United States Patent

[11] **3,536,088**

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A division of Ser. No. 634,958, May 1, 1967, now Patent No. 3,498,309.
[45] Patented **Oct. 27, 1970**

[54] **DEVICE FOR MEASURING CONCENTRATION OF NARCOTIC GASES**
4 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **137/88,** 73/23, 128/188
[51] **Int. Cl.** **G05d 11/08,** A61m 17/00, G01d 5/34

[56] **References Cited**

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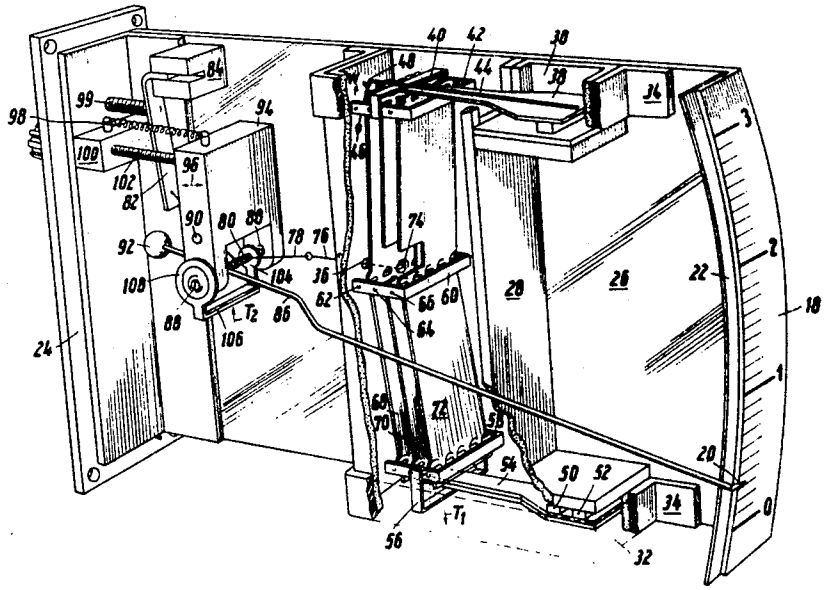
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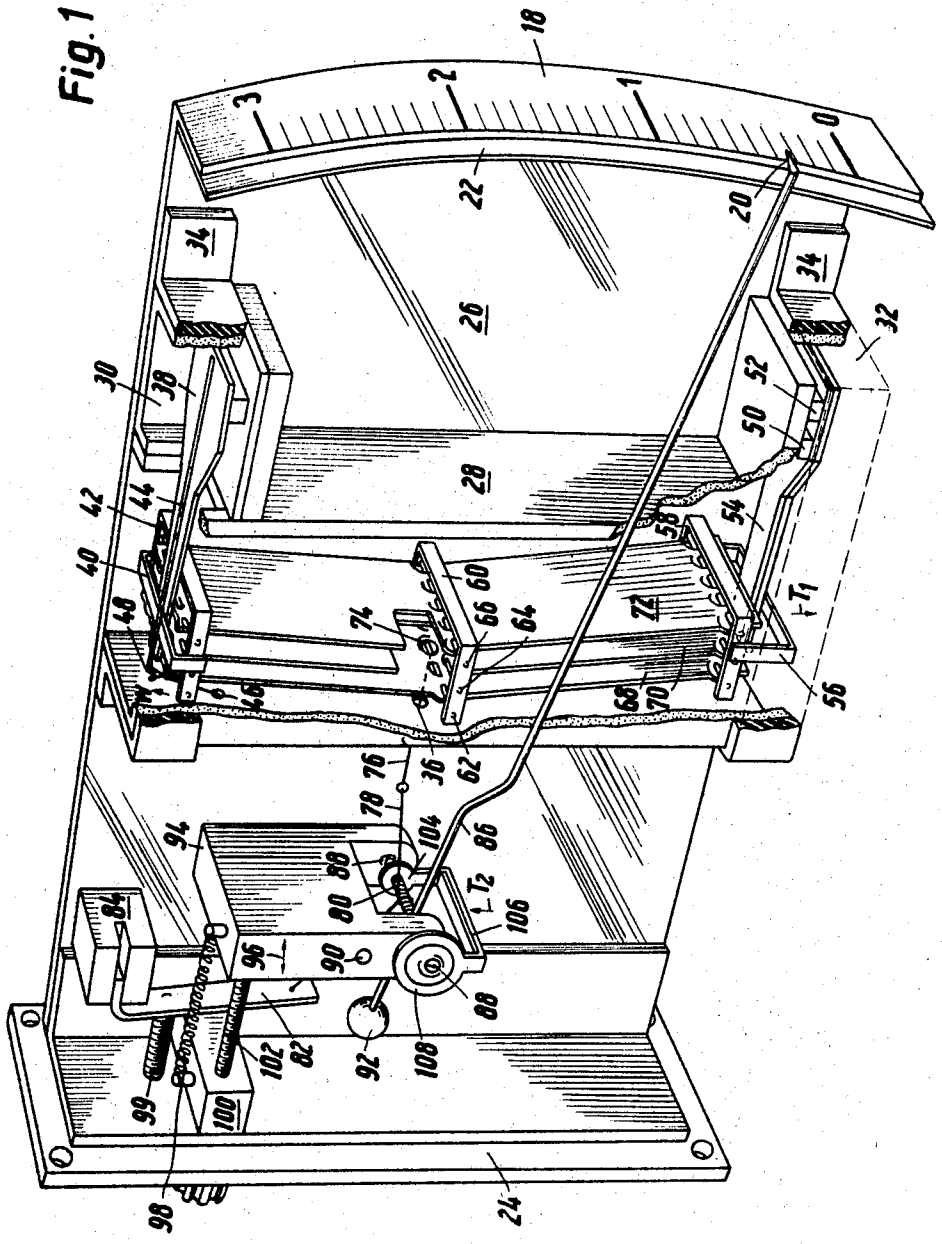
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ABSTRACT: A device for measuring the concentration of a narcotic vapor in a gaseous flow to be inhaled by a patient comprises a casing housing at least one tape of a material that is capable of reversibly swelling in the presence of the narcotic vapor in the gaseous flow, the preferred material being silicone rubber having a thickness between **0.1** mm and **1** mm. The tape is supported and mechanically biased, and the casing comprises means for transferring a variation of the length of the tape that is due to the narcotic vapor to an indicating member or to optical detecting means, and means for compensating for water vapor carried by the gaseous flow. The optical detecting means may generate electrical signals for controlling a recorder or for controlling the addition of the narcotic vapor to the gaseous flow.



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Fig. 1



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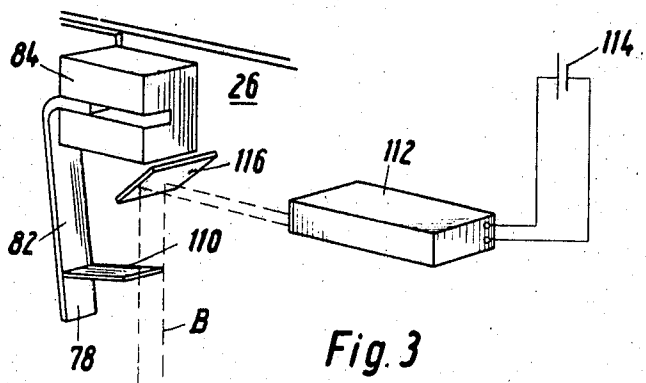
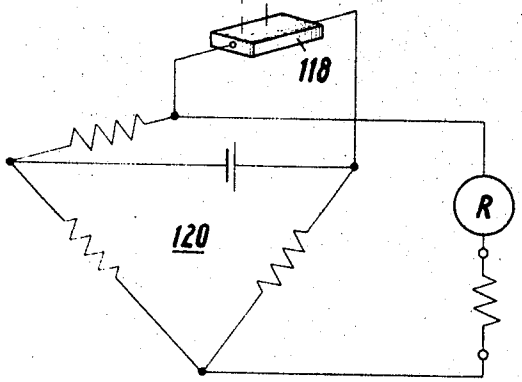


Fig. 3



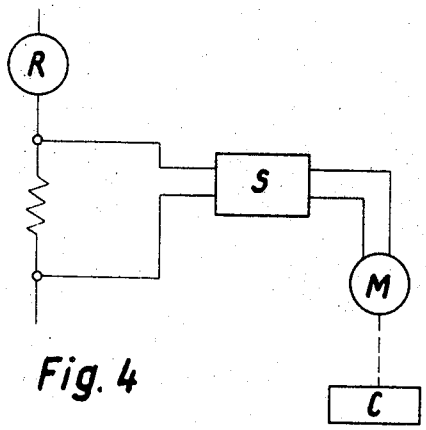


Fig. 4

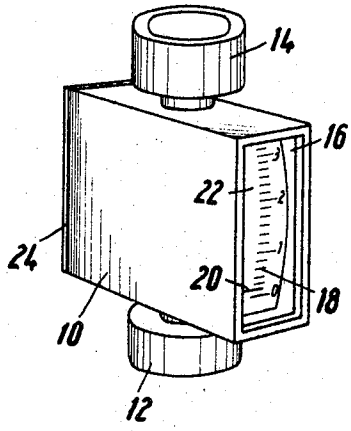


Fig. 2

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DEVICE FOR MEASURING CONCENTRATION OF NARCOTIC GASES

CROSS REFERENCE TO RELATED APPLICATION

This is a division of application Ser. No. 634,958, filed May 1, 1967 now U.S. Pat. No. 3,498,309.

BACKGROUND OF THE INVENTION

This invention relates to measuring instruments for use in clinics and particularly to instruments by which the concentration of narcotic gases or vapors within a gaseous stream to be applied to a patient can be indicated, recorded or controlled.

In performing surgical operations, the patient may be narcotized by diethylether and also by cyclopropane in some cases. The vapors of these substances are inflammable in the air and therefore tend to deflagrations and explosions. As more and more electrical devices are applied in surgery, increased danger of fire and explosions occurs, when using the respiratory anaesthetics mentioned before. The operation of electrical devices often causes sparking, whereby the narcotic vapors are lighted.

In recent years incombustible narcotics have therefore entered into use in surgery, *e.g.* 1-bromo-1-chloro-2,2,2-trifluoroethane; 1,1,1-trifluoro-2-chloro-2-bromoethane; 1-bromo-1-chloro-2,2-difluoropropane and 2,2-dichloro-1,1-difluoroethylmethylether. In supplying the named incombustible narcotic gases to the patient, considerable technical difficulties, however, have occurred with respect to their dosage.

For instance, the saturation partial pressure of 1-bromo-1-chloro-2,2,2-trifluoroethane amounts to about 240 mm. Hg or to 30 percent by volume of an air mixture. On the other hand, the concentration to be supplied to the patient may not exceed 1.5 percent by volume, because a small overdosage can certainly result in depression or stagnation of respiration and/or circulation of the blood.

German Pat. No. 1,142,677 discloses that the evaporative rate of the narcotic substance and thereby its concentration in the flow of fresh gas to be applied to the patient can be maintained at a small extent by different means. In this way, a partial protection for the patient against overdosage is imparted; a complete observation of the concentration of the narcotic gas to be supplied to the patient, however, is not possible, so that accidents due to an overdosage are not excluded.

When using 2,2-dichloro-1,1-difluoroethylmethylether as a respiratory anaesthetic, there is the danger that this substance will deposit in the form of globules or small pools on its way to the patient from the evaporator due to its easy condensation characteristics. If the evaporator is cut off or removed to avoid an overdosage, these globules or pools will volatilize, so that the patient receives the undesired overdosage of the narcotic, although the operator assumes that the supply to the patient has been finished.

In order to assure the necessary dilution of the narcotic vapors in each case, vigorous supply of fresh gas is therefore preferred, but only a fraction of the supplied gases or vapors can be utilized by the patient. The remaining fresh gas which is mixed with the diluted narcotic again enters the room. The air of the room of surgical operations, however, accumulates the narcotic gases which affect the personnel, when staying in that room for a long time, and such accumulation in the air causes headaches and nausea.

According to German Pat. No. 856,795 a control device adjusts the addition of a narcotic vapor to the flow of fresh gas in response to cooling of the evaporating narcotic liquid. The smaller the concentration of the evaporated narcotic substance in the gaseous condition, the more insensitive the control device, so that the device is well suitable for a narcosis utilizing diethylether, but not suitable for a narcosis using the non-inflammable 1-bromo-1-chloro-2,2,2-trifluoroethane (compare the partial pressures in the air).

Furthermore it is known that the moisture, *i.e.* the quantity of water vapor enclosed within a room filled with air or another gas, can be measured by means of a hygrometer. Its function is based on the fact that some organic substances vary their lengths or their volumes in response to the relative humidity of the gas. Prepared hairs of women, membranes of animals, several types of wood, foils of plastics and fibers of textiles are used for the mentioned purpose. Hygrometers using hairs are often applied and comparatively work with good accuracy. For calibration, the knowledge of some degrees of moisture is required, which are adjusted by means of a hygrostat. Only such hairs can be utilized which are reversible *i.e.* their response must be such that the pointer of the meter returns to its initial reading after a stand at a very high extent of moisture. Also hairs which lengthen themselves continuously are not useful, because the pointer can not reach a final stand.

The designers of the known hair-hygrometers assert sometimes that not only the content of moisture within the air, but also the presence of some organic substances, *e.g.* benzene, gasoline or tetrachloromethane in the air can be determined by these meters. Such a theoretical conclusion appears to be evident to those skilled in the art; in practice, however, the difficulty arises to find materials which will respond to such organic substances like the human hair responds to water vapor, *i.e.* will also swell in a completely reversible manner. The observation that, for instance, natural or synthetic rubbers will swell in gasoline vapor, however, appears to be not sufficient to assure that these materials are suitable for designing measuring devices which will operate according to the principle of the hair-hygrometers. Rubber swells in gasoline vapors nonreversibly, as it elongates itself continuously, so that the pointer does not reach any final stand.

It has been known from the book with the title: "Ullmanns Encyklopadie der technischen Chemie", third edition of volume No. 9, Berlin and Munich 1957, pg. 350, that products vulcanized from silicone gum are swelled by solvents, *e.g.* aliphatic, aromatic and chlorinated hydrocarbons, and are attacked by concentrated acids and leaches. Also their good persistancy without any aging effects has been known.

SUMMARY OF THE INVENTION

It has now been found that the swelling characteristics of silicone rubber in the presence of the said respiratory anaesthetics, which belong to the class of halogenated hydrocarbons and ethers, are completely reversible, similarly to the characteristics of human hairs within water vapor; said characteristics are utilized for designing a device which can measure narcotic gases and vapors and will work according to the principle of the hair-hygrometer, so that a relatively inexpensive device for measuring the concentration of respiratory anaesthetics is available for surgical operations in clinics.

Large systems for measuring the concentration of the incombustible narcotic vapors mentioned previously are used in research and science; they utilize certain optical absorption bands within the ultraviolet or infrared range of the spectrum. The ultraviolet radiation decomposes these narcotics in a chemical process, in which poisonous derivatives are formed; in consequence thereof, it is not possible to measure the concentration of the narcotic gas in the gaseous flow to be applied to the patient directly, because the patient and the hospital personnel would be harmed by these poisonous substances. The measurements within the infrared spectrum, whereby poisonous derivatives are not formed, require enormous expense to eliminate a plurality of disturbing factors; the expense appears to be too large for clinical routine.

The primary object of the invention is to provide a reliable mechanical device simply designed for measuring the concentration of narcotic vapors in the gaseous flow to be supplied to the patient for the purpose of anaesthesia in clinical routine.

A further object of the invention is to provide an inexpensive device for measuring the concentration of narcotic vapors in a gaseous flow, whereby the effects of temperature variations and of admixture of water vapor are compensated.

A still further object of the invention is to connect an inexpensive mechanical device for measuring the concentration of narcotic vapors in a gaseous flow to be applied to the patient with electrical means for recording the measuring results.

An additional object of the invention is to connect an inexpensive device for measuring the concentration of narcotic substances in a gaseous flow to be applied to the patient with electro-mechanical means for controlling the addition of the narcotic vapor to a stream of fresh gas.

In a preferred embodiment of the invention, the end portions of at least one tape of a material capable of reversibly swelling in narcotic vapors are supported and biased mechanically within a casing having an inlet and an outlet, and mechanical means are used to transfer a variation of the length of said tape, caused by the presence of the said vapors, to an indicating member. Preferably, the said tape consists of silicone rubber, and its thickness can be in the range between 0.1 mm and 1 mm.

Preferably, the variation of length of the said tape caused by narcotic vapors is increased by provision of a kink in the intermediate portion of the length of the said tape and by biasing the kink of the tape towards said mechanical transfer means.

In order to avoid undesired effects on the measurements due to variations of temperature, mechanical compensating means can be provided. To avoid troubles due to variations of the content of water vapor in the gaseous flow carrying narcotics, mechanical means for compensating for the water vapor variations are provided.

In order to record the readings, the indicating member can be associated with a mask varying the size of a light beam of a photoelectric apparatus, with which a recorder is connected.

In order to control the addition of the narcotic vapors to the flow of fresh gas, the indicating member can be associated with a mask varying the size of a light beam within a photoelectric apparatus, with which a servo-mechanism and a positioning motor for a control valve are connected.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of the internal body of the meter, wherein walls and gaskets of the chute guiding the gaseous flow are partly broken away;

FIG. 2 is a perspective view of the casing of the meter;

FIG. 3 is a schematic view of an apparatus for connecting the meter with a recorder;

FIG. 4 is a schematic view of an apparatus for connecting the meter with a controller.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 2 of the drawings, the external casing of the device for measuring narcotic gases is shown. It includes a parallelepiped block **10**, the bottom of which carries a pipe fitting **12**; a second pipe fitting **14** is provided on the top of the block **10**. Preferably the lower fitting **12** can be connected with a manifold (not shown), which introduces fresh gas which is intermixed with respiratory anaesthetic vapors or gases to be measured. The gaseous flow containing the narcotic passes the block **10** and emanates from the outlet **14**, with which a pipe (not shown) is connected; in this way the flow is supplied to the patient. The front of the block **10** is covered with a glass plate **16**; a graduation plate **18** of the meter is arranged behind the said plate **16**. A pointer **20** moves in front of a white area **22**. The pointer **20** and the graduation **18** are arranged in such a relation that the indications can be read without any parallax.

Measuring means, as shown in FIG. **1** in detail, can be shifted into the block **10**, when grasping an end plate **24** by hand. The end plate **24** is screwed on the block **10** at that end remote from the glass plate **16**, and a gasket (not shown) is inserted. If not stated otherwise, all attaching means of the members of the meter are provided by adhesives, preferably by epoxy resins, in order to avoid the use of a screw or other mechanical means which may loosen and vibrate. Also, all members housed in the block **10** consist of materials resistant to corrosion caused by water, carbon dioxide and narcotic vapors, if not indicated otherwise.

A vertical base **26** extends to the graduation plate **18** from the end plate **24**; substantially all members of the device are mounted on the base **26**. Also it forms one side wall of a chute **28**, through which the main gaseous flow is directed from the bottom upwardly. Sieves (not shown) are positioned between both the fitting **12** and the inlet of the chute **28** and the fitting **14** and the outlet, to prevent coarse impurities from entering the chute **28**. Two side walls of the chute are partly broken away, to allow an interior view to the chute.

Each end of the chute **28** is widened by one compartment **30** and **32**, respectively. Sealing felts **34** are laid around both ends of the chute **28** and both compartments **30** and **32**; the felts are also partly broken away. They cause the entering gaseous flow to be limited substantially to the chute **28**, although small volumes of the gas to be measured can leave the chute **28** through a hole **36** in one side wall and can spread themselves out in the whole inside space of the block **10**.

The broad end of a flat spring **38** is attached to the bottom wall of the compartment **30** by a block; the tapered opposite end of the spring projects into the chute, and there it supports a U-shaped frame **42** in a substantially horizontal position by means of a yoke **40**. A wire **44** extends on the surface of the flat spring **38** substantially along a central line and protrudes beyond the tapered end of the spring **38**, so that a small free end of the wire **44** can be bent in the form of a hook.

A string **48** of a polyamide-plastic, *e.g.* nylon, is in tension between the hooked end of the wire **44** and an ear **46** on the one side wall of the chute **28**. This string compensates for the influence of the water vapor carried by the gaseous flow, thus affecting the measurements. The string **48** expands, if the concentration of water vapor is increasing, whereby the tapered end of the biased flat spring **38** will turn up. The expansion of the string **48** in saturated water vapor amounts to about 8 to 10 percent of its length, compared with a dry atmosphere, and the elongation of the string **48** due to the water vapor is indicated by an arrow W.

The broad end of a slightly curved bimetal-spring **54** is fixed by two blocks **50** and **52** to the covering wall of the compartment **32**, partly broken away. When assembling the meter, the block **52** is adhered to the covering wall of the compartment **32**, also partly broken away, and to the bimetal-spring **54**, while the block **50** is movable for calibrating the meter. As the slight curvatures can be different between the springs, the spring **54** can be biased the desired degree by shifting the block **50**. During the calibration the block **50** is attached to the covering plate. The end of the spring **54** remote from the broad end freely projects into the chute **28** and is similarly tapered as the end of the flat spring **38**. A yoke **56** is connected with this free end; it carries a U-shaped frame **58** in a substantially horizontal position. This frame **58** corresponds to the frame **42** and to a third frame **60**.

Some thin rods **62**, **64** and **66** are arranged in parallel between the two brackets of the U-shaped frames **42**, **58** and **60** (only one end of the rods can be seen in the three frames). Tapes **68**, **70** and **72** produced from silicone rubber are pricked through by these rods several times, as one can see from the rod **62** in the frame **60**. There are parts broken out of the tapes **70** and **72**, so that one can see, in which manner the rod **62** extends through the central portion of the tape **68**. A thin wire **76** produced from a corrosion-resistive metal, *e.g.* stainless steel is slung around the rod **62** at a place **74**; it extends through the hole **36** in the one side wall of the chute **28**. A string **78** produced from terylene-type terephthalacid-polyester-fiber having the trademark "Trevira" is affixed to the opposite end of the wire **76**. This string **78** exhibits a very small swelling in water vapor which amounts to 0.2 to 0.3 percent of its length and can therefore be used as substantially inert mechanical transfer means. It extends around a shaft **80** journaled without any substantial friction to a biased leaf spring **82** which tends to cause the string **78** engaging the shaft

80 by friction to draw away from the tapes 68, 70 and 72 of silicone rubber. The upper end of the spring 82 is clamped and fastened in a block 84 which is adhered to the base 26.

Due to biasing the spring 82, the tapes 68, 70 and 72 fastened substantially in their middle portions by the frame 60 to each other, are kinked by the frame 60. The degree of bending out depends on the positions of the springs 38, 54 and 82 relatively to each other. In each case, the tapes 68, 70 and 72 are continuously biased uniformly. If their lengths change due to swelling, the kink angle and the position of the lower end of the biasing spring 82 will also vary, because the wire 76 and the string 78 transfer the slight variation of lengths as a translational motion to the end of the spring 82. As the string 78 engages the shaft 80 by friction, its translational motion is converted into rotational motion of the shaft 80. Both ends of the shaft 80 are journaled on points by means of bearing jewels within a block 94 without having any appreciable friction; the block 94 can be tilted by a small angle around a fixed pivot 90, as indicated by a double arrow 96 above the visible end of the pivot 90. A member 86 of the pointer 20 extends through a transverse bore in the shaft 80; for reasons of a more favorable balance, the end of the member 86 remote from the pointer 20 carries a counterweight 92, as represented by a ball of lead. In place of such a ball, also one or more screw threads and balancing nuts can be used for adjusting the uniform load on the shaft 80 by hand.

The end of the pivot 90 (not shown) is firmly fitted in the base 26. A helical tension spring 98 is fastened to the top face of the block 94 and continuously tends to cause the block 94 to tilt around the pivot 90 counterclockwise. The other end of the tension spring 98 is fastened to a stationary block 100 mounted on the base 26 also. A screw 102 and a setscrew 99 extend through the end plate 24; the bias of the spring 82 can be adjusted by means of the setscrew 99 from outside, whereby the sensitivity of the meter can be changed deliberately. An adjusting knob is provided on the end of the screw 102 projecting from the end plate 24 outwardly, while the other end rests on the back wall of the tiltable block 94. Upon rotating the adjusting knob, the block 94 tilts around the pivot 90. Due to this motion, also the shaft 80 rotates around the pivot 90. If the string 78 is not subjected to any translational motion, the shaft 80 is slightly rotated due to the frictional engagement of the resting string 78, whereby the pointer 20 slightly migrates adjacent the graduation plate 18. In this way the zero position of the pointer 20 can be improved by means of the adjusting knob by hand.

A collar 104 seats on the shaft 80 journaled on points without any substantial friction and carries a bimetal strip 106 extending in parallel with the shaft 80. An annulus 108 is fixed to the free end of the bimetal strip 106 projecting beyond the front face of the block 94. At a predetermined temperature of 20° Celsius, for instance, the center of gravity of this annulus 108 is nearly coincident with the extended central axis of the shaft 80. In this condition, the rotatable system consisting of the shaft 80, the pointer 20, the member 86, the counterweight 92, the collar 104, the bimetal strip 106 and the annulus 108 is balanced such that no rotational force is acting upon the shaft 80 in each angular position of the system, which force would tend to rotate the shaft 80. As soon as the temperature, however, rises in the inside of the casing 10, the bimetal strip 106 bends upwardly, as indicated by an arrow T_2, and the annulus 108 is raised slightly.

Now it may be assumed that due to this small motion of the annulus 108 the mechanical system disclosed above is deflected into a second position of unstable balance from the first position in which the system is in an indifferent balance at each angle. Upon raising the annulus 108, the system should furthermore be in such condition of unstable balance in an angular position, in which the pointer 20 indicates the zero mark of the graduation 18. This zero position should remain unchanged upon temperature variations within the casing 10.

If fresh gas intermixed with narcotic vapors now flows through the chute 28, the tapes 68, 70 and 72 expand due to their swelling. At the predetermined temperature of 20° Celsius, as mentioned above, this expansion of the tapes is proportional to the concentration of the narcotic vapor in the gaseous flow and is directly indicated in volume percent by the graduation plate 18 at an atmospheric pressure of 760 mm. Hg, after the necessary calibration has been performed. If the stream of fresh gas exhibits an increased temperature of 30° Celsius, for instance, the tapes 68, 70 and 72 only expand themselves due to this temperature increase, if no narcotic vapor is admixed. Because of this thermal expansion, the pointer 20 adjusted to zero would migrate by some extent upwardly, as the tapes will kink to a greater extent. To prevent this, the bimetal strip 54 opposes in such a manner that it draws the lower ends of the tapes in the direction of an arrow T_1. By this action, the linear effect of expansion of the tapes with increasing temperature is compensated.

A second temperature effect is superimposed upon this first linear effect in the presence of the narcotic vapors and can be derived from Henry Dalton's Law. In other words, the higher the temperature, the smaller the variation of length of the tapes 68, 70 and 72 at a given concentration of the narcotic vapor. In absence of the narcotic, this second effect does not occur, because swelling does not take place. This second temperature effect is compensated for by means of the mechanical system rotatable within the block 94, as described above. In the zero position of the pointer 20 adjacent the graduation plate 18, the annulus 108 is raised by the bimetal strip 106 in the direction of the arrow T_2, so that the system occupies a position of unstable balance. If the narcotic vapor is admixed to the gaseous flow, the variations of length of the tapes 68, 70 and 72 occurring at increasing concentrations are converted to rotation of the shaft 80. Because of the unstable balance of the mechanical system caused by bending the bimetal strip 106, a torque growing with increasing angle is added to this rotational motion of the pointer 20 from the zero position adjacent the graduation 18.

The first effect of temperature, *i.e.* the variation of the length of the tape produced from silicone rubber in response to the temperature in the absence of any swelling agent (water vapor or narcotic) amounts to about 0.2 percent of the length of the tape per degree Celsius. Because of the kinked suspension of the tapes 68, 70 and 72, this effect is multiplied by a factor of 4 to 5. The second temperature effect, *i.e.* the variation of length due to a reduced swelling with increasing temperature at the same concentration of narcotic, amounts to about 4 percent per degree Celsius of the variation of length of the tape which is caused by variation of the concentrations of the narcotic applied to the patient.

Silicone rubber of the tapes 68, 70 and 72 can be replaced by some other plastic whose swelling in the narcotic vapors is completely reversible, in case the plastic is free of aging and memory effects.

FIG. 3 shows how the mechanical device for measuring narcotic gases and vapors (FIGS. 1 and 2) can be connected with a recorder R electrically. The biasing spring 82 which draws the string 78 of "Trevira" and is clamped in the block 84 on the base 26 at its one end, carries a metallic leaf 110 which extends in a substantially horizontal direction and is sharpened at its free end like a knife edge. This end projects into an optical beam B, as indicated by dashed lines.

The beam B is produced within a casing 112 housing an electrical lamp and a collimating lens (both not shown) and also fastened to the base 26. The lamp is fed from DC source 114 which is outside the block 10 of the meter (FIG. 2). Furthermore, a mirror 116 is mounted on the base 26 and deflects the beam emanating from the casing 112 by an angle of nearly 90° and directs it to a photoresistor 118. The supply lines of the lamp and the output lines of the photoresistor 118 pass the end plate 24 by hermetical sealings (not shown). A bridge circuit 120 connected with the photoresistor 118 is outside the block 10 (FIG. 2) and is designed, as known per se, so that it will not be described in detail. The bridge circuit 120 includes the recorder R.

The translational motion of the string **78** which is converted to the rotational motion of the shaft **80** and to the indicating motion of the pointer **20** (FIG. 1), is also transferred to the metallic leaf **110** attached to the biased spring **82**. As this leaf **110** projects into the optical beam B, the diameter of the beam B is increased or reduced due to the motion of the string **78**; this variation is again detected by the photoresistor **118** and is recorded by the deflection of the recorder R.

As one can see from FIG. **4**, the bridge circuit **120** can also be connected with a servo-mechanism S having a motor M for controlling a control valve C, as known per se. This valve C regulates the addition of the narcotic vapor to the flow of the fresh gas and thus its concentration automatically. In this way, the concentration of the narcotic vapor in the gaseous flow to be applied to the patient can be maintained constant, although the temperature of the gaseous flow and its content of water vapor may vary in the course of the surgical operation. The circuit of FIG. **4** and the design of the control valve C are known per se, and therefore they are not described in detail.

I claim:

1. Device for measuring the concentration of at least one narcotic vapor in a gaseous flow to be inhaled by a patient in clinical routine, comprising a casing housing at least one tape of a material that is capable of reversibly swelling in the presence of the narcotic vapor in the gaseous flow, the tape being supported and mechanically biased, and the casing comprising means for mechanically transferring to an indicating member a variation of the length of the tape that is due to the narcotic vapor, and means compensating for water vapor carried by said gaseous flow.

2. Device according to claim **1**, comprising mechanical means for compensating for variations of the length of the tape due to temperature variations of the gaseous flow.

3. Device according to claim **1** wherein the indicating member comprises optical detecting means, and wherein means for generating electrical signals, for controlling a recorder, are controlled by the optical detecting means.

4. Device according to claim **1** wherein the indicating member comprises optical detecting means, and wherein means for generating electrical signals are controlled by the optical detecting means, and means are provided for controlling the addition of the narcotic vapor to the gaseous flow to be inhaled by the patient in response to the generated electric signals.