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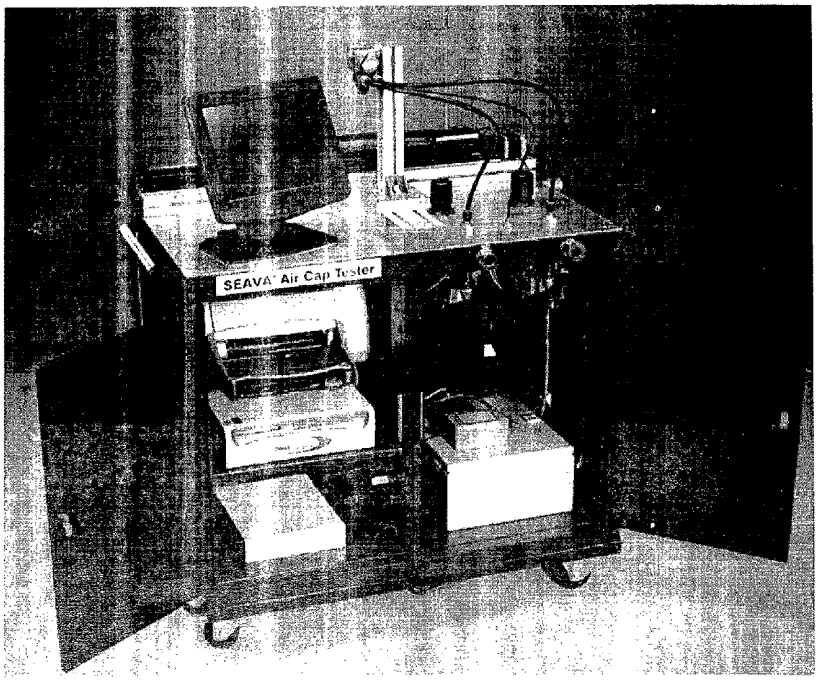
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(54) Title: AIR FLOW ANALYZER



(57) Abstract: A method, apparatus and system for precise measurement of air velocity profiles from coatings applicators such as paint spray guns. Multi-dimensional sensing arrays are used to characterize air velocity data. The system may be an integrated unit or may be constructed with the sensing array housed separately for remote operation in hazardous environments.

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AIR FLOW ANALYZER

Field of Invention

This invention relates to a method and apparatus for precise measurement of air velocity profile data from coatings applicators. Coatings may be paints, adhesives, ink, other chemicals or substrates.

Background of the Invention

It is known to derive air velocity from differential pressure data. This is commonly done using a pitot tube and peizo-electric differential pressure transducer. The pitot tube provides the mechanism for sensing total and static air pressure in the air stream. The differential pressure transducer outputs a millivolt electrical signal in proportion to the deflection of a piezo-resistive silicon strain gauge, that which is being acted upon by the total and static air pressures from the pitot tube. The millivolt signal is in turn amplified and converted for display or acquisition.

It is known to measure air velocity from temperature differential of solid-state electronics. This is commonly done using a microprocessor to regulate the temperature of a thermistor, and record the amount of current required to maintain a constant temperature while immersed in an air stream. The co-efficients of air-cooling are known, thus air velocity is derived from heat loss information. This device typically requires that the solid-state thermistor be heated to approximately 170 degrees F, making is unsuitable for hazardous or explosive environments.

It is known to characterize air velocity data from a paint gun utilizing one of the above technologies. Currently, a method exists whereby an air velocity probe is indexed with an open loop actuator horizontally through the centerline of a paint gun air stream. The resulting air velocity profile is

somewhat useful, but lacks completeness, in that only a small portion of the air stream is represented in the data. Moving the air velocity probe vertically up or down from the centerline will yield different results, as the air velocity changes near the edges of the pattern. This data is useful, and may yield the answers to many questions regarding paint gun performance. To date, taking multiple tests at various heights, and manually compiling the data into a composite profile of the air stream have accomplished this. This is very time consuming, and lacks accuracy due to operator error.

It is also known in the coatings industry to apply the actual final coating to a test panel, and measure the thickness of the deposited material to derive film build data. Film build is the true indicator of applicator performance. However, this is a very time consuming and labor intensive process, and is subject to operator error. This method also requires the use of the expensive coating material, as well as the handling of hazardous materials in some cases. Typically, a film build profile takes several hours to a day to achieve.

Summary of the Invention

A method and apparatus is described for precise measurement of air velocity profile data from coatings applicators. An array of pressure sensing points is inserted into the air stream of a coatings applicator, to derive air velocity data at predefined intervals. A plurality of differential pressure sensors connected to various types of pressure sensing devices comprising an array are used to acquire multiple readings at once, generating a comprehensive display of air velocity data over the entire affected area. Said data is acquired, displayed, and analyzed with custom software and analog to digital microprocessor controllers. A multiplicity of ambient conditions may also be monitored (dew point, humidity, temperature, mass or volumetric air flow, air pressure, and film build data), and subsequently integrated into the analysis software. The present method and apparatus is more accurate, more versatile, faster, cheaper, and provides considerably more data than prior art systems in

which single point air velocity readings are acquired and must be manually integrated to form an equivalent data table. Prior art also uses hot wire air velocity detection technology, prohibiting use in hazardous environments.

Brief Description of the Drawings

Figure 1 is a front view of a single dimension array;

Figure 2 is a side view of the single array showing the applicator and the air stream.

Figure 3 is a top view of a single array showing the range of motion used to collect all data points in the air stream.

Figure 4 is a further side view showing the indexing means.

Figure 5 is a matrix array shown in use to measure data from a bell gun type applicator.

Figure 6 is a graph of sample data output from the system.

Figure 7 is a cross-sectional view of one embodiment of the pitot tube array.

Figure 8 is a perspective view of the entire system with accessory components.

Figure 9 is a schematic view of the entire air flow analyzing system.

Figure 10 is a perspective view of the multi-dimensional sensing array.

Figure 11 is a sample data profile produced by the analyzer.

Detailed Description of the Invention

In order to more clearly understand the present invention part numbers as assigned in the following parts list will be used:

Part Number	Description
1	Single Dimension Array
3	Housing of Sensing Array
5	Air Velocity Sensing Ports
7	Mounting Plate
9	Indexer

10	Paint Gun or Other Applicator
12	Air Stream
14	Pitot Tube Array
16	Electrical Box Housing Differential Pressure Sensors and A/D Hardware
18	Air Spray Pattern
20	Sensor
22	Motion of sensor
30	Applicator
32	Bell Gun Air Stream Pattern
40	Sensor Array

The invention teaches a method for precise measurement of air velocity profile data from coatings applicators by utilizing a plurality of pressure sensing ports or mechanisms configured in precise increments of measure from each other, to comprise an array, to acquire total and static air pressure data from the air stream of the coatings applicator. The differential pressure sensors are connected to an array of pressure sensing ports or mechanisms placed in the air stream of the coatings applicator.

The pressure sensors are characterized by a sensor component in an electrical circuit with a control means, the sensor component being responsive to applied pressure to modulate an electrical signal applied to it by the control means. The magnitude and polarity of the signal changes according to the magnitude of the applied pressure and the side of the sensor component to which the pressure is applied. The high pressure reference source port is connected to the pressure sensing ports in the air velocity stream (total pressure), and the negative pressure port is connected to known positive and negative pressure sources (static pressure).

Analog to digital microprocessors are used to convert the electrical signals from the pressure sensors into numeric data to be interpreted by the

control software. The software converts numeric pressure data to air velocity using established fluid dynamics algorithms.

The software can acquire, display, and analyze velocity data interpolated from the pressure sensors to present useful coating applicator air velocity data and data analysis to the end user.

The custom software can also acquire and control ambient conditions from peripheral sensors and equipment to control testing parameters, including but not limited to air pressure and air flow to the coatings applicator. It can also derive statistical conclusions regarding the coating applicator's performance.

The array of pressure sensing ports or mechanisms can use a plurality of pitot tubes to acquire total and static air pressure data. They are configured in precise increments of measure from each other, to comprise an array, to acquire air pressure data from the air stream of the coatings applicator.

Singular open ports can also be utilized as sensing ports to acquire total air pressure data, configured in precise increments of measure from each other, to comprise an array, and sensing static pressure in a different location separate from the array and outside of the coating applicator's air velocity window.

Finally air cylinders can also be used as sensors, being configured in precise increments of measure from each other, to comprise an array, to acquire air pressure data from the air stream of the coatings applicator. The air cylinders can be provided with calibrated plates attached to a moving piston rod, coupling the ports of the piston to the positive and negative ports of the pressure sensors. The force of the air velocity acting on the plate will displace the piston, generating positive and negative pressure readings that represent total and static air pressure to be converted to air velocity data.

The air cylinders can also be used to amplify and/or dampen the air velocity activity existing in the coating applicator air stream.

Peripheral sensors and equipment are provided to analyze ambient conditions and compensate or adjust the air velocity data accordingly to achieve a calibrated or zero state.

In one embodiment a single, vertical, single column array of sensors is provided, of appropriate height to encompass or exceed the height of the coating applicator's air stream. This array is indexed with an appropriate actuator across the entirety of the coating applicator's horizontal air stream, recording air velocity data from the array at each index or interval, compiling said data, to derive a complete image of the air velocity performance of the coating applicator.

In another embodiment multiple vertical, single column arrays of sensors are provided, of appropriate height to encompass or exceed the height of the coating applicator's air stream. Indexing these arrays is accomplished with an appropriate actuator across the entirety of the coating applicator's horizontal air stream, recording air velocity data from the array at each index or interval, compiling said data, to derive a complete image of the air velocity performance of the coating applicator.

In a further, more complicated embodiment a single, multiple column, multiple row array of sensors is provided, again of appropriate height to encompass or exceed the height of the coating applicator's air stream, and of appropriate width to encompass or exceed the horizontal size of the coating applicator's air stream, recording air velocity data from all of the array points simultaneously, compiling said data, to derive a complete image of the air velocity performance of the coating applicator.

An open loop actuator, comprised of a stepper motor, coupled to a screw drive or belt drive mechanism, supported by a stabilizing means, and controlled by the system software can be used to move the sensor array before a fixed coating applicator.

Alternatively, a closed loop actuator can be used, comprised of a servo motor, coupled to a screw drive or belt drive mechanism, supported by a stabilizing means, and controlled by the system software to move the sensor array. Finally, an exterior actuator can be used, comprised of a conveyor system, to move the sensor array.

In another embodiment, the applicator can be moved instead of the array. Here a stationary sensor array is provided, and the coating applicator is moved with an external actuator, including open loop and closed loop linear actuators, articulated robot arms, and human manipulation.

The system is designed using an approved container for hazardous or explosive environments. The container houses the electrical controls and pressure sensors, attaching sensor arrays, additional sensing equipment, and controls to a carrier mechanism designed for use in the manufacturing environment, powering controls and sensors with re-chargeable batteries, and broadcasting the acquired data wirelessly to a server, for achieving a means of distributing the data to multiple users. Data can be distributed to multiple users over a LAN, said data displayed on desktop PC's websites, and/or handheld computing devices, and being accessible worldwide and in real-time.

In summary, the present system uses an array of velocity sensors, instead of the prior single sensor, to provide greater accuracy, improved resolution, and reduced testing times.

In one embodiment, a single vertical array of velocity sensors replaces the single point sensor on existing systems, and provides a great deal of new information. The array eliminates the need for manual interpolation of multiple tests at different heights from the centerline of the paint gun.

Paint guns currently being tested with the prior art use an air atomizing technique to atomize the paint, and fan air to shape the pattern. This results in an oval shaped pattern of paint, ranging in width from 300 to 500 mm, and in height from 100 to 200 mm.

A typical single-point test with the prior art takes about 90 seconds, using a 10mm index size, and a 600mm effective stroke. This produces a single slice of data, and would have to be repeated as many as 10 to 20 times at varying heights (in 10mm increments) to capture the same data as the present system. The accumulated testing time would be 900 to 1800 seconds.

Considering a single dimension array of the present system with 10mm spacing between the air velocity sensors, and a total of 20 sensors, the above example would be tested in 90 seconds.

In another embodiment for applicators with larger air streams, or strictly for speed of testing, a multi-dimensional array of velocity sensors can be used. This eliminates the need to index the applicator or the velocity sensor, and also provides real time data regarding air velocity performance and fluid dynamics phenomenon.

There exists two particular applications for which the prior art is not capable of being used, bell gun testing and on-line testing.

A bell gun is particular style or methodology of paint gun that uses a rotary atomizer and shaping air to distribute paint. The pattern produced by this method of painting is large and round. The pattern is similar to the shape

of a bell (hence the name), and the pattern area is typically in the range of 20" to 30" in diameter. The single point test method will not work in this application, as the number of data points is so large, and the area is also 2-dimensional. Taking single data points will not provide the data required.

A large, multi-dimensioned array of air velocity sensors spaced evenly would show the entire bell profile in real time, and also allow for statistical analysis of this data at a later date. The sensor array may take the form of a 1" x 1" matrix, 30" x 30" square in size, resulting in 900 sensors acquiring data at once. The size and spacing of the sensors is arbitrary and may increase or decrease depending on the required resolution dictated by the customer.

The prior art is only suitable for laboratory use, therefore limiting the effectiveness of the data that may be obtained. It is desirable for customers to view the cumulative effects of paint equipment variations in the actual production environment. No known method exists for this application.

Use of the present system, when tailored for use in the hazardous environment, will provide performance data, as expressed in air velocity performance, of the entire paint application system. Currently, there exists a number of automated paint applicators in each automotive paint shop. These are typically robotic systems, complete with complex paint delivery systems and automatic paint guns. It is assumed but not proven that the final result of the paint process will vary from robot to robot, paint gun to paint gun, and between paint delivery systems. This variance is estimated to be as high as 50%, resulting in poor paint quality.

The present system would allow the user to qualify the output of each system by viewing the end result: air velocity profiles from the paint gun. Use of the aforementioned multi-dimensional air velocity sensor array would allow users to test their equipment as they use it. This may show problems with

air velocity performance as the robots move thru different motions (kinking and air line or fluid line).

It will be understood that modifications can be made in the embodiments of the invention described herein.

CLAIMS:

1. An air flow analyzer to measure air velocity profile data from a coating applicator comprising:

a sensing array;

a control means;

a plurality of pressure sensors incorporated into the array, each sensor including a sensing component responsive to applied pressure to modulate electrical signals applied to it by the control means, the magnitude and polarity of the signal changing according to the magnitude of the applied pressure and the side of the sensing component to which the pressure is applied:

2. An air flow analyzer as claimed in Claim 1 wherein the sensing array is moved into and out of sensing position by an external actuator.

3. A method for measuring air velocity data from coatings applicators comprising:

utilizing pressure sensors located in a multi-dimensional array in an electrical circuit with a control means;

calibrating pressure sensors with a reference sensor to determine the actual pressures existing between high and low pressure areas to be sensed by the array.

4. A system for characterizing the air velocity profile generated by coatings applicators comprising:

a multi-dimensional sensing array;

a means for collecting data from the sensing array;

processing said data to establish air velocity profiles from said data.

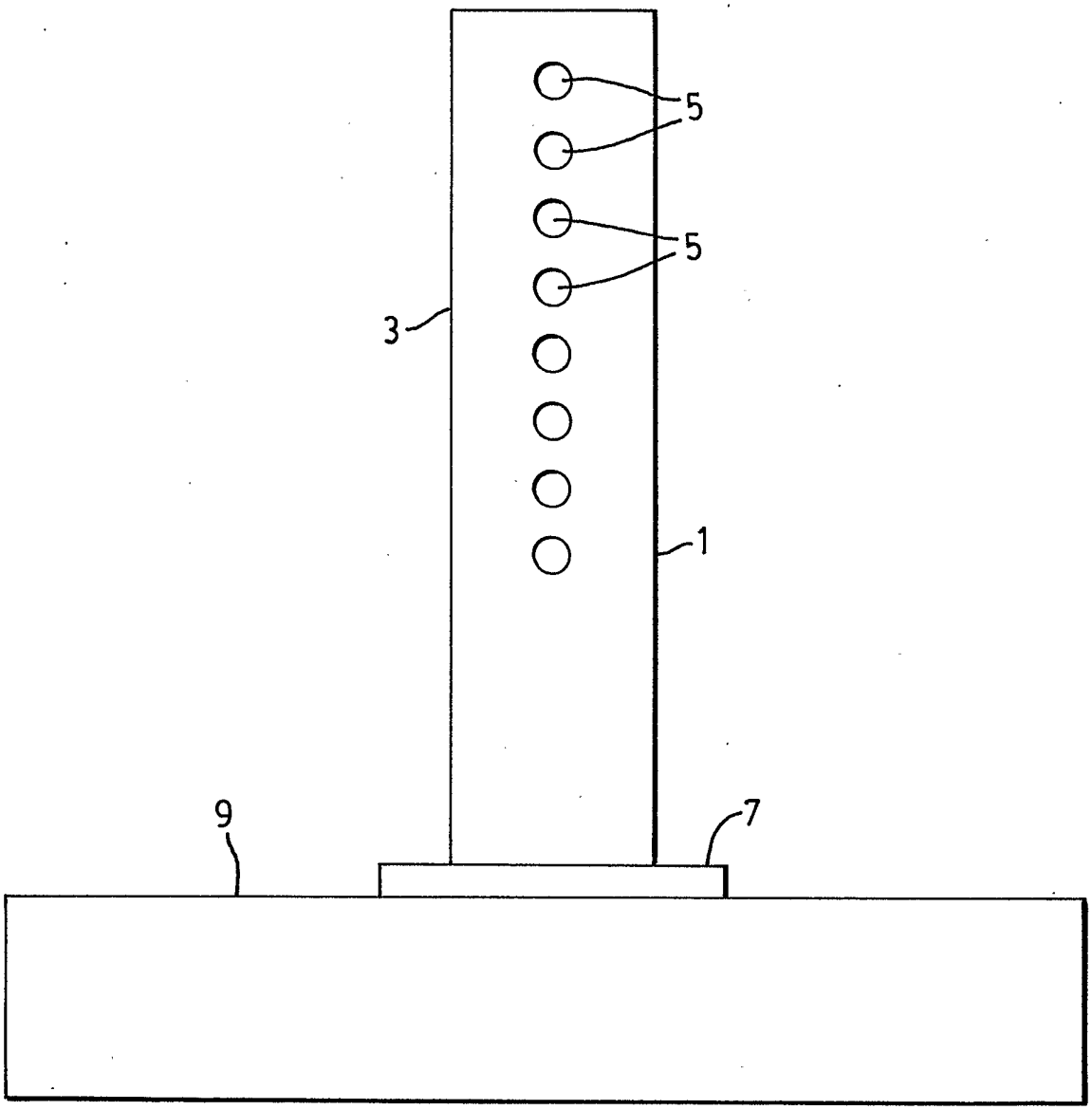


FIG. 1

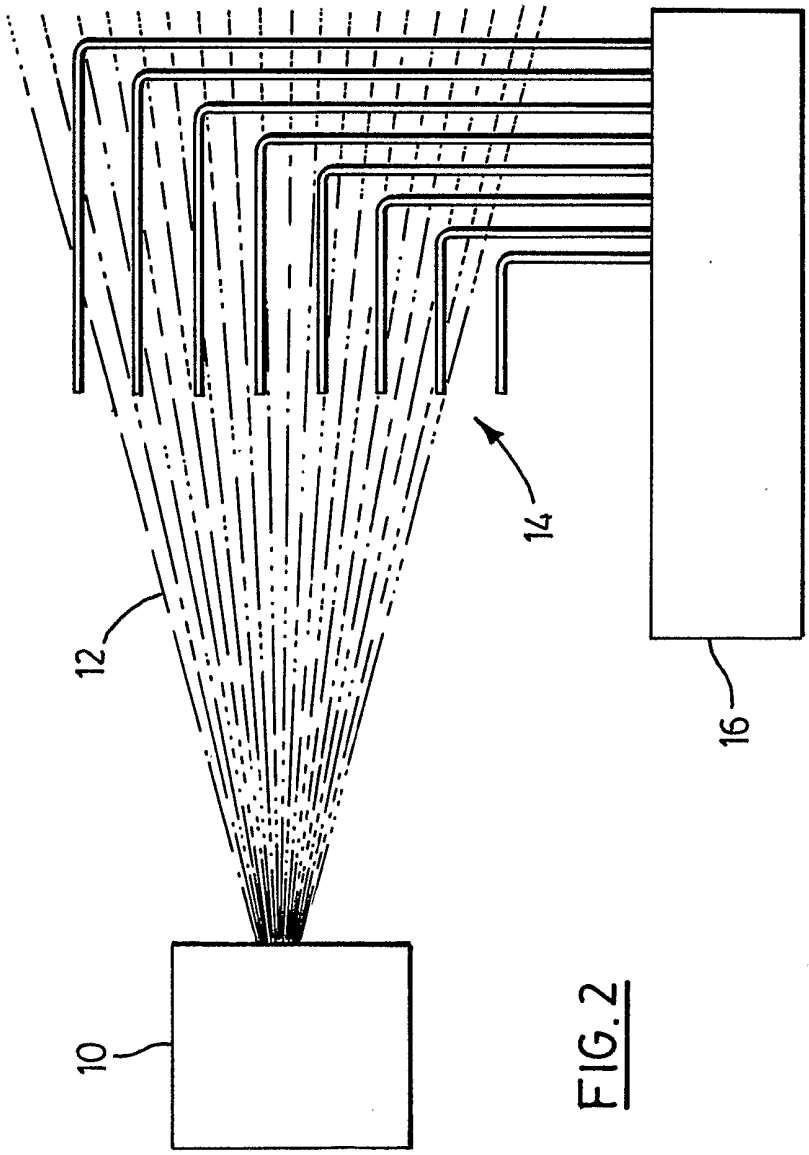


FIG. 2

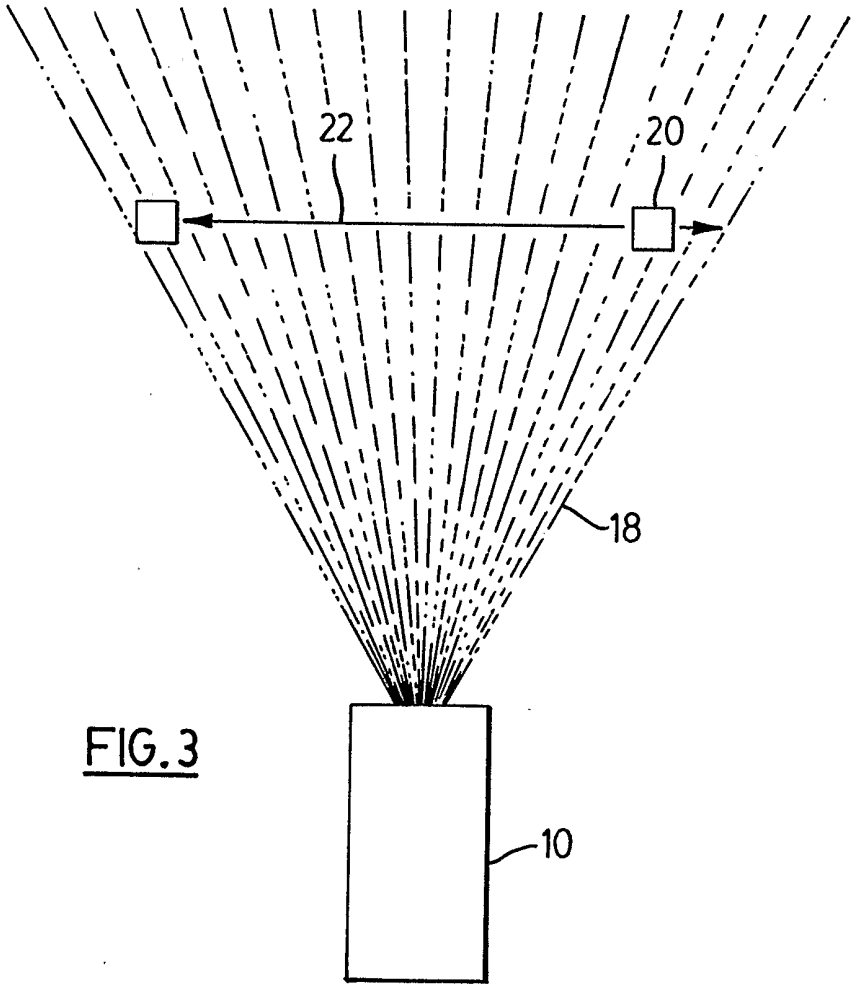


FIG. 3

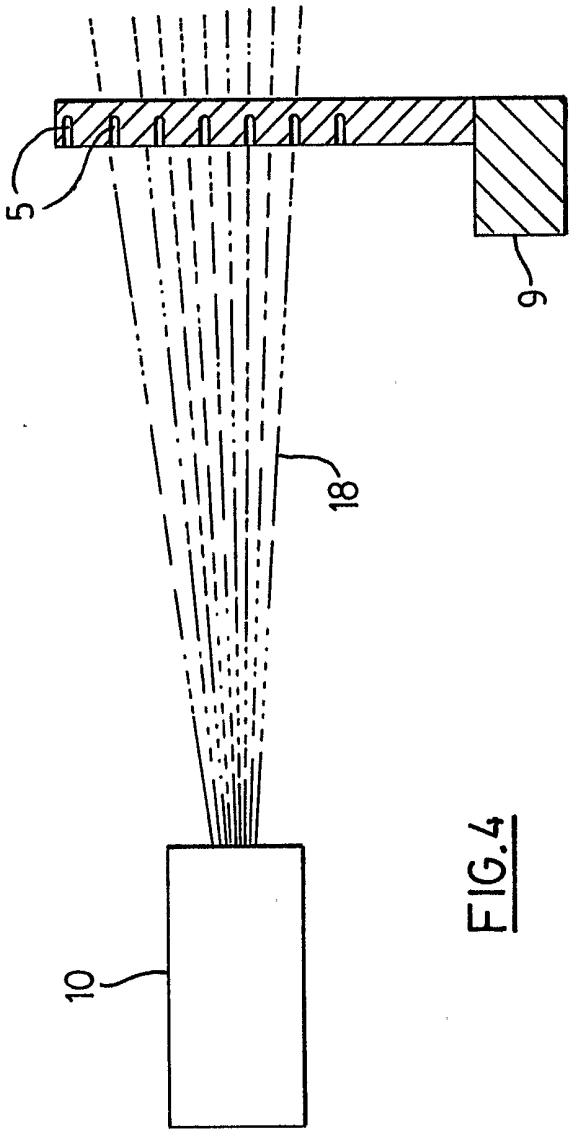


FIG.4

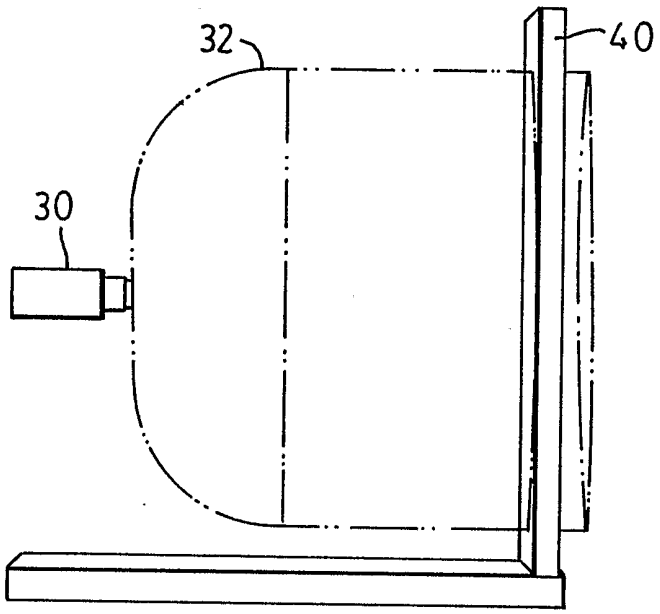


FIG.5a

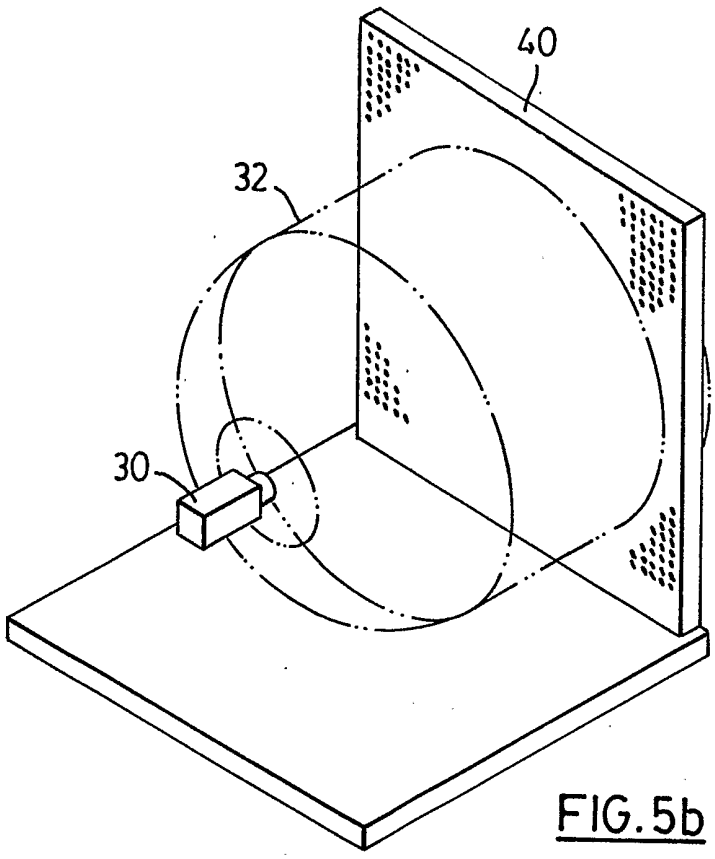


FIG.5b

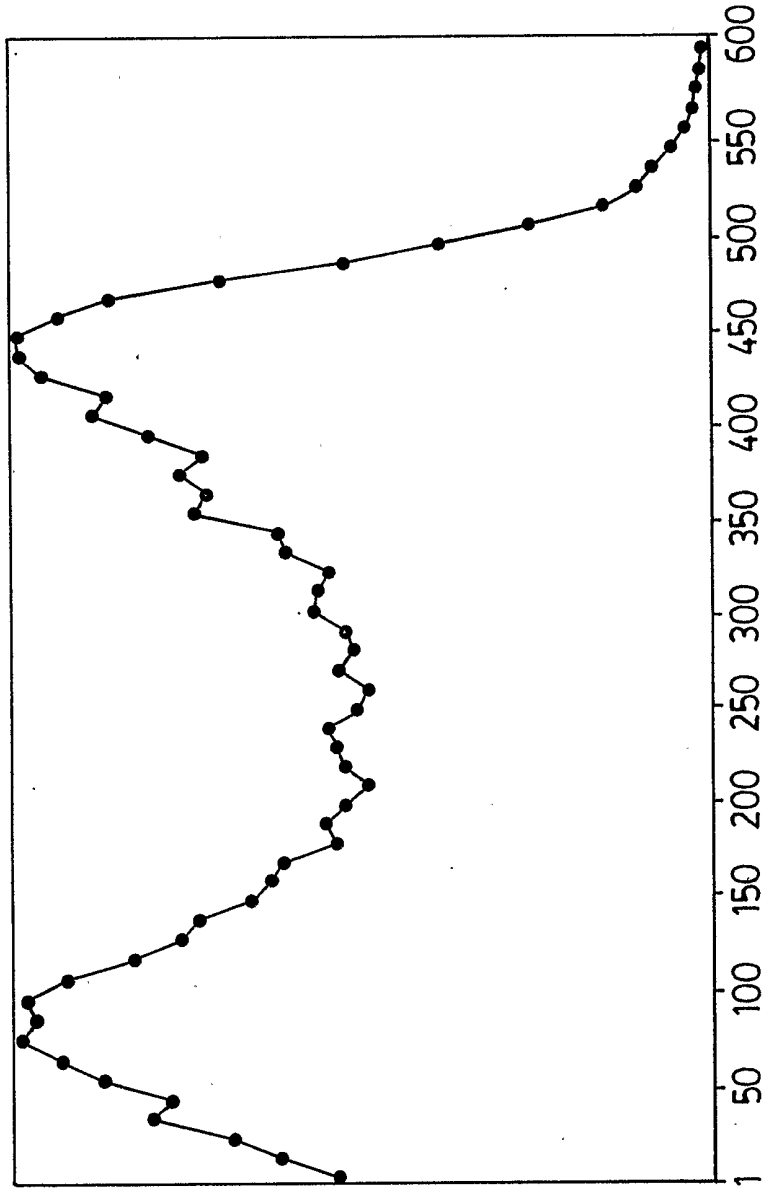


FIG. 6

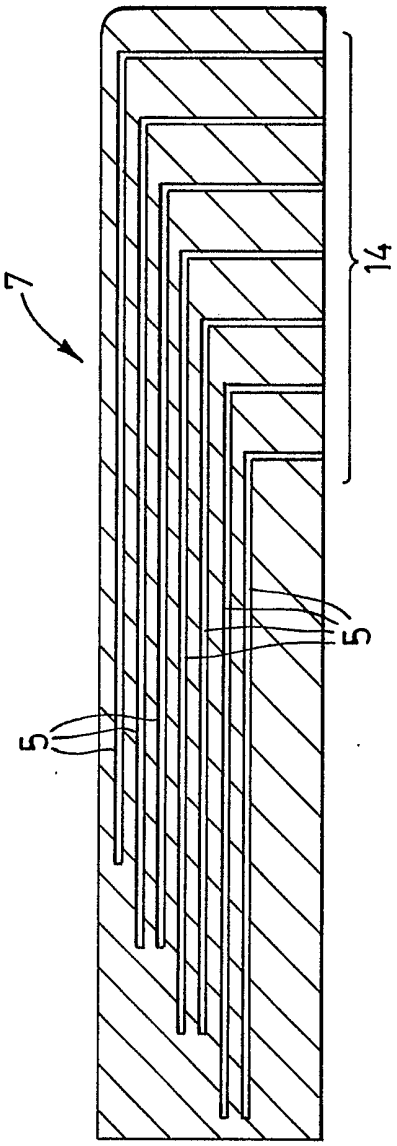


FIG. 7

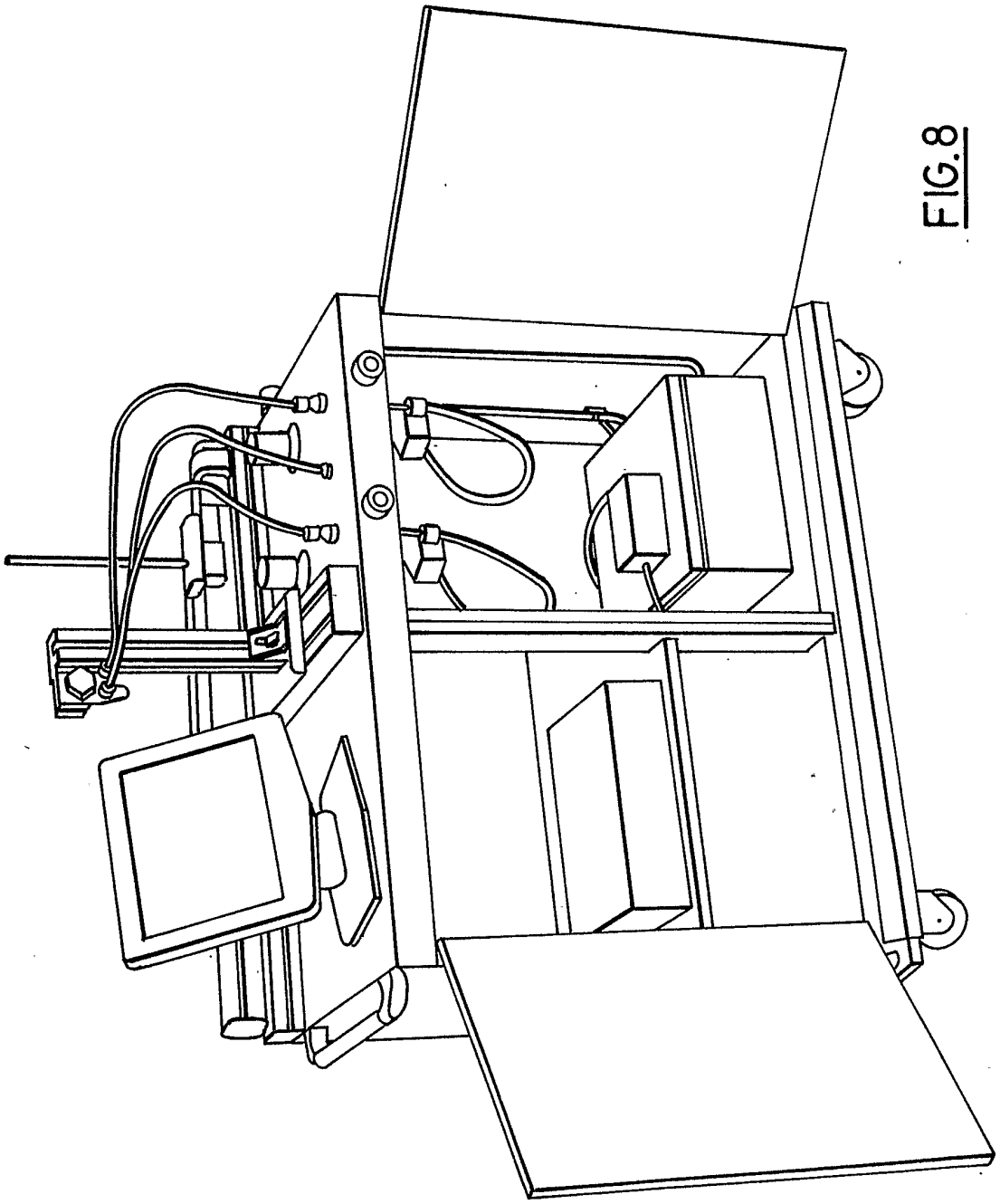


FIG.8

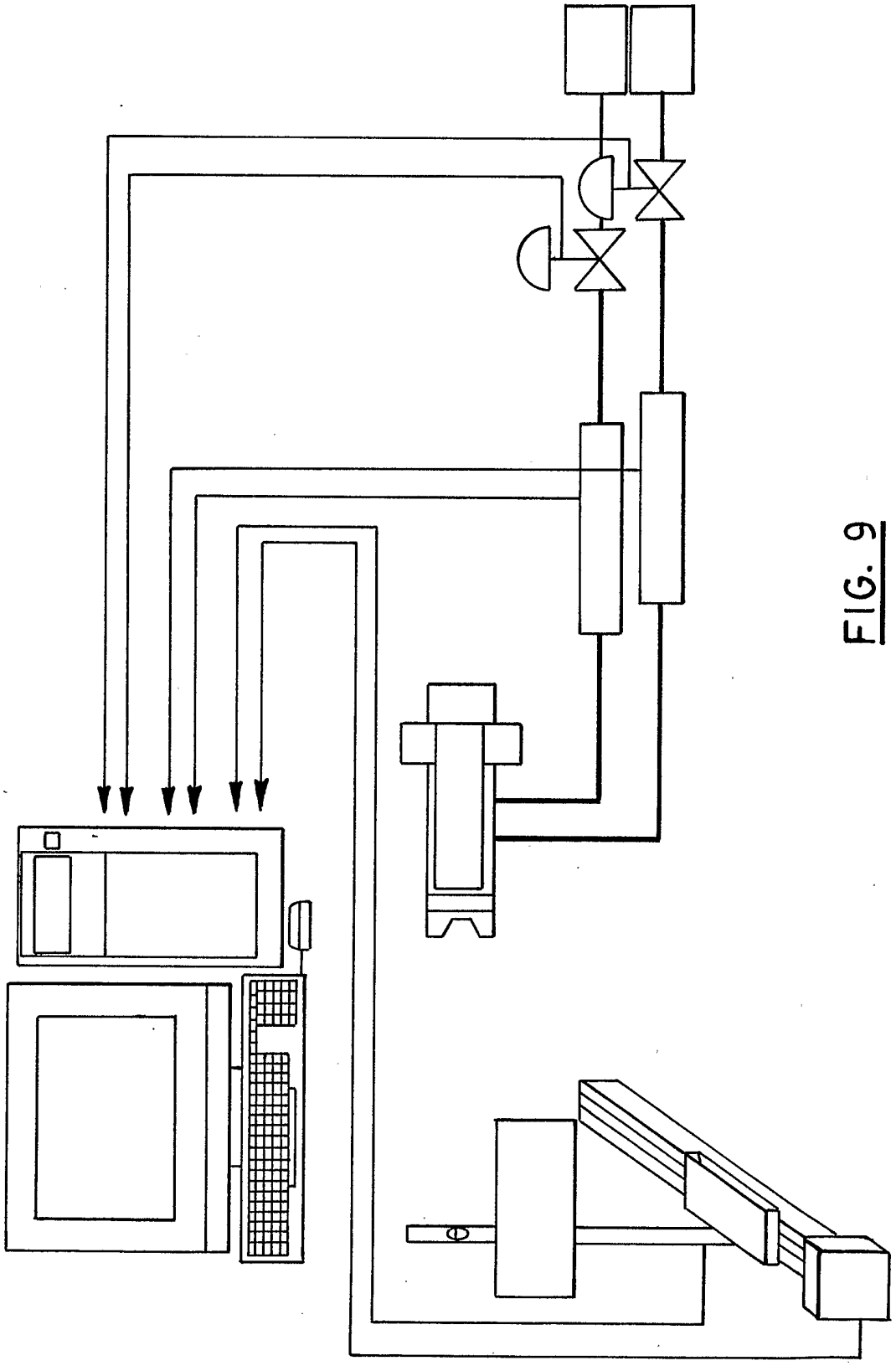


FIG. 9

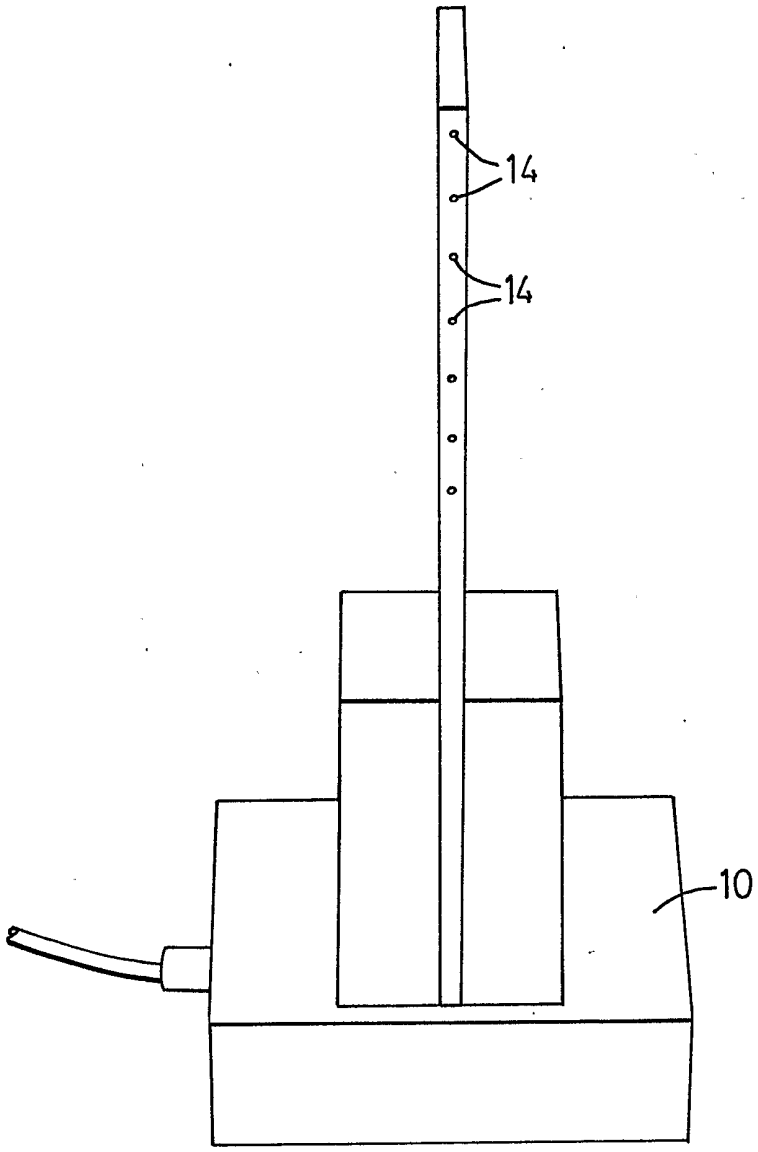


FIG. 10

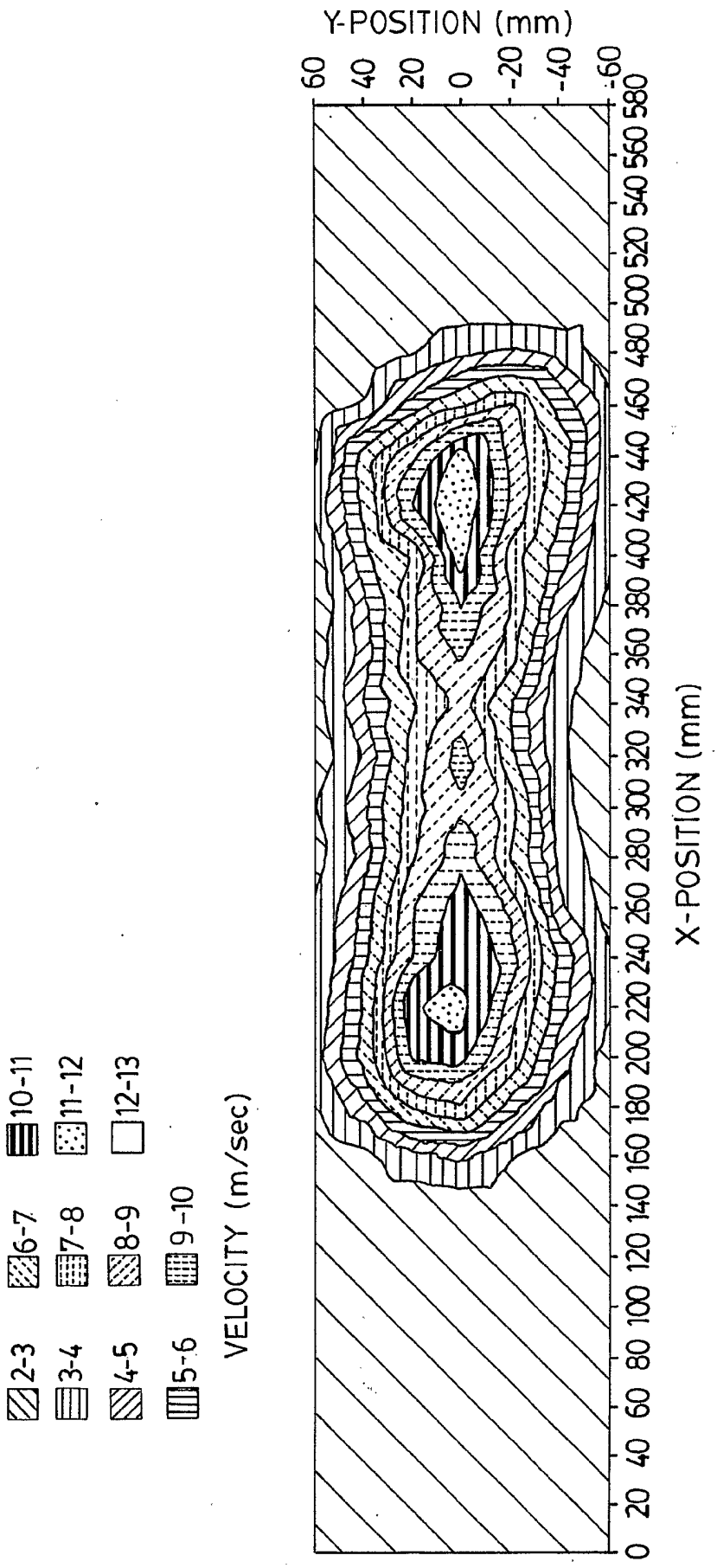

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X-POSITION (mm)
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VELOCITY (m/sec)
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3-4
4-5
5-6
6-7
7-8
8-9
9-10
10-11
11-12
12-13

FIG. 11a

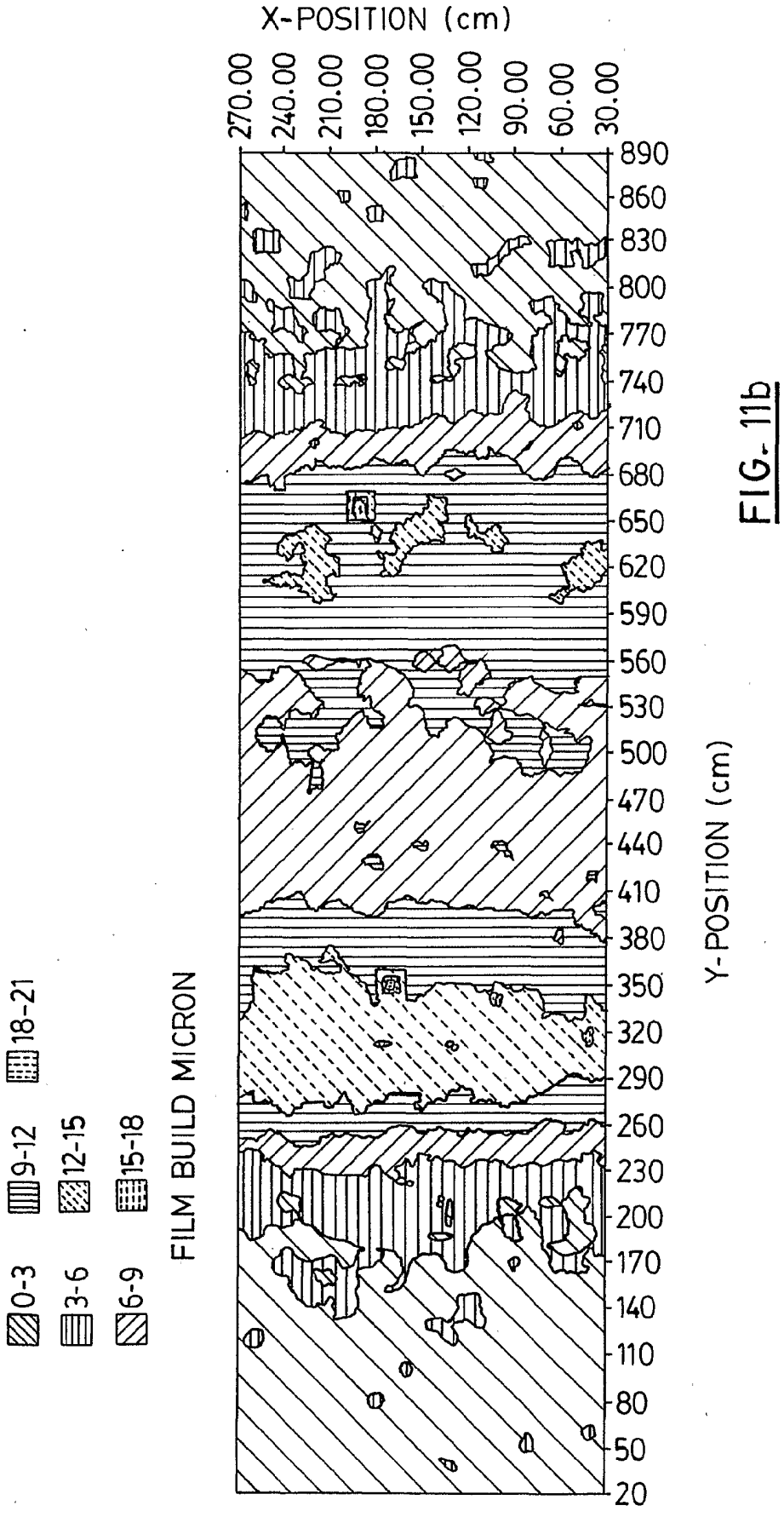

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140
110
80
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20
Y-POSITION (cm)
FILM BUILD MICRON
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3-6
6-9
9-12
12-15
15-18
18-21

FIG. 11b