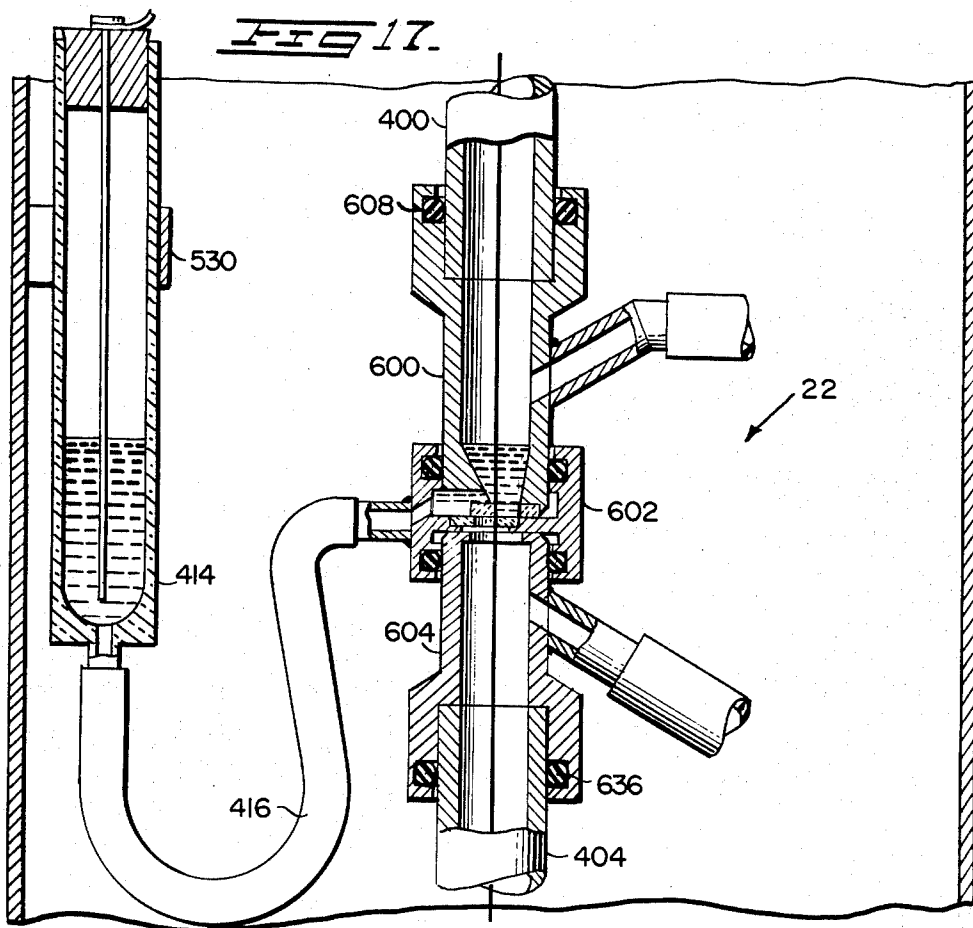
FIG 16.



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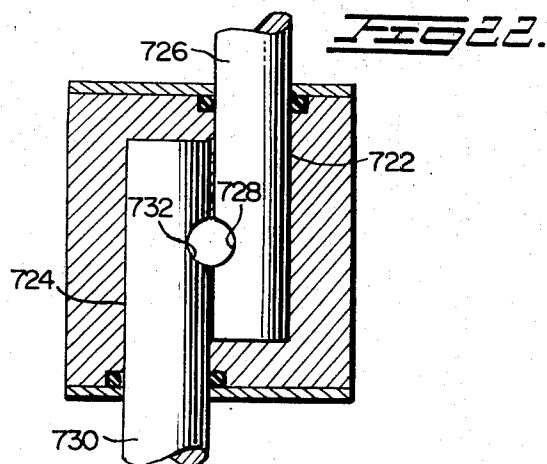
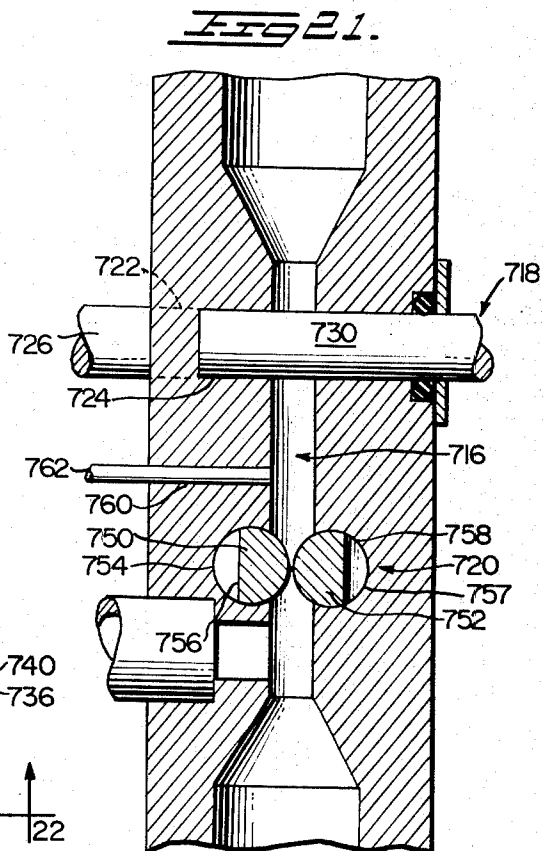
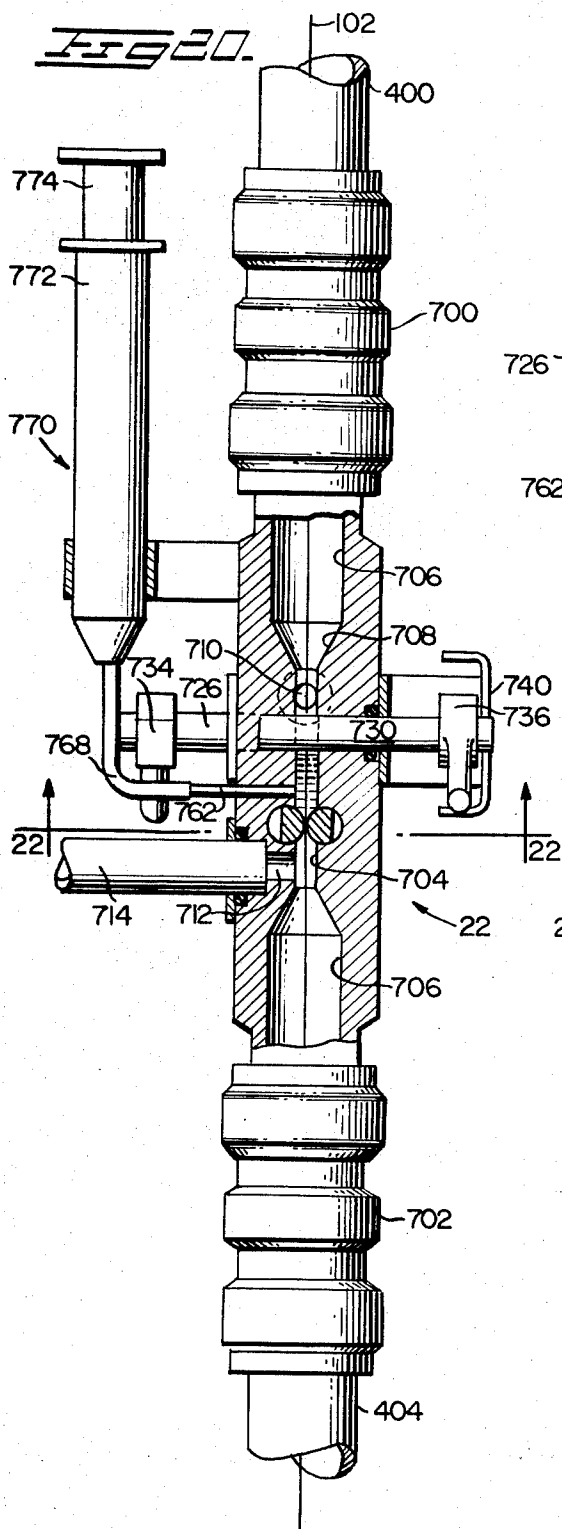
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FILAMENT PLATING SYSTEM

This invention relates to a system for making high strength refractory filaments, the term filaments being used herein to denote elongated elements of various cross-sectional shapes including ribbons.

The invention is particularly directed to a system for making high strength refractory filaments of unrestricted length comprising or coated with boron.

The high strength refractory filaments made by the system of the invention are particularly useful for the production of composite structures comprising a random or regular array of such filaments embedded in a plastic, elastic, vitreous, metallic, ceramic or cementitious matrix.

Unrestricted lengths of high strength refractory filaments are produced by passing an elongated substrate at a substantially constant speed through an ambient gaseous composition containing a vaporizable compound of boron while maintaining the filamentary substrate at a temperature effective to cause the deposition of boron on the substrate. Typically, the gaseous composition may consist of or comprise a thermally decomposable halide or hydride of boron or a mixture of such a halide with hydrogen. For example, the gaseous composition may comprise a mixture of boron trichloride and hydrogen. At least a portion of the substrate in contact with the gaseous composition is maintained at a temperature above about 1,850° F but below the melting points of boron and the substrate, and particularly in the range from about 1,900° F to about 2,400° F, a massive deposit of amorphous or microcrystalline boron is deposited on the substrate to form filaments of high tensile strength.

As used herein the term "microcrystalline" is used to designate structures in which the mean diameter of the crystals contained therein does not exceed the order of 100 Angstroms as determined by X-ray diffraction. Structures having a mean crystal diameter exceeding the order of 100 Angstroms are considered macrocrystalline. The speed of the substrate through the zone of contact thereof with the gaseous composition is adjusted with respect to the temperature thereof and the rate of deposition of the boron to obtain a deposit of the desired character and thickness.

Among the substrates which can advantageously be used for the preparation of boron filaments are tungsten, rhenium, tantalum, titanium, molybdenum, iron, copper, nickel, nichrome, aluminum, magnesium and graphite.

The filament plating system of the invention is particularly useful for high capacity production in generally vertical filament flow modules and in the illustrated form of the invention the module is a six station machine with certain of the mechanisms in each of the six stations being independent of one another while other of the mechanisms are unitary and interdependent.

The novel features of the filament plating system will be more particularly described in reference to the accompanying drawings wherein:

FIG. 1 is a side elevational view, particularly in section, of one module of a vertical filament production unit;

FIG. 2 is a front elevational view of the apparatus illustrated in FIG. 1;

FIG. 3 is an enlarged fragmentary, partial section view of the letoff mechanism for the apparatus shown in FIGS. 1 and 2;

FIG. 4 is a sectional view, substantially on line 4—4 of FIG. 3 with the spool of substrate being indicated in phantom lines;

FIG. 5 is an enlarged partial sectional view through the capstan drive and spooling mechanism for the plated filament;

FIG. 6 is an enlarged fragmentary partial section view of the takeup spool rotating mechanism and the random winding traversing mechanism;

FIG. 7 is an enlarged fragmentary partial sectional view through a portion of the capstan wheel drive mechanism for the filament;

FIG. 8 is an enlarged fragmentary partial sectional view illustrating the random winding mechanism;

FIG. 9 is a view of the constant diameter eccentric and followers for the random winding mechanism;

FIG. 10 is a view on line 10—10 of FIG. 9;

FIG. 11 is an enlarged fragmentary view of the degassing and plating sections of the apparatus shown in FIG. 1;

FIG. 12 is an enlarged vertical sectional view through the combination gas seal and electrical connector, generally designated 22 in FIG. 11;

FIG. 13 is a greatly enlarged vertical sectional view through a portion of the structure shown in FIG. 12;

FIG. 14 is an enlarged fragmentary partial vertical sectional view of a modified form of gas seal;

FIG. 15 is an enlarged fragmentary detail of a portion of the structure shown in FIG. 14;

FIG. 16 is a section substantially on line 16—16 of FIG. 15;

FIG. 17 is an enlarged fragmentary vertical sectional view through another form of gas seal;

FIG. 18 is an enlarged vertical sectional view of a portion of the structure shown in FIG. 17;

FIG. 19 is a section substantially on line 19—19 of FIG. 18;

FIG. 20 is an enlarged fragmentary partial sectional view of a further form of gas seal means;

FIG. 21 is a vertical sectional view of a portion of the structure shown in FIG. 20; and

FIG. 22 is a section substantially on line 22—22 of FIG. 20.

Referring particularly to FIGS. 1 and 2 of the drawings, 10 generally designates a vertical production module consisting of a six station filament plating machine. In each of the six stations, more clearly shown in FIG. 2 and designated A, B, C, D, E and F, a spool 12 of, for example, 0.5 mil tungsten is pulled from a letoff mechanism generally designated 14, by a capstan drive wheel arrangement generally designated 16, which, as to be more fully described hereinafter, is driven by a single gear head motor which serves each of the six stations. After leaving the letoff mechanism 14 the substrate passes through a first mercury gas seal and electrical contact means 18 into an out-gassing chamber 20 where the substrate is heated electrically to, for example, 2,200° F. and wherein the substrate is exposed to a flow of hydrogen gas.

A second gas seal and a further electrical contact means is generally designated 22 and is positioned at the lower end of the out gassing chamber 20. From the

second seal 22 the heated substrate passes into the plating chamber 24 having central plating gas outlet connection 26 connected to return conduit 28, whereby the plating gases flow upwardly and downwardly to the centrally positioned outlet means 26. The plated filaments 32 exit from the lower gas sealing means 30 and pass about an idler wheel 34 to enter the capstan drive assembly 16 which serves to regulate the speed of passage of the substrate through the processing chambers 20 and 24.

From the capstan wheel drive means 16, the plated filaments pass to a rim driven take-up spooling means generally designated 36. Suitable monitors such as illustrated at 38 and electrical control means 40 are mounted adjacent the spooling mechanism and capstan driving means 36 and 16 as more clearly shown in FIG. 1 of the drawings.

Each of the plural runs or stations of the module are encased in vertical housing members 42 having openable doors at the upper and lower ends through which the filaments to be plated may be inserted into the chambers with the lower doors being designated 44 and illustrated in FIG. 2. Further, the front and back panels 46 and 48 are constructed of glass or clear plastic so that the operators may visually ascertain if malfunctions or the like exist in the purging chamber 20, or the plating chamber 24.

Referring particularly to FIGS. 3 and 4 of the drawings there is illustrated the improved substrate letoff units 14. It has been found that in order to produce satisfactory filament having a predetermined diameter in unrestricted lengths an exacting substrate tensing means is required, which will maintain the substrate at a relatively uniform tension through a limited range of changes of travel speed of the substrate through the treating chambers. Apparatus suitable for maintaining such uniform tension through a limited range of letoff speeds is illustrated in FIGS. 3 and 4 and generally comprises a spindle 100 adapted to receive a spool 12 of fine, for example, tungsten filament 102, between a lower fixed flange 104 and a removable flange 106 threadedly received at the upper end of spindle 100.

The lower end of the spindle 100 is suitably mounted in spaced bearing means 108 and 110 carried by bearing housing 112 suitably mounted to a housing generally designated 114 for the letoff mechanism. Between the upper bearing 110 and the lower spool flange 104 is mounted a non-magnetic disc 116. In the illustrated form of the invention, disc 116 comprises aluminum. An outer segment of the aluminum disc 116 is adapted to rotate in the air gap 118 formed between pole pieces 120 and 122 of permanent magnet 124. Permanent magnet 124 is pivotally mounted in a U-shaped yoke member 126 which yoke is secured to frame member 128 secured to the upper surface of base 130 of housing 114. The upper bearing 132 for the magnet 124 is illustrated in FIGS. 3 and 4 and the cooperating lower bearing is not illustrated in the drawing whereby the permanent magnet 124 and its housing is free to pivot on an axis generally parallel to the axis of spindle 100. The base 128 carrying the yoke 126 also supports a stand generally designated 134 at the upper end of which is rotatably mounted a pulley or sheave 136 about which is trained a cord 138. One extended

end of the cord is secured to the frame carrying the permanent magnet 124 at 140 while the other end of the cord 138 is secured to a weight 142 moveable in a housing 144 forming a part of standard 134.

The weight 142 and its attach cord 138 normally bias the permanent magnet 124 in the direction of directional arrow A, FIG. 4 of the drawing. Upon drawing the substrate 102 from the spool 12 the spool rotates in the direction of directional arrow B, FIG. 4, and for a particular speed of rotation of the spool, its spindle 100 and the aluminum disc 116, the permanent magnet 124 will pivot in the direction of directional arrow C to reduce the number of lines of force cut by the rotating disc 116, to thereby establish a balance between the urging of the permanent magnet 124 in the direction of directional arrow A by the weight 142 and rotation of the permanent magnet 124 in the opposite direction to reduce the number of lines of force being cut for a particular speed of rotation of the aluminum disc 116. The braking effect is the resistance to rotation of the disc 116 through the air gap 118 of the magnet. If optimum plating occurs at a higher feed rate for substrate 102 causing the disc 116 to rotate at a greater speed, tension on the substrate 102 remains constant as the number of lines of force cut by the disc 116 is further reduced by further pivoting of the permanent magnet 124 in the direction of directional arrow C. Conversely, if the speed of rotation of the disc 116 is reduced, reducing the eddy current effect, the permanent magnet 124 would then return to some equilibrium point in the direction of directional arrow A. Thus it will be seen that through a predetermined range, a relatively uniform drag is maintained on the rotating disc 116, and in turn the spool 12, to maintain relatively constant the tension on the substrate 102 as it passes through the treating chambers.

Referring particularly to FIGS. 5, 7, 8 and 9, the capstan drive mechanism for the filament, generally designated 16, comprises in detail a first shaft 200 journaled in a plurality of spaced bearing blocks 202. Secured to the shaft 200 are six drive wheels 204 A, B, C, D, E and F corresponding to plating chambers A to F. Each of the wheels 204 A through F has an outer peripheral surface or rim 206 preferably constructed of synthetic or natural rubber to provide some resiliency for the surface contacting the plated filaments 32. Centrally of the shaft 200 is a fixed gear 208 which meshes with an idler gear 210 suitably mounted adjacent the bed 212 of the capstan drive mechanism. Idler gear 210 is driven by gear 215 connected to shaft 216 which in turn is connected to motor 218 via motor reduction gearing means 220 all more clearly shown in FIG. 7, whereby upon actuation of the electric motor 218 shaft 200 drives each of the six drive wheels 204 A through F in the direction of directional arrow D, FIGS. 5 and 7 of the drawing. The assembly also includes idler wheels 214 A through F, one for each drive wheel 204 A through F. Each of the idler wheels 214 is mounted on a suitable shaft 217 carried at the extended ends of pivot arms 219. The opposite end of each of the pivot arms 219 is pivotally mounted on a pin 221 carried by each of the standards 222 for each assembly, which standards are secured to the base 212 of the capstan drive mechanism, whereby the wheels 214 may be individually raised by suitable handle means 224 to

facilitate stringing the filaments during set-up of the plating apparatus. The outer peripheral surface or rim of each of the wheels 214 is also provided with a resilient band 226 whereby when the wheels 214 are in the position illustrated in FIGS. 5, 7 and 8 the filament associated therewith is effectively retained in the nip between rolls 204 and 214 and is cushioned by the resilient surfaces 206 and 226. Each of the capstan drive mechanisms also includes a third idler wheel means 228 A through F; one for each of the drive wheels 204 A through F.

Each of the idler wheels 228 A through F is mounted for rotation on suitable bearing shafts carried by the respective standards 222. The spacing between the axis of rotation of the wheels 228 relative to the axis of rotation of wheels 224 is such that when the idler wheels 214 are in their operative positions as illustrated, for example, in FIG. 7, wheels 228 are driven via contact with idler wheels 214, which in turn are driven by driven wheels 204. The outer peripheral surfaces of wheels 228 are also provided with resilient rims 230 which act as a cushion as the filaments pass over a portion of the upper peripheral surfaces of the last in a series of idler wheels 228, thence through guide members 232 (FIG. 5) to feed onto spools of the spooling mechanism generally designated 36.

In order to vary the speed of travel of the substrate through the plating chamber, a synchronous electric motor 218 is connected to the source of electric current and the speed of rotation of the driven wheels 204 of the capstan drive assembly is effectively controlled by use of change gears or the electric motor could be connected to the electric current through a suitable rheostat. The plated filaments paying from the upper surfaces of the last of the idler wheels 228 are under substantially zero tension, but for the tension applied by the random winding mechanism generally designated 36, which will be described in greater detail in reference to FIGS. 1, 2, 5, 7, 8, 9 and 10. Referring to these drawings, each of the plating stations A through F is provided with its own takeup reel 300 A through F. These spools 300 A through F are of the central hub, flanged sidewall type with the flanges adapted to engage a pair of shafts 302 and 304 carried in a traversing frame assembly generally designated 306. The spacing between shafts 302 and 304 in traversing frame 306 is such that each of the spools is effectively cradled between said shafts as shown, for example, in FIG. 5. Of the pair of shafts 302 and 304, shaft 302 is positively driven while shaft 304 is an idler shaft. Drive for the shaft 302 is via electric motor 308, angle gearhead 310, shaft 312, sprocket 314, chain 316, and sprocket 318 secured to the extended end of shaft 302. With this form of drive it will be seen that the spools 300 A through F are driven only by frictional engagement between the outer peripheral edges or rims of the side flanges of the spools in contact with the driven shaft 302 whereby each of the spools 300 A through F may be rotating at a different speed not greater than the effective speed of rotation of the driven shaft 302 whereby each of the spools may be reeling a different amount of filament than the other spools of the assembly. This form of drive permits each of the spools to rotate at its proper speed according to the amount of filament on the hub of the spool and

maintain a relatively uniform tension in the very brittle but high strength boron filament being wound thereon. In the illustrated form of the invention the driven shaft 302 is shown as having associated therewith a plurality of drive spools 320, one for each spool with the outer peripheral surface of the drive spools 320 being shaped to engage and center its spool 300 A through F. Further, each of the spindles 320 comprises friction clutch mechanism to permit slippage between the rotating drive shaft 302 and the spools 300. The slippage takes place between the outer peripheral surface 322 of each friction clutch member 320 and the shaft 302. Further, where desired, a suitable spool engaging spindle 324 may be carried at each winding station by idler shaft 304.

As hereinbefore discussed, the driven and idler shafts 302 and 304 of the spooling assembly are carried in a quadrangular box-like housing 306 which is mounted for reciprocation on four stub shafts. At the extreme right-hand side the stub shafts comprise shafts 330 and 332 mounted in housings 334 and 336, respectively. The extended ends of shafts 330 and 332 are received in bearing members 340 carried by angle bracket 342 secured to the stationary portion of the apparatus. The opposite end of the traversing frame is also provided with stub shafts, one of which is illustrated at 344 in FIG. 2. Stub shaft 344 is secured to mounting block 346 and is slidably mounted in bearing 348 carried by angle iron 350 secured to the fixed portion of the main frame, as more clearly illustrated in FIG. 5.

Mechanism for causing the spool carrying frame 306 to reciprocate is more clearly illustrated in FIGS. 5, 6, 8, 9 and 10 and comprises a cam or eccentric 360 mounted for rotation on shaft 362 which shaft forms a portion of angle drive means 364. Angle drive 364 is driven via coupling 366, shaft 368, reduction gear means comprising gears 370, 372, 374 and 376, with the latter gear being secured to shaft 312 driven by motor 308. The eccentric 360 revolves in conjunction with a pair of fixed followers 380 and 382 secured to frame member 384 rigidly secured to a main beam element 386 of the fixed portion of the machine. Since the followers 380 and 382 contact diametrically opposite peripheral surfaces of the eccentric 360, the eccentric is of the constant diameter type so that when the eccentric 360 is rotated via shaft 362 each of the followers 380 and 382 is always in contact with its segment of the peripheral surface of the eccentric.

Now referring to particularly FIG. 8, it will be seen that since the followers 380 and 382 are fixed to the main beam 386, upon rotation of the constant diameter eccentric the entire frame 306 is caused to reciprocate back and forth at a speed corresponding to the speed of rotation of the eccentric.

It will be recognized by those skilled in the art that the traversing of the spool carrying frame 306 may be such that level winding of the filament on the spools is accomplished. However, in the winding of such fine filaments random winding is preferred as it prevents tangling of the wound filament, particularly during unwinding of the spools, such random winding being more illustrated in FIG. 8 of the drawings. Using the illustrated apparatus, particularly satisfactory results are obtained when the rapid traverse spaces each turn approximately 0.5 inch apart. With this method sub-

sequent layers of filament are added directly without the necessity for paper interleaving. Further, to prevent a buildup at stand cross-over points, gear ratios between the traverse drive and the spool drive are selected to give a stepping action to the winding process.

Referring particularly to FIGS. 11 through 13, the purging section 20 having the upper and lower seals 18 and 22, provides a chamber approximately 8 inches in length, immediately preceding the plating section 24 which, in the illustrated form of the invention, is approximately 70 inches in length. The combination seal, gas inlet and outlet, and electrical contact means 22 is illustrated in detail in FIGS. 12 and 13. It will be seen from FIGS. 12 and 13 that the purging section 20 is formed of a glass tube 400 having an internal diameter of approximately one-half inch. Hydrogen is directed into the tube 400 at hydrogen inlet and gas seal 18, and is removed at the upper end of seal 22. Seal 22 is connected to tube 400 by a suitable bushing type connector 402, and similarly, the seal 22 is connected to plating chamber glass tube 404 by separable connector 406. Intermediate the two connectors 402 and 406 the seal 22 tapers inwardly as at 408 to provide a constricted opening 410 through which the fine substrate 102 will pass, and when so passing, a pool of mercury 112 will be maintained above the opening 410. The pool of mercury 412 is prevented from flowing through the opening 410 by properly sizing the opening such that when the substrate 102 is threaded through the opening surface tension of the mercury prevents passage of the mercury through the opening. A suitable supply 414 for the mercury is connected via flexible tube 416 to a nipple 418 forming a portion of the seal 22. The reservoir 414 for the mercury is provided with an electrode 420 to which an electrical conductor 422 is connected whereby a D.C. heating current flowing in the conductor 422 is transferred to the substrate 102 via conductor 420 and mercury pool 412. Above the upper surface of the mercury pool 412 a further nipple 424 is connected via a conduit 426 to an outgassing means through which hydrogen and purged gases are removed from the purging chamber 20.

Immediately below the opening 410 a further nipple 428 has connection to a conduit 430 which in turn is connected to a source of plating gas. It will be particularly noted that with the improved seal fresh plating gas immediately contacts the heated substrate as soon as it enters the plating chamber to thereby have an enriched source of, for example, hydrogen and boron trichloride at the very start of the plating process.

Very satisfactory results are obtained with a reduction in the inside diameter of the tube forming the seal such that the opening 410 is from about 0.01 to 0.015 inch. An opening of this magnitude has been found to be adequate to allow the passage of a 0.5 mil. filament or substrate yet contain the mercury within the mercury seal. Further, it has been found that the surface tension of mercury at ambient condition is such that a column 0.5 inch high is readily supported before spill-through will occur when a 0.010 inch hole is located at the bottom of the seal. Further, it will be noted particularly from FIG. 13 that the inside surfaces of the seal are smoothly contoured toward the opening so that a length of filament can be pushed through the various

chambers as a string-up tool to bring new substrate into the machine.

While the seal shown in FIGS. 12 and 13 have proved to be very adequate, improved operation is obtained where the orifice is variable and a large opening is initially provided to facilitate string-up, which large opening may be manually closed off to, for example, 0.010 to 0.015 inch. Apparatus for providing such a variable orifice seal is illustrated in FIGS. 14, 15 and 16. The seal illustrated in FIGS. 14, 15 and 16 corresponds to seal 22 between the purging section and the plating section of the apparatus, and therefore includes means for removing hydrogen gas from the purging section and means for introducing plating gases into the upper end of the plating chamber.

In FIGS. 14, 15 and 16 structures like those illustrated in FIGS. 11, 12 and 13 are provided with corresponding reference characters. The lower end of the purging section tube 400 is coupled to the gas seal 22' via a conventional metallic coupling 402. The lower end of the seal is coupled to the plating section tube 404 via conventional coupling 406. Immediately downstream of the upper coupling 402 is a hydrogen gas outlet section 500, having an out-gassing nipple 502. Below the lower edge of the nipple 502, the section 500 is provided with an eccentric opening 504 having a diameter less than one-half the internal diameter of the tubing forming the purging and plating sections. It will be particularly noted that the internal walls 506 and 508 taper toward the opening 504 to facilitate string-up. The lower end of section 500 is rotatably received in a bushing or ferrule 510 provided with an eccentric opening 512 which eccentric opening is adapted to receive a bushing or washer 514 constructed, for example, of an alumina ceramic material to provide a good wear surface and to electrically insulate the metallic filament from the other metal parts of the seal. The lower end of the bushing or ferrule 510 receives the lowermost section 516 of the seal, which lower section is provided with a nipple 518 having connection to the source of plating gas. Further, as more clearly shown in FIG. 15, a transverse bore 520 communicates with an annular well 522. The well in turn communicates with inlet nipple 524 which has connection to the flexible conduit 416, the extended end of which is connected to the mercury reservoir 414. The reservoir may be identical in function and construction to that previously described in reference to FIG. 12 of the drawing.

In re-string operation of the structure shown in FIGS. 14, 15 and 16 the reservoir 414 is removed from its wall clip 530 and lowered so that the pool of mercury in the seal flows into the unfilled space in the reservoir. With the mercury removed from the seal, ferrule 510 is rotated such that the bore in the ceramic washer 514 is axially aligned with the bore 504 in seal member 500. With the two bores aligned, a large diameter opening is provided in the seal and the substrate 102, with a small weight attached thereto, may be readily fed from the upper end through the seal. After the substrate has fed through the large diameter opening, the ferrule 510 is again rotated to the position illustrated in FIGS. 14, 15 and 16 and the reservoir 514 is again slipped into its clip 530 to permit mercury from the reservoir to feed into the seal. Following this operation the seal is then ready for continued operation of the plating apparatus.

A further form of eccentric seal is illustrated in FIGS. 17, 18 and 19. In this form of the invention a pair of eccentric ceramic washers are employed and in describing this form of the invention reference characters used in describing FIGS. 11, 12 and 13 are employed to designate identical structures in FIGS. 17, 18 and 19. The seal illustrated in FIGS. 17 through 19 is composed of three metallic sections, namely an upper section 600, an intermediate section 602, and a lower section 604. The upper section 600 receives the lower end of the gas purging chamber 400 and is maintained in gas tight assembly therewith via O-ring seal 608. The lower end of upper section 600 is provided with an eccentric bore 610 which receives a ceramic washer 612. The side wall 614 of the upper section 600 is smoothly tapered to the bore 616 in the washer 612 and a transverse bore 618 is positioned to communicate with the inner chamber of the upper portion 600 of the seal. Further, a nipple 620 communicates with the inner portion of the upper seal member to provide an outlet passage for hydrogen flowing through the gas purging section as described in reference to FIGS. 11 through 13.

The intermediate portion of the seal includes an eccentric bore 622 adapted to receive a ceramic washer 624 having a central bore 626 therein. The upper surface of washer 624 is in sliding contact with a portion of the lower surface of washer 612 carried by the upper segment 600 of the improved seal. Further, the intermediate portion 602 is provided with a transverse bore 630 which communicates with a nipple 634, which nipple receives the extended end of flexible conduit 416 having connection to the mercury reservoir 414 normally maintained in the illustrated position on the inner side wall of the housing via spring clip 530. The lowermost section of the improved seal 604 receives the upper end of the glass plating chamber tube 404 and a gas tight seal is established between these elements via O-ring seal 636. The upper end of the lower portion 604 is provided with a concentric or axial bore 638 which communicates in part with the eccentric bore 622 in the intermediate portion 602.

In operation of this form of the invention the mercury reservoir 414 is removed from its clip 530 and lowered to permit draining of the pool of mercury from the seal. With the mercury removed the intermediate portion of the seal 602 is rotated so that the bore 626 in the washer 624 carried by the intermediate section is axially aligned with the bore 616 in washer 610 at the lower end of the upper portion 600 of the seal. With these two washers aligned a large opening exists through the seal whereby the filament 102 having a weight attached to its lower end may be readily passed through the apparatus. Once the filament 102 has passed through the large opening the intermediate section 602 is again rotated such that the pair of ceramic washers 612 and 624 are in the positions illustrated in FIGS. 18 and 19. With the washers in the illustrated position, the reservoir 414 may be replaced in its clip 530 to permit mercury to again flow into the structure and perform its gas sealing and electric contacting functions.

Another form of variable orifice gas seal is illustrated in FIGS. 20, 21 and 22. In the following description of this form of the invention, structures equivalent to those illustrated and described in reference to FIGS.

11, 12 and 13 are provided with identical reference characters. The lower end of the gas purging section 400 is coupled to the upper end of the improved seal via conventional coupling 700 while the upper end of the gas plating chamber tube 404 is similarly coupled to the lower end of the seal via coupling 702. Intermediate the two seals is an axial bore 704 having a diameter approximately one-fourth the internal diameter 706 of the tube forming the seal. Between the upper and lower ends of the bore 704 and the large diameter bore 706 the walls of the seal are tapered as at 708, to permit simple string-up of the apparatus.

Just below the upper end of bore 704 a transverse bore and accompanying nipple is provided for removal of hydrogen gas from the purging chamber; the bore being illustrated with the reference character 710. Just above the lower end of the bore 704 is a further transverse bore 712 communicating with nipple 714 for directing plating gasses into the upper end of the filament plating chamber. Between the transverse bores is the gas sealing chamber 716 bound at the upper and lower ends by variable orifice forming means generally designated 718 and 720. Variable orifice means 718 comprises a pair of transverse bores 722 and 724. Bore 722 is fitted with a ceramic dowel 726 which dowel is provided with a peripheral recess 728 which communicates with the bore 704 when the dowel is rotated to the position shown in FIG. 22. The parallel bore 724 is fitted with a dowel 730 which is also provided with a recess 732 which, when the dowel is rotated to the position illustrated in FIG. 22, is aligned with the bore 704 in the seal. One extended end of each of the dowels 726 and 730 is provided with a manual operating lever 734 and 736 respectively, and as illustrated in FIG. 20. Stop brackets such as shown at 740 may be included in the assembly so that the operator can determine the exact position of the recesses 732 and 728 in the dowels.

Below the pair of dowels 726 and 730 are a further pair of dowels 750 and 752 which are identical to dowel 726 and 730 except that their axes of rotation are aligned normal to the axes of the upper pair of dowels. Dowel 750 rotates in bore 754 and the dowel is provided with a recessed portion 756. Similarly, dowel 752 rotates in bore 757 and is provided with recess 758.

Each of the pair of dowels 750 and 752 is provided with an actuating handle, not shown, in a manner similar to the actuating handle assemblies for dowels 726 and 730. The assembly also includes a transverse bore 760 adapted to receive a small bore tube 762, which small bore tube is received at the extended end of the outlet 768 of a syringe generally designated 770 and composed of a barrel or reservoir portion 772 and a finger-operating plunger 774. The syringe 770 comprises a reservoir for mercury to provide the mercury seal and a means for injecting and removing mercury from the seal.

In operation of the structures shown in FIGS. 20, 21 and 22, the four dowels 726, 730, 750 and 752 are rotated so that their respective recesses 732, 728, 756 and 758 are aligned with the bore 704. Then the substrate 102 with a weight attached can be dropped vertically through the seal. With the substrate in place, each of the dowels 726, 730, 750 and 752 is then rotated 180°, thus centering the filament in the bore 706 and

reducing the opening in the bore 704, in the zone of the pairs of dowels, to from about 0.01 to about 0.015 inch spacing between the outer surfaces of the pairs of parallel dowels. With the dowels rotated and the filament 102 centered, the plunger 774 of the syringe type mercury reservoir is pressed inwardly forcing mercury through the small bore tube 762 into the cavity between the pairs of dowels represented by the bore 704, to thereby provide an effective gas seal. When it becomes necessary to re-string the device, the plunger 774 of the syringe 770 is urged upwardly to withdraw the mercury from the bore 704 prior to rotation of the dowels to open the upper and lower ends of said bore.

In operation of the entire system after the filament has been strung through the treating chambers and started on the pick-up reel or spool and the mercury seals have been filled, a suitable electric current is fed to the filament in the gas purging and plating sections via the seals 18, 20 and 30. Then hydrogen or other purging gas is supplied to the purging section 20 through hydrogen inlet 21 and removed via conduit 23. For the purpose of removing absorbed, adsorbed or reacted oxygen from the surface of the substrate filament as it passes through the chamber 20. Any lubricants or other superficial impurities are also removed from the filament by evaporation or by reaction with the hydrogen.

Boron halide may be supplied to the plating chamber 24 together with a reducing gas, such as hydrogen, via conduit 430 at the upper end and 25 at the lower end.

Residual gasses and vapors pass out of the plating chamber via conduit 29 FIG. 11 of the drawing.

When the vaporizable compound of boron comes in contact with the heated substrate, deposition of boron takes place on the substrate. The rate of passage of the filament and the temperature of the filament are suitably maintained to provide a boron plated filament of the required diameter.

In general, using the apparatus hereinbefore described, the following range of plating gases have been found to be typical:

	Vol.% BCl ₃	Vol.% H ₂
Gas inlet at top of plating chamber	26 to 31	74 to 69
Gas inlet at bottom of plating chamber	51 to 58	49 to 42

Further, it has been found that at the start of a plating run, prior to applying the voltage (which will cause a current flow of 240 to 260 milliamperes) to the substrate, additional hydrogen in the amount of 950 cc/min is entranced at the lower plating gas inlet of the plating chamber in order to balance the thermal conductivities of the gases already being admitted to the chamber. Then, after the voltage is applied, this flow of additional hydrogen is allowed to persist for about ten seconds and is then shut off. This procedure is used in order to get the substrate to heat and glow evenly over the entire length of the reactor.

The following is a representative example of operation of the system of the invention:

An 0.5 mil. tungsten wire is passed at a speed of about 10 feet per minute through the apparatus of a type illustrated in the drawing, having an 8 inch degassing chamber maintained at about 2,200° F. to about 2,250° F. and a 70 inch plating chamber. The

out-gassing chamber is supplied with about 667 cc. of hydrogen per minute and the substrate was heated by a current of 300 ma. The deposition chamber is maintained at about 2,200° to 2,250° F. and is supplied at the upper inlet with 4,400 cc per min. of a gas consisting of 26 percent by volume of BCl₃ and 74 percent by volume of H₂, and at the lower inlet with 2,400 cc/min. of a gas consisting of 57 percent by volume of BCl₃ and 43 percent by volume of H₂. The plating current was maintained at about 250 ma. and ranged from 240 to 260 ma. The substrate was tensioned at about 5-7 grams. Under these conditions a boron filament about 4 mil. in final diameter is obtained in continuous length of, for example, up to 100,000 feet, having breaking strength of the order of 4×10^5 pounds per square inch.

From the foregoing description it will be seen that the present invention provides a highly useful production module for producing coated continuous-length filament.

We claim:

1. A system for producing plated filaments comprising means for drawing a fine filamentary substrate, at a constant speed, from a spool source thereof through a purging station and a plating station, means controlling the letoff of the substrate from such spool of substrate to maintain a constant tension on said substrate; means for electrically heating the substrate in said purging station and means for electrically heating said substrate to a plating temperature in said plating station; means continuously directing a flow of purging gas through the purging station and plating gas through the plating station, and means continuously reeling said plated filament at a predetermined tension independent of the tension in the purging and plating stations, wherein tension on the substrate is maintained in the purging and plating stations by an eddy current spool breaking mechanism.

2. The invention defined in claim 1 wherein the eddy current spool braking mechanism is characterized by a permanent magnet having an air gap between the pole faces thereof, a non-magnetic conductive disc adapted to cut the magnetic lines of force in said air gap upon rotation of the spool containing the filamentary substrate, to thereby apply a braking force on said spool.

3. The invention defined in claim 2 wherein said permanent magnet is mounted on a pivotal axis normal to the plane of the non-magnetic disc whereby the eddy current braking effect of said permanent magnet is maintained substantially constant through variable speeds of rotation of the non-magnetic disc.

4. The invention defined in claim 3 wherein the permanent magnet is biased in a direction such that a maximum number of lines of force are cut upon rotation of the non-magnetic disc.

5. The system defined in claim 4 wherein a cluster consisting of a three-wheel capstan drive arrangement is employed to draw the substrate from a spool source thereof.

6. The system defined in claim 5 wherein only one of the wheels of the cluster is driven and the other wheels of the cluster are idle wheels.

7. The system defined in claim 4 wherein the means for continuously reeling said plated filament at a predetermined tension comprises a rim-driven spool assembly.

8. The invention defined in claim 7 wherein the tension in the reeled filament is determined by the frictional engagement between the rim of the spool and a driven shaft in contact with the rim.

9. The invention defined in claim 7 including means for rapidly traversing the spool to provide for random spooling of the reeled filament.

10. A system for producing plated filaments comprising means for drawing a fine filamentary substrate, at a constant speed, from a spool source thereof through a purging station and a plating station; means controlling the letoff of the substrate from such spool of substrate to maintain a constant tension on said substrate; means for electrically heating the substrate in said purging station and means for electrically heating said substrate to a plating temperature in said plating station; means continuously directing a flow of purging gas through the purging station and plating gas through the plating station, and means continuously reeling said plated filament at a predetermined tension independent of the tension in the purging and plating stations, including gas sealing means positioned at the upper and lower

ends of the purging station and at the upper and lower ends of the plating station, wherein the openings in the gas seals are so sized that a pool of mercury may be maintained above the openings in each seal, and wherein the openings in the seals are variable from an operative mercury retaining position to an inoperative filament re-string position.

11. The invention defined in claim 10 wherein the variable openings in each seal are provided by a fixed eccentric opening in the seal and a cooperating rotating eccentric opening.

12. The invention defined in claim 11 wherein the eccentric openings are relatively rotatable and are defined by ceramic washers.

13. The invention defined in claim 10 wherein said variable openings are provided by parallel pairs of rotatable dowels, each of which is provided with a peripheral recess.

14. The invention defined in claim 13 wherein said dowels are constructed of ceramic material.

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