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Sadler et al.

[54] **METHOD FOR APPLYING LIQUID TO YARN**

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Related U.S. Application Data

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[51] **Int. Cl.**[4] **B05D 3/12**; B05D 1/02; B05D 7/00; B05D 5/00

[52] **U.S. Cl.** **427/57**; 118/300; 427/421

[58] **Field of Search** 427/57, 44; 118/300; 239/4, 102; 261/DIG. 48; 68/3

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,589,854 6/1971 Cobb et al. 8/154
3,591,672 7/1971 Davis et al. 264/167
4,431,684 2/1984 Strohmaier 427/57

Primary Examiner—John F. Terapane
Assistant Examiner—Eric Jorgensen

[57] **ABSTRACT**

A method for intermittently applying a liquid to a threadline wherein varying the amplitude of vibration of an atomizing surface of an ultrasonic vibrator is the vehicle for atomizing and propelling the liquid onto a threadline passing in close proximity to the atomizing surface.

6 Claims, 4 Drawing Figures

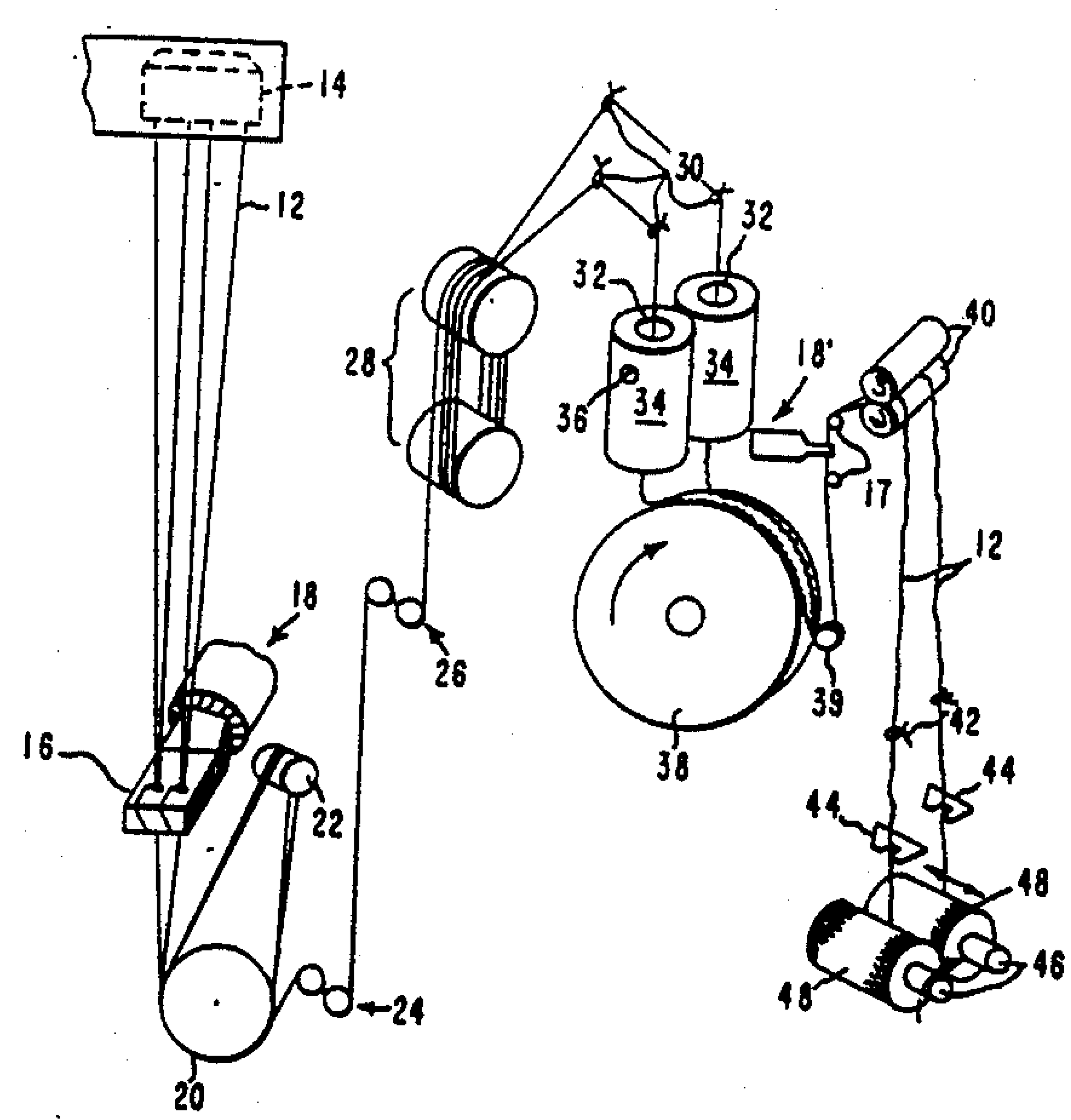


FIG. 1

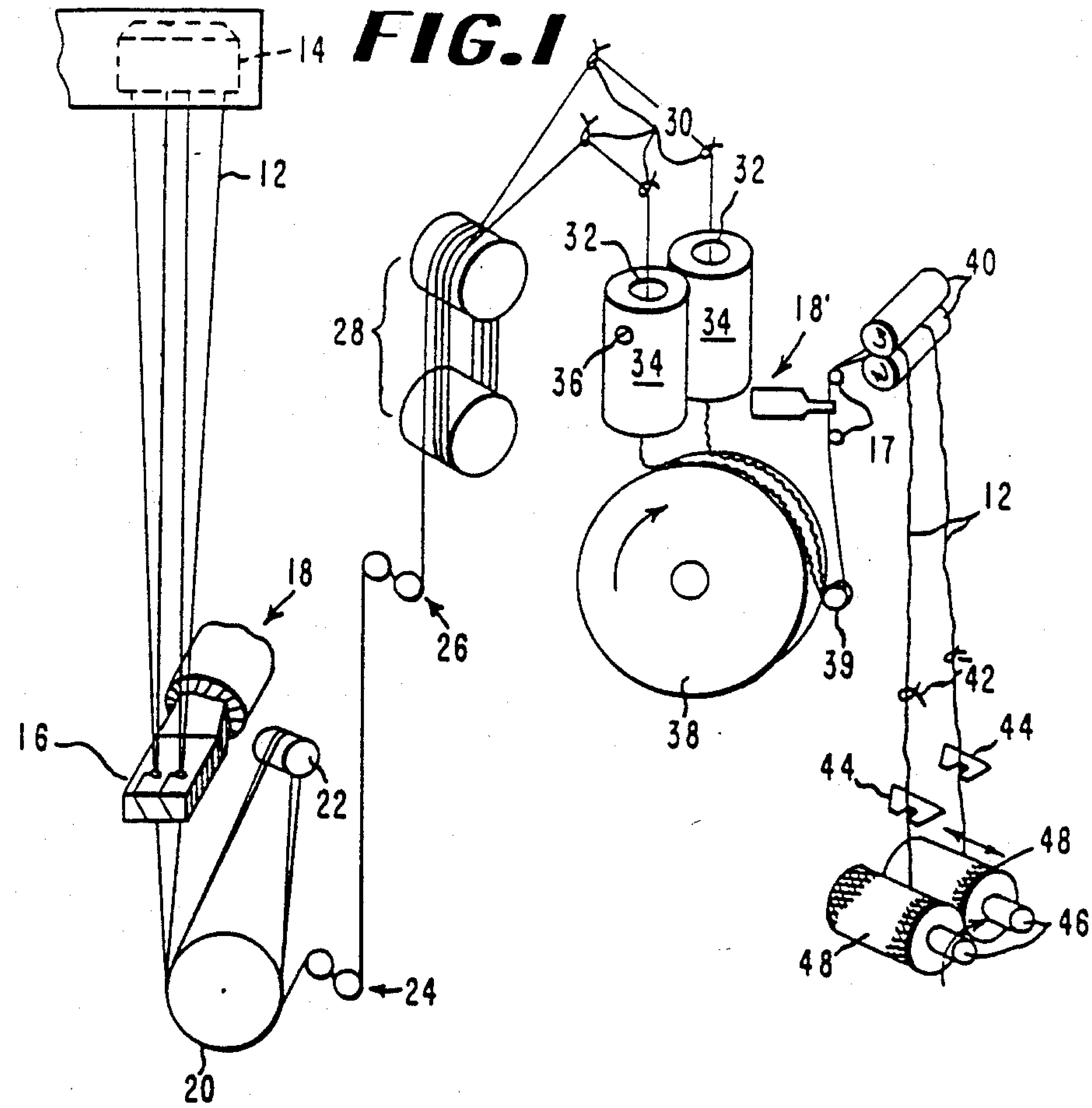
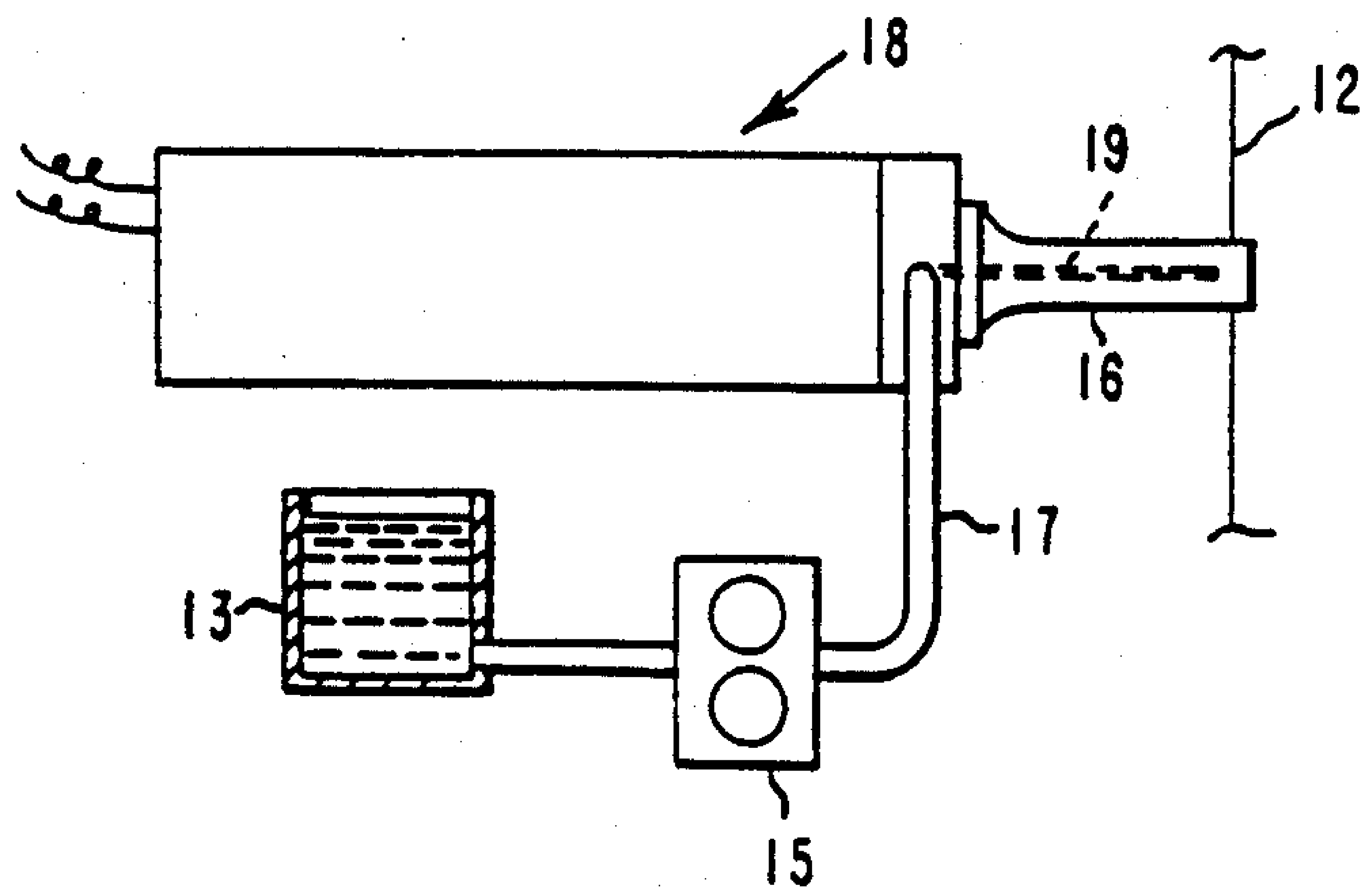

14
12
30
32
32
28
34
34
36
18'
40
17
12
18
26
39
42
44
44
16
22
38
48
46
48
24
20

FIG. 2


18
12
19
16
17
13
15

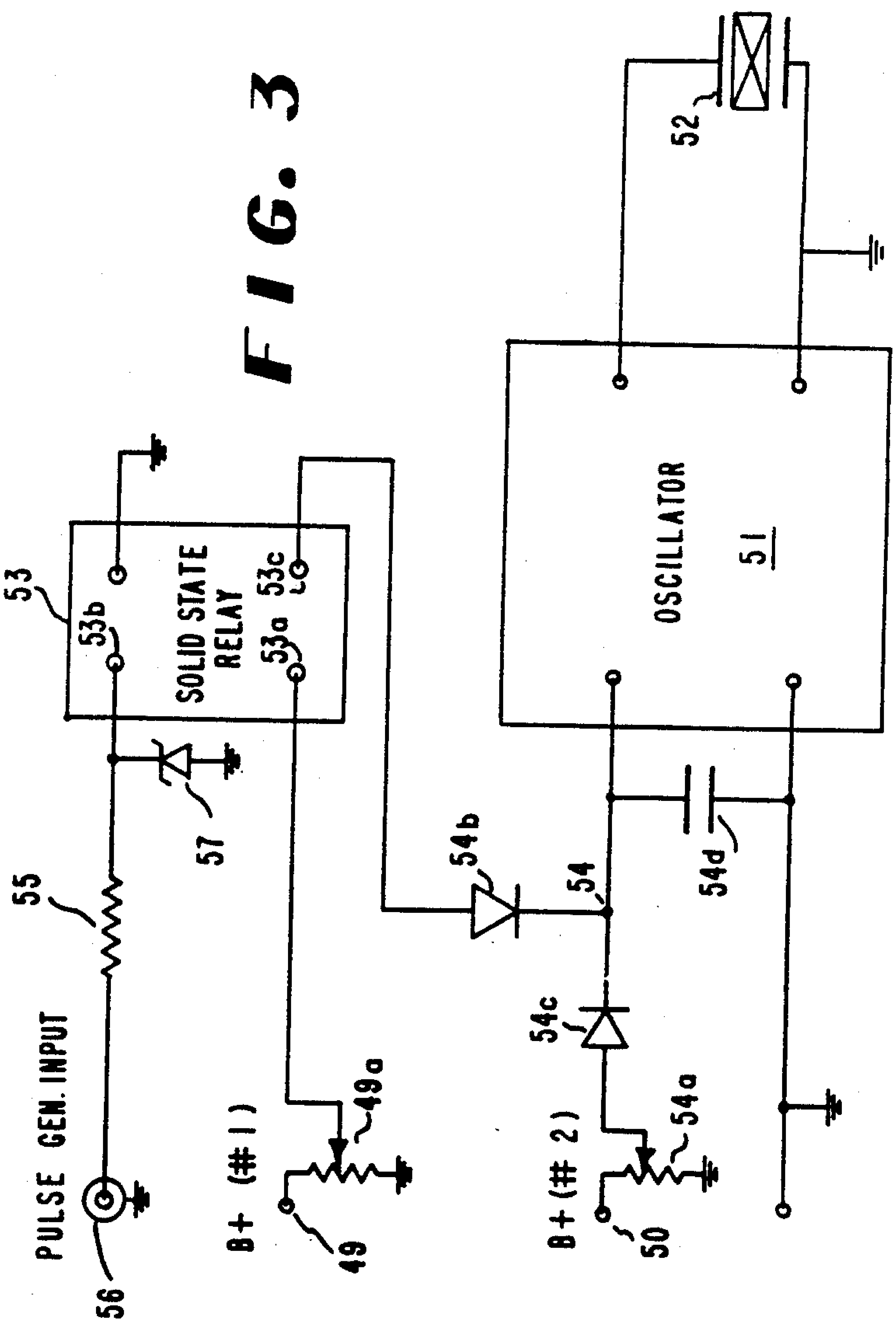

PULSE GEN. INPUT
56
55
57
53
53b
SOLID STATE
RELAY
53a
53c
B+ (#1)
49
49a
B+ (#2)
50
54a
54c
54
54b
54d
OSCILLATOR
51
52

FIG. 3

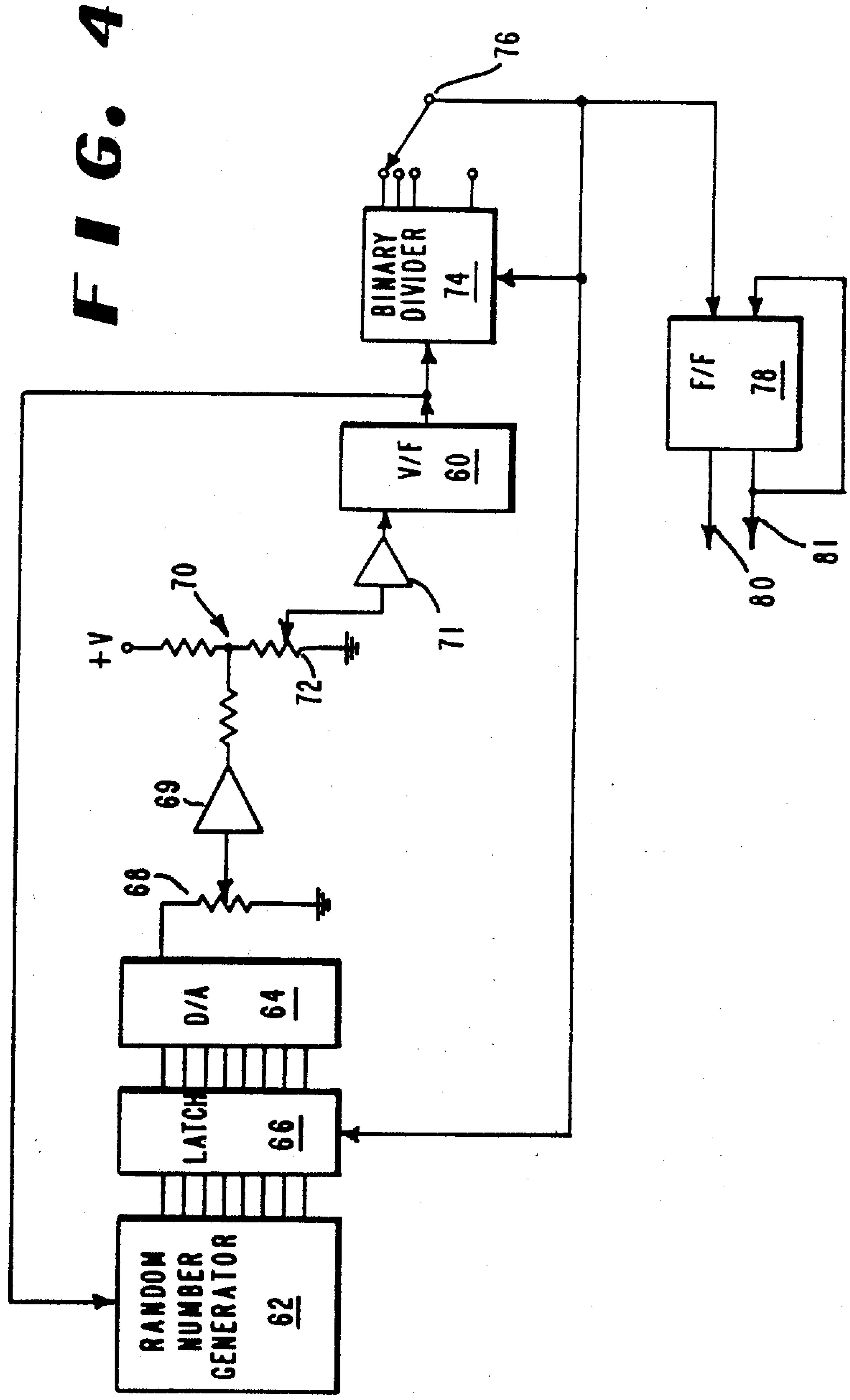

76
BINARY DIVIDER 74
F/F 78
81
80
V/F 60
70
+V
71
72
69
68
D/A 64
LATCH 66
RANDOM NUMBER GENERATOR 62

FIG. 4

METHOD FOR APPLYING LIQUID TO YARN

This application is a continuation, of application Ser. No. 631,747 filed July 17, 1984.

BACKGROUND OF THE INVENTION

This invention relates to the intermittent application of liquids or liquid suspensions to yarns, more particularly, it relates to such application by ultrasonic vibrations conducted above and below an atomization threshold in a regular or irregular fashion.

In the manufacture of textile fibers, the common method of modifying the dyeability of the yarn is by changing the composition of the polymer. This can be done in nylon by changing ratio of standard ingredients or by adding a special additive to the salt before polymerization or injecting certain additives after polymerization.

It is known to modify yarn dyeability by adding additive to the running threadline but this is not the general method of dye modification. Some cases even exist which add modifiers at alternating distances along a threadline. All existing systems have at least two limitations: very short lengths (less than 1 inch in length of about 700 ypm) are not possible and control or change of the pattern to give fully patterned control is not available. This invention allows the pattern to be adjusted instantly and can even give carpet pattern prediction once carpet construction is known.

SUMMARY OF THE INVENTION

This invention relates to the application of dye modification substances or liquid suspensions to a moving threadline, the threadlines being either single monofilament, multifilament bundles or tow; more particularly it involves a method for intermittently applying a liquid to a moving threadline comprising: supplying a liquid in a metered stream to an atomizing surface of an active horn of an ultrasonic vibrator; moving the threadline in a path in close proximity to said atomizing surface; and intermittently atomizing and propelling the liquid onto the yarn by varying the amplitude of vibration of said surface.

It contains the ability to pulse the application of dye modification substances up to 600 Hz at either regular or preferred irregular pulse rates.

The ability to pulse the liquid with an ultrasonic applicator, that would not be possible to the same degree from other applicators, comes from the way atomization is formed with an ultrasonic applicator as disclosed in U.S. Pat. No. 4,431,684. The liquid to be atomized passes through the liquid passage; e.g., **19** in FIG. **2** and forms a layer on the atomizing surface. The ultrasonic vibrations which are normal to this surface cause surface capillary waves in the liquid. Atomization occurs when the amplitude of vibration is high enough to break off the tips of the waves formed, producing droplets of a size governed mostly by the frequency of vibration and, to a lesser extent, by physical properties of the liquid (density, surface tension and viscosity).

Because atomization occurs only when the amplitude of the vibration exceeds a given threshold level for any liquid, it is not necessary to stop ultrasonic vibration of the applicator. Thus intermittent application may be accomplished by causing the applicator vibration amplitude to rapidly alternate above and below the atomization threshold. The liquid that is fed continuously by the metering pump accumulates in the liquid layer on the atomizing surface during the low vibration, or "off", portions of the pulse cycle.

The vibration amplitude alternations have been effected in this case, by driving the applicator's transducer and oscillator with a bilevel switching power supply. This power supply provides alternating drive voltage levels to the oscillator, the lower voltage adjusted to produce a vibration amplitude below the atomization threshold, and the higher voltage above this threshold. Since the applicator tip is continuously vibrating, rapid switching between levels is possible. An additional benefit of the continuous applicator vibrations is that friction, or "snubbing", of the yarn that passes through the applicator tip remains low at all times, thus minimizing yarn nonuniformities that would otherwise result from variable drawing tensions through the applicator itself.

The bilevel switching power supply is controlled by a logic-level signal from a pulse generator. Several pulse generator types may be used, including a conventional function generator for pulses with a regular period, or a preferred random pulse generator to produce pulses with randomly varying "on" and "off" periods. Yarns produced by intermittently applying dye modifiers with a high percent randomness will make carpets with a truly random appearance, i.e., exhibiting neither subtle patterning or "chevroning". Alternatively, a programmed pulse generator may be employed to produce yarn for carpets of any desired pattern, which can be predicted in advance once the carpet construction is known.

Two or more liquids, e.g., finishes or dye modifiers, can be alternately co-applied by employing intermittent ultrasonic applicators in tandem, i.e., closely spaced in series along the moving threadline. The pulse generator that controls the applicators produces a unique pulse train for each applicator that individually and sequentially switches each applicator "on", i.e., into its atomizing mode, in such a manner that the treated segments intermingle along the yarn without overlap. In the case of two tandem applicators alternately applying two different liquids, the two pulse trains from the generator will be complements of one another.

The random pulse generator developed for intermittent finish application is described below, and produces a train of logic pulses that can be randomized on either a pulse rate or a period basis, with percent variability, i.e., randomness, and average pulse repetition rate separately adjustable. Percent variability from 0 to 100% and pulse repetition rates from 4 Hz to 1024 Hz have been incorporated into the design.

As is true with ultrasonic finish applicators in general, the intermittent application of liquids can be performed with applicators vibrating in the range of 10 kHz to 100 kHz, but preferably in the range of 20 kHz to 50 kHz.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic drawing showing use of the subject invention at two locations in a yarn manufacturing operation.

FIG. **2** is a schematic side elevation view of the vibrator used as a finish applicator at a first location.

FIG. **3** is a schematic drawing of a bilevel switched power supply for an intermittent ultrasonic applicator.

FIG. **4** is a block diagram of a random pulse generator system.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

The process chosen for purposes of illustration in FIG. **1** includes a yarn **12** being spun as two separate threadlines from a spinneret **14** and each threadline is forwarded through the passages in the tip of the horn **16** of a first vibrating finish applicator generally designated **18**. Next the threadline passes around feed roll **20** and its associated separator roll **22** around draw pin assemblies **24**, **26** to draw rolls **28** where it is forwarded by the rolls **28** at a constant speed through yarn guides **30** and through the yarn passageways **32** of the jet bulking devices **34**. In the jets **34** the threadlines **12** are subjected to the bulking action of a hot fluid directed through inlets **36** (only one shown). The hot fluid exhausts with the threadline against a rotating drum **38** having a perforated surface on which the yarn cools to set the crimp. From the drum the threadlines in bulky form pass to a guide **39** and continue in a path over a pair of guides **17** past the end of the vibrating applicator **18'** then to a pair of driven take-up rolls **40**. Bulky yarns of this type are disclosed in U.S. Pat. No. 3,186,155 to Breen and Lauterbach. The threadlines are then directed through fixed guides **42** and traversing guides **44** onto rotating cores **46** to form packages **48**.

In FIG. **2** the vibrating finish applicator **18** is supplied with liquid finish by means of a gear pump **15** connected to a reservoir **13**. The gear pump supplies a precisely metered stream of liquid finish via pipe **17** to an internal passage **19** in the horn **16**. An applicator tip at which the yarn **12** meets the finish is either mounted on the end of or forms an integral part of the horn of the ultrasonic vibrator.

FIG. **3** is a circuit schematic for a 50 kHz bilevel switched power supply and oscillator for the intermittent ultrasonic applicator. Two separate, adjustable B+ regulated voltage supplies designated **49**, **50** alternately provide the drive voltage for a 50 kHz oscillator **51**, typically a Branson L—5 "Sonomax" with DC bridge and filter capacitor removed. The oscillator **51** is connected to and drives the ultrasonic transducer and applicator **52**. Voltage supply **49**, the higher of the two voltage supplies, is adjustable via potentiometer **49*a***, and is input to terminal **53*a*** of solid state relay **53**. Solid state relay **53**, typically a type 603-3 manufactured by Teledyne, is a full on, full off switching device that responds quickly (time constant >100 microseconds) to a logic-level signal that is applied to its control terminal **53*b***. When the relay closes, the voltage from supply **49** appears at output terminal **53*c*** and at junction **54** where it overrides the lower B+ voltage supply **50** adjusted via potentiometer **54*a***. Two IN4005 diodes **54*b***, **54*c*** conduct the two voltages to junction **54**, while isolating the two DC supplies **49**, **50** from each other. A 0.1 uF capacitor **54*d***, connecting junction **54** with circuit common at the input terminals of oscillator **51**, provides some DC filtering without markedly reducing the switching times between voltage supply levels.

A logic-level pulse train, typically furnished to terminal **56** by a programmable square wave generator, or a random pulse generator is applied to terminal **53*b*** of solid state relay **53** via a 10 ohm limiting resistor **55**. A Zener diode **57** serves as an input protection device for the relay **53**. The particular signal generator that is selected is dependent upon the repetition frequency, pattern and regularity of the finish application required. With either the random pulse or square wave generator arrangement, the input signal to oscillator **51** can be switched at rates between 4 and 600 Hz (the practical upper limit) with duty cycles ranging between 0 and 100%.

In operation, the DC input to oscillator **51** is a bilevel voltage that varies between two values (rather than full on-full off) to produce a corresponding alternation in the applicator vibration amplitude above and below the atomization threshold levels for a given liquid. Additional benefits gained by pulsing the ultrasonic transducer between two vibration levels, are that oscillator stability is maintained and stresses on both the transducer and power output circuitry are minimized.

The rapid switching speeds attainable with this system sharply define the transition between atomization and nonatomization of the finishing liquid at the applicator tip. As a result, the treated and untreated regions along a threadline moving at 2000 ypm can be well-defined down to one inch lengths.

FIG. **4** is the block diagram for a random pulse generator that is capable of randomizing the switching of oscillator **51** between two levels. Although random pulse generators are available on the market, the multimode features of the instant circuit are distinctive in that each is readily selectable from the same circuit. These include:

- Modes 0, 1—Random ON time; fixed (but adjustable) OFF time
- Modes 2, 3—Random OFF time; fixed (but adjustable) ON time
- Modes 4, 5—Random ON time; random OFF time
- Modes 6, 7—Random pulse repetition frequency; fixed (but adjustable) ON/OFF time ratio
- Modes 8, 9—Random ON/OFF time ratio; fixed (but adjustable) pulse repetition frequency.

Controls are provided to set pulse duration, pulse interval, pulse repetition frequency (PRF), and variability (the degree of randomness of either PRF or period).

This generator provides complementary pulse outputs, so that two applicators can be operated in tandem, simultaneously.

The principal component is a voltage-to-frequency (V/F) converter, **60**. This device generators a continuous stream of binary-valued pulses at a rate directly proportional to the input voltage. In this case the input voltage comprises the sum of a fixed voltage, which defines an average pulse rate, and a random voltage, which defines the degree of variation of the pulse rate about its average value. The V/F converter **60** is operated so as to produce pulse rates somewhat higher than what is needed at the final system output terminals **80**, **81**.

The random component of the pulse-rate-determining-voltage is obtained by means of a pseudorandom number generator, **62**, coupled to a digital-to-analog (D/A) converter, **64**, through a data latch, **66**. The D/A converter **64** is configured to produce a bipolar analog voltage which varies in proportion to the size of the digital word input to it via the latch, **66**. The D/A converter **64** uses offset binary decoding, i.e., the most significant bit of the digital word determines the polarity of the voltage, and the remaining bits determine the voltage magnitude. The bipolar voltages produced by this part of the circuit are random from one sample to the next, and the probability of occurrence of any voltage in the range of the D/A converter is equal to any other. Statistically, the voltage samples are randomly and uniformly distributed between fixed limits with a zero average value.

The degree to which the final input to the V/F converter **60** contains a random component is determined by the setting of potentiometer **68**. The fixed component contribution is scaled by a resistive mixing network such that at network node **70**, the fixed voltage and the maximum random voltage have equal weight. This allows potentiometer **68** to be calibrated in percent variability about the average. Potentiometer **72** permits one to vary the mixture of fixed and random components over a 2:1 range, while maintaining unchanged the ratio of these components as defined by the setting of potentiometer **68**.

Because the pulse generator's final output must cover a wide range of pulse rates, the system is designed to make available a selection of fixed ranges to provide a coarse pulse-rate control, and means to interpolate within each range to provide a fine control. To accomplish this, the output of the V/F converter **60** is input to a binary divider, **74**, which provides outputs for each divisor stage. Switch **76** selects the approximate pulse rate desired. Since succeeding divider outputs differ by a factor of two from one another, and the nonrandom voltage input to the V/F converter **60** can be varied over a 2:1 range by potentiometer **72**, the circuit will produce the desired result of continuous pulse rate adjustment over a wide range. The undivided pulses from the V/F converter **60** also are used as a convenient clock for the random number generator **62**, which at each clock pulse produces a new random number.

Each half-cycle of the final output pulse period is generated independently, i.e., the "on" time and "off" time durations are separately determined for each cycle. When the number of output pulses from the V/F converter **60** equals that selected by switch **76**, the binary divider **74**, output will change from a logic level 0 to a logic level 1. This signal then starts the next half-cycle of the output pulse by toggling flip-flop **78** and resetting the binary divider **74**. The transition also triggers latch **66** to sample the next random number whose analog voltage value, attenuated by potentiometer **68**, is added to a fixed voltage at junction **70**, via buffer **69**. It is the voltage at junction **70**, after modification by potentiometer **72** and isolation by buffer **71** that instantaneously determines the pulse rate at the output of the V/F converter **60**. This pulse rate remains constant for the instant half-cycle. When the binary divider **74** output signal changes to a logic 1 at the pole of switch **76**, the procedure described above is repeated.

For purposes of simple explanation, FIG. **4** represents only one of several operating modes of the random pulse generator. In fact, the flip-flow **78** outputs and the binary divider **74** reset pulses are input to a mode controlling network, which operates latch **66** and other subcircuits (not shown). In particular, FIG. **4** shows the option of obtaining output pulses having, on the average, a 50% on-off duty cycle with selectable pulse rate and percent variability independently applied to each portion of the cycle. The random pulse output can be obtained from either or both outputs **80**, **81** of flip-flop **78**, the two outputs being the complements of one another.

In plant test runs, yarns that have been treated with an intermittent ultrasonic applicator, using average pulse repetition rates of 12 Hz to 500 Hz, have exhibited dyed lengths of 33 in. (84 cm) down to 0.8 in. (2.0 cm) for bulked continuous filament yarn wound at 2000 ypm (1827 m/min). Above 600 Hz, the inertia of the ultrasonic applicator and transducer begins to override the power supply switching with the result that atomization becomes continuous.

EXAMPLE I

Polyhexamethylene adipamide having a relative viscosity of about 63 and 75 amine-end groups and micro equivalents per gram of polymer (equivalents per 10^6 grams of polymer) is melt spun into a yarn containing 136 filaments and processed using apparatus similar to that shown in FIGS. **1-4** except only the first of the applicators (**18**) shown is used. Either location works equally well for application of dye modifiers. The spun filaments are passed through the tip of an ultrasonic finish applicator operating at 50 kHz and pulsing at 150 Hz at 100% random variability. A dye resist chemical mixed with a yarn finish is atomized and propelled onto the spun yarn. The yarn is then forwarded to a feed roll running at a surface speed of 680 yards (624 meters) per minute. The applicator has the configuration shown in FIG. **1**. The dye resist chemical (N-acetyl-succinimide) produces lighter dyeing sections randomly distributed along the threadline. Table 1 lists the lengths of the yarn treated showing lengths of 0.5 inches (1.3 cm) to 10.5 inches (26.7 cm). This length variability and random distribution cannot be duplicated by any other known method on a threadline traveling at 680 ypm (624 meters/min.).

Yarns were run more than 4 hours without a threadline break, showing that on-line dye modification performs as well as the standard process.

The treated yarn was then drawn to a denier of 1350 by draw rolls running at a surface speed of 2154 ypm (1976 meters/min.), then bulked and wound up. This yarn was tufted into a carpet, then dyed. Only carpets with tone-on-tone coloration were produced using this dye modifier, but it is expected that cationic and other modifiers can be found which will allow production of yarns for carpets of any color combination desired.

TABLE 1

Measurement of length of dye resist applied along threadline as per Example I ultrasonic pulser set at 150 Hz and 100% variability. Measurements are made in inches on a 70 foot length of yarn sample.

1.5	5.00	3.50	2.00	1.50	2.50
4.0	3.00	4.50	6.50	5.50	5.50
1.0	1.00	3.00	2.00	3.00	2.00
1.25	2.00	3.00	3.00	4.00	3.00
1.00	2.00	8.00	4.50	4.50	2.50
3.50	3.50	4.00	3.50	2.25	
.50	3.00	3.00	5.00	1.00	
.50	1.00	3.00	4.00	4.25	
5.50	2.00	10.00	1.00	2.50	
4.00	3.00	6.00	5.00	4.50	
4.00	10.00	10.50	3.00	2.00	
4.00	3.00	3.00	5.00	4.00	
2.50	4.50	3.50	1.50	9.00	
2.00	8.00	4.50	2.50	1.00	
2.50	8.00	3.50	4.00	5.00	
1.00	1.00	1.00	4.00	2.00	
3.00	5.00	1.50	5.50	2.50	
2.00	6.00	2.50	6.00	1.00	
4.50	2.00	10.00	5.00	1.00	
2.00	9.50	4.00	3.00	4.00	
5.00	5.00	7.00	1.00	2.00	
5.00	10.50	7.00	1.50	4.50	
3.00	1.00	1.50	6.00	9.50	
5.00	3.00	2.00	2.00	2.50	

EXAMPLE 2

A 1350 denier yarn is prepared in a manner similar to that described in Example 1 except antisoil finish is applied as a primary finish at the first location **18** and the dye modifier is added at the bulking drum location **18'**. The process runs well and dye patterns similar to those of Example 1 result on the final carpet.

We claim:

1. A method for intermittently applying a liquid to a moving threadline comprising: supplying a liquid in a metered stream to a continuously vibrating atomizing surface of an active horn of an ultrasonic vibrator, said liquid having a threshold level of vibration amplitude for atomizing said liquid; moving the threadline in a path in close proximity to said atomizing surface; and intermittently atomizing and propelling the liquid onto the yarn by using bilevel excitation of the horn to vary the amplitude of vibration of said continuously vibrating atomizing surface above and below said threshold level thereby adding liquid to said threadline intermittently to produce liquid treated and untreated regions along the threadline.

2. The method as defined in claim **1**, said amplitude being varied at the rate of from about 12 to about 500 Hz, said threadline moving at speeds up to 2000 yards per minute.

3. The method of claim **1**, wherein varying the amplitude of vibration of said surface is periodic.

4. The method of claim **1**, wherein varying the amplitude of vibration of said surface is random.

5. The method of claim **1**, wherein varying the amplitude of vibration of said surface is in a programmed manner.

6. The method of claim **1**, wherein at least two ultrasonic vibrators are employed closely spaced in series along the moving threadline.

* * * * *