United States Patent

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[73] Assignee **Beckman Instruments, Inc.**

[54] **SAMPLE CHANGING ELEVATOR AND LIGHT SEALING MECHANISM FOR SCINTILLATION COUNTING**

14 Claims, 2 Drawing Figs.

[52] U.S. Cl. **250/106, 250/71.5**
[51] Int. Cl. **G01t 1/20, G01t 7/02**
[50] Field of Search ..... 250/106 SC, 71.5; 95/61

[56] **References Cited**

UNITED STATES PATENTS

422,825	3/1890	Perry, Jr.	95/61
3,163,756	12/1964	Meeder et al.	250/106 SC

OTHER REFERENCES

Solderholm, Lars G., " Elevator and Index Mechanism Handle Samples in Radiation Detector," Design News, Aug. 4, 1961

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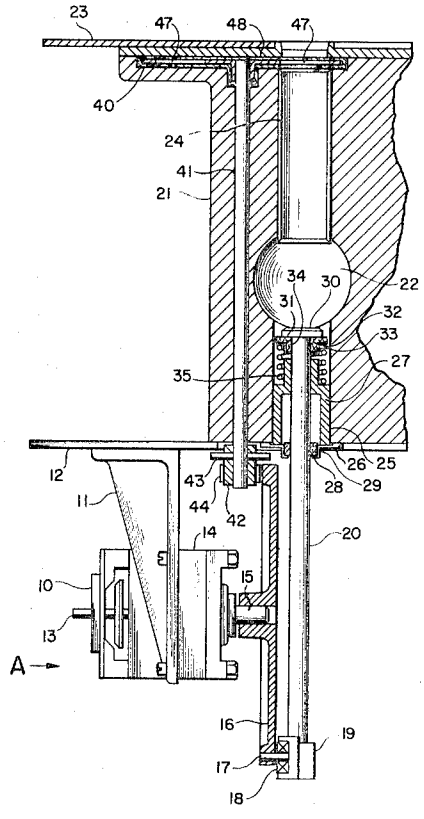
ABSTRACT: Describes a sample handling system for a liquid scintillation counter or the like having a sinusoidal drive for a sample changer elevator with a positively interlocked upper shutter mechanism and a cooperating lower light seal carried by the elevator which overlaps the lower end of the elevator passage while the shutter is open. The mechanism is driven by a unidirectional motor.



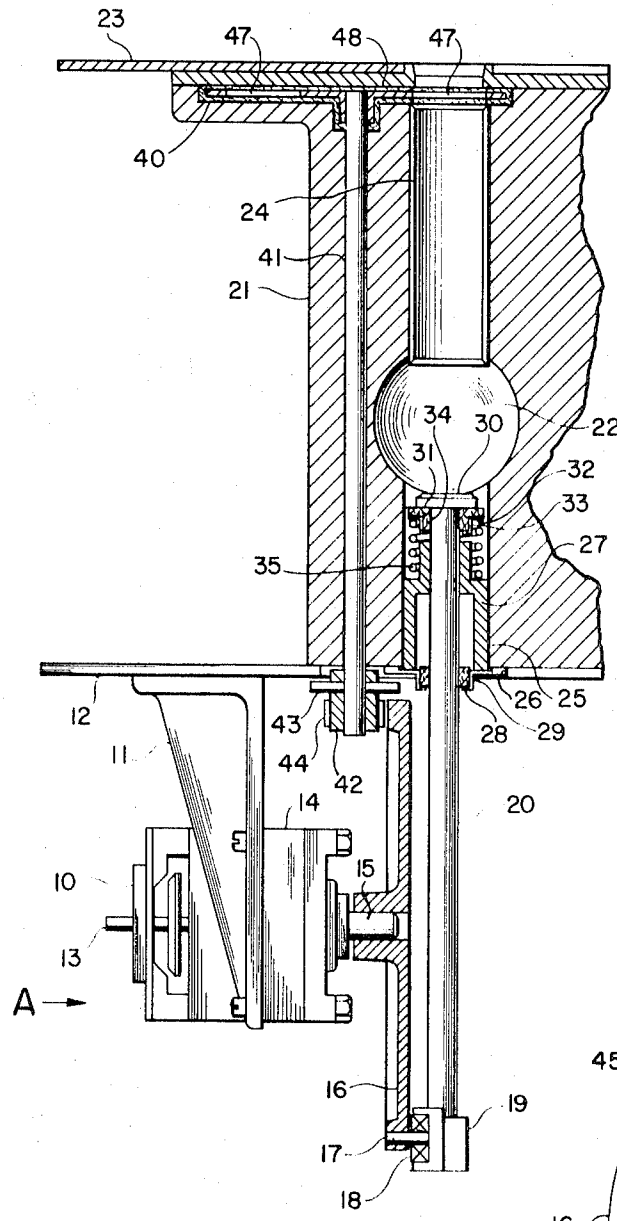


FIG. 1

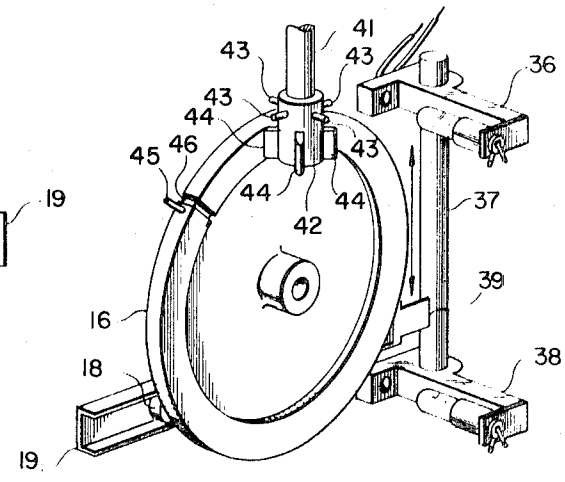


FIG. 2

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SAMPLE CHANGING ELEVATOR AND LIGHT SEALING MECHANISM FOR SCINTILLATION COUNTING

This invention relates to a sample conveying elevator and light sealing mechanism for moving a sample vial from one vertical plane to another from a sample conveying chain to a position in a counting chamber, exposing the sample to photomultiplier tubes for counting light scintillations emanating therefrom and, more particularly, to such a mechanism in which the light sealing mechanism and drive mechanism for the sample elevator and shutter is simple and highly reliable in order to insure smooth operation and that no light from outside the counting chamber will reach the photomultiplier tubes when they are activated.

Prior art liquid scintillation counting systems first employed a mechanism such as disclosed in U.S. Pat. No. 3,085,155, Kern et al. in which a sample containing vial is placed on a shutter over a photomultiplier tube. The shutter is interlocked with a cover which is brought down over the sample to shield it from outside light and radiation such that it is only open when the cover is down. Such a system has the obvious disadvantage that only a single sample can be measured at a time and requires replacement by an operator. The mechanism is not readily susceptible to automation.

In attempting to automate a liquid scintillation counting system such that a number of samples carried by a conveyor could be automatically lowered into a counting chamber, the prior art also employed a device in which a sample is first lowered by one elevator onto a rotating disc or mechanism which will serve to laterally transfer the sample to a second elevator. Prior to opening a shutter to lower the sample down the second elevator, a shutter is closed in the first elevator, then the second elevator lowers the sample down between the photomultiplier tubes. Such an arrangement is obviously mechanically complex and expensive.

In an attempt to further improve mechanisms for sample conveying and light sealing, the device of U.S. Pat. No. 3,163,756, Meeder et al. was conceived. This device employs a number of sealing rings carried by the sample conveying elevator which cooperate with a shutter. The shutter is closed during the period when the elevator is down in the counting chamber. When the elevator goes up to discharge a sample and pick up the next sample, prior to the time the shutter opens, the sealing rings will engage the wall of the elevator passage between the counting chamber and the conveyor, preventing light from impinging upon the photomultiplier tubes. This device requires that the elevator and seal be machined accurately to fit snugly in the elevator passage and that the elevator be driven with precision such that it does not bind upon entering the passage.

In addition, the shaft in this device is provided with gear teeth to drive it up and down by means of a spur gear, driven in turn by a reversible motor. Conventional limit switches are used to sense the up and down positions and a relatively expensive bidirectional motor is required to drive the device. This tends to complicate the associated electronic control because a memory or reset circuit must be employed. The output at the elevator shaft is linear, making acceleration and deceleration severe, tending to cause rough operation of the elevator and undue stress on the rack and spur gear. This is so rough that a relatively expensive shock absorbing device has to be used in the form of two coaxial shafts, isolated from each other by springs.

The linear motion output also requires that the elevator shaft be braked effectively upon reaching the upper or lower limits, at which times it is going at full speed when it contacts the limit switch. Even the most effective braking system will allow some amount of over-run, presenting a problem of reproducible accuracy of positioning. Also, the type of limit switches used display an adverse characteristic commonly termed "bounce" which means that when the switch is actuated, the contacts make and break several times and give several signals to the electronics which are only looking for one signal. This requires additional circuitry to blank out all but the first signal.

The shutter mechanism, which cooperates with the light seal on the elevator shaft, utilizes a push-pull cable actuated by a ramp cut into the elevator shaft, which in turn actuates the leaf shutter by means of an actuating arm and spring return. There is no mechanical interlock to prevent the tubes from being exposed to external light or radiation should the shutter fail to close, which will happen from time to time. The spring return can fail structurally or the push-pull cable can become stiff and binding from lack of lubrication, or become kinked, or the lever arm and shutter leaf can bind, preventing the shutter from closing. Also, when operating in a manual mode, the operator may put a distorted plastic vial in the machine, or not let go of the vial soon enough, resulting in the shutter closing on the vial.

Another approach to solving the problem of sample conveying and light sealing in a liquid scintillation spectrometer is illustrated in U.S. Pat. Nos. 3,188,468, Packard and 3,198,948, Olson. In this mechanism, the elevator shaft is raised and lowered by means of a cable, one end of which is attached to one end of the elevator shaft. The cable is routed over an idler drum positioned very close to the elevator, then to a motor driven pay-in, payout drum and back over the idler drum and finally to the other end of the elevator shaft. A reversible motor is used so that the elevator can be made to move up or down. Position sensing is again accomplished using limit switches.

This mechanism again necessitates the use of reversible motors with the aforerecited disadvantages and it also has a linear output, requiring a solution of the problems associated therewith as well as those associated with the limit switches aforementioned.

In this mechanism, a light pipe is employed between the photomultiplier tubes, and the seals carried by the elevator shaft are expanded and contracted. They are contracted when passing the light pipe so as not to rub against the pipe, and are expanded when in the elevator passage above the light pipe. This requires the use of a complicated actuating mechanism for the seals and again requires accurate machining and driving of the elevator mechanism.

This mechanism also uses a leaf shutter that moves back and forth for the upper light seal, but it is driven differently. A length of thin, rectangular bar stock, twisted approximately 90°, is connected to the leaf shutter and is rotated by means of a hollow tube connected to the elevator shaft by brackets. Pins positioned in the tube allow the thin section of rectangular bar stock to pass freely. As the tube is raised or lowered, the pins engage the twisted portion of the rectangular bar and turn it. If a sample vial gets in the way of the shutter, when the shutter is closing as mentioned above, the rectangular bar could incur damage by twisting, exposing and damaging the photomultiplier tubes.

The main purpose of the invention includes three aspects. The first is to provide a new and improved sample changing elevator for scintillation counting to accomplish the movement of a sample vial from one vertical plane to another, position it accurately and provide a signal to an electronic section when in position, moving the sample in a smooth manner with an uncomplicated and inexpensive mechanism. The second is to provide a timed and mechanically interlocked light-tight shutter in the elevator passage for cooperating with a simple sealing mechanism which closes off the lower end of the elevator passage when the shutter is open, to protect the photomultiplier tubes from light and yet enable the sample vial to be inserted and withdrawn from a detector chamber. The third is to provide an improved light sealing mechanism in which a seal carried by the elevator shaft does not enter the elevator passage but overlaps its lower end, reducing the amount of machining and driving accuracy required.

These and other objects are achieved by providing a sample changing elevator and light sealing mechanism of the type having an elevator shaft and table for lowering samples from a sample conveyor through an elevator passage to a direction chamber and returning them to the conveyor, characterized

by a unidirectional drive motor connected to said elevator shaft to drive it in a nonlinear manner, a rotating shutter mechanism for opening and closing a shutter at the top of said passage, interlocking means connecting said shutter mechanism for intermittent actuation by said motor to only open said shutter when said table has entered said passage at its lower end and to always close said shutter before said table leaves said passage at its lower end, and a light seal cooperating with said shaft to withdraw with said table when it leaves the lower end of said passage and to extend from said shaft to a position overlapping the lower end of said passage to block light from going therebetween when said table enters or is in said passage.

The novel features which are believed to be characteristic of the invention are set forth with particularity in the appended claims. The invention, and further objects and advantages thereof, can best be understood by reference to the following description and accompanying drawings in which:

FIG. 1 is a view of a cross section through the center of a detector housing, shutter and shutter drive wheel, elevator drive wheel and elevator guide bearing, exposing the elevator shaft, table and seal and shutter drive shaft and illustrating the motor mounting bracket and unidirectional motor, of one embodiment of the invention; and,

FIG. 2 is an isometric drawing of the elevator and shutter driving mechanism illustrated in FIG. 1, taken in the direction A and illustrating a photocell mounting bracket, not illustrated in FIG. 1 for purpose of clarity.

Turning now to the drawings, it can be seen that a unidirectional motor **10** is mounted on a motor mounting bracket **11**, to a lower mounting plate **12**. Motor **10** has a shaft **13**, connected through a gear box **14** to a gear motor output drive shaft **15**, which serves to drive the elevator drive wheel **16**, and is positively, pin-connected thereto. A bearing shaft **17** is mounted perpendicular to and through drive wheel **16** at a point near its circumference for mounting a drive bearing **18** thereon. Drive bearing **18**, in turn, cooperates with a channel in drive track **19**, which is attached to the lower end of an elevator shaft **20**.

A detector housing **21** containing a detection chamber **22** is mounted on lower mounting plate **12** and extends upwardly to conveyor base-plate **23**, over which the sample conveyor chain carrying the sample bottles (not illustrated) rides. Such a conveyor is illustrated more fully in a copending application entitled "Control Tower and Method for Programming Automatic Radioactivity Measuring System," R. E. Nather, (Beckman Docket 7D–128) filed concurrently herewith and assigned to the assignee of the present invention.

An elevator passage **24** extends downwardly from conveyor base-plate **23** and is formed of a cylindrical tube contained in a hole in detector housing **21**. Passage **24** extends slightly down into the detection chamber **22**. An elevator access hole **25** extends downwardly from detection chamber **22**, in axial alignment with elevator passage **24**, and over a hole **26** in lower mounting plate **12**. An elevator guide bearing **27** is contained in the lower portion of elevator access hole **25**, secured to detector housing **21** and having a reduced diameter portion at its upper end to provide a relatively snug fit to serve as a bearing surface and guide for elevator shaft **20**.

Light is kept from entering the lower portion of the detection chamber **22** by the seal **28**, which may be made of wool felt and fits snugly against elevator shaft **20**, mounted on the bracket **29** to housing **21** and bearing **27**. The upper end of elevator shaft **20** contains an elevator table **30**, which is a round disc having a diameter smaller than that of elevator passage **24** and elevator access hole **25**. The disc may be screwed into the end of the elevator shaft **20**, as illustrated.

Below elevator table **30**, an elevator shaft seal **31**, which may be made of a soft material such as wool felt, is mounted around the elevator shaft **20**. Seal **31** rides on the upper lip **32** of a cup-shaped metallic member **33**, which contains two other washer-shaped seal members **34** of smaller diameter than seal **31**. Cup **33** is made of metal and has a hole in the bottom through which elevator shaft **20** extends. The elevator shaft **20** can ride through the seals **31**, **34** and cup **33** without undue friction since the hole in the bottom of cup **33** has a slightly larger diameter than elevator shaft **20**. However, the seals cooperate with elevator shaft **20** to provide a light seal therebetween. The diameter of seal **31** is greater than that of passage **24** but less than that of access hole **25**.

A compression spring **35**, in the form of a cylindrical coil, has its lower end surrounding and fitted to the reduced diameter portion of elevator guide bearing **27**, and its upper end surrounding and fitted to cup **33**, urging it upward and, in turn, urging the seal **31** against the elevator table **30** in such a manner that when the elevator shaft goes up through detection chamber **22** and table **30** enters passage **24**, table **30** will proceed upward through passage **24** while seal **31** will engage the end of the portion of passage **24** extending down into detection chamber **22**, in an overlapping manner, will not enter passage **24**, and will be urged against it by the spring **35**. The seal **31** will then keep light from coming down the passage **24** while the elevator table **30** is in the passage **24** by sealing from across the lower portion of passage **24** to a sliding seal against the shaft **20**.

The unidirectional motor **10** and gear box **14** together make up a 10 r.p.m. gear motor for driving the elevator drive wheel **16** at 10 r.p.m. As can be seen better, referring to FIG. 2, the bearing **18** cooperates with the channel in guide rail **19** as wheel **16** revolves, here in a counterclockwise direction, in a manner such that at the extremes of up and down, the guide rail **19** will be moving slowly. The overall motion of the guide rail in the up and down direction will be nonlinear, sinusoidal in nature, and the resulting up and down movement of the elevator shaft **20** will be sinusoidal, such that at the top and bottom limits of its excursion it is moving very slowly, avoiding the aforementioned problems which are incurred with linear motion.

In FIG. 2, a photocell assembly **36** is shown, adjustably mounted on an upper portion of a rod **37**. A second photocell assembly **38** is adjustably mounted on the lower portion of the rod **37**, the rod **37** being mounted downwardly from the lower mounting plate **12** (not illustrated in FIG. 2). The right-hand extremity of the drive track **19** carries a flag **39** which cooperates with the upper and lower photocell assemblies **36** and **38** when the track **19** is in its upper and lower positions and the elevator shaft **20** is correspondingly in its upper and lower positions, to actuate the controls (not illustrated) for unidirectional motor **10**. These photocell assemblies **36** and **38** avoid the problems associated with the bounce of the limit switches, aforementioned.

The upper end of housing **21** contains a shutter wheel **40**, which is pin-connected to and rotated by a shutter drive shaft **41** and contains holes **47** therein. Holes **47** will index with the passage **24** when the shutter is to be opened to receive a sample bottle during the time when table **30** and shaft **20** are in passage **24** and the seal **31** is closing off light at the lower end of passage **24**, keeping it out of detection chamber **22**. Felt packing **48** is placed around wheel **40** to keep light from leaking around it into the passage **24**. Packing **48** has holes in it directly over passage **24**. The lower end of shutter drive shaft **41** carries a shutter drive wheel **42**, pin attached thereto.

Operation of the shutter mechanism will be better understood by referring again to FIG. 2, in which the shutter drive shaft **41** and wheel **42** are illustrated in more detail. Wheel **42** carries a set of upper teeth **43** and a set of lower teeth **44**. Upper teeth **43** extend along two lines perpendicular to each other and lower teeth **44** also extend along two lines perpendicular to each other, displaced 45° around the axis of the shaft **41** from teeth **43**. The teeth **43** extend outwardly over the circumference of the wheel **16** when directed thereat and serve to engage a drive pin **45**, which will then serve to rotate the shaft **41** in a counterclockwise direction, at the same time inserting one of the lower teeth **44** into a notch **46** in the circumference of wheel **16**, which will permit shaft **41** to turn. This will serve to rotate the shaft **41** and the shutter **40** to

place the shutter in the open position if previously closed, or in the closed position if previously open, by rotating them 90°.

The drive pin 45 is positioned on the circumference of wheel 16, together with the notch 46, at a point to actuate the shutter mechanism when the elevator 30 has just entered or is about to leave passage 24. As can be seen from the drawing of FIG. 1, the table 30 is in passage 24 for over half the time of the excursion of shaft 20, or for over half the time of the total rotation of wheel 16. A second drive pin and notch (not illustrated) similar to drive pin 45 and notch 46, are positioned at another point on the circumference of wheel 16 to perform a similar function. For every revolution of wheel 16, shaft 20 goes up and down once and a pin 45 is actuated to turn shaft 41 twice, 90° each time, such that shutter 40 turns 180° for each revolution of the wheel 16. This is why shutter 40 contains the two holes 47 rather than one.

After the lower teeth 44 have entered the notch 46 and rotated the shaft 41, two of them are again positioned adjacent the wheel 16 and at 45° angles thereto to prevent the shaft 41 from any further rotation until the next pin 45 and notch 46 are encountered, thus providing a positive mechanical interlock. The invention uses a rotary shutter rather than the reciprocating shutter used on the other systems referred to. The interlock mechanism is sturdy enough to stall the elevator motor 10 in the event of a malfunction, which will prevent damage to the photomultiplier tubes in the detection chamber 22.

It can be seen from the foregoing description that the elevator drive wheel 16 and bearing 18, cooperating with the drive track 19, will drive the elevator shaft 20 in a sinusoidal manner, which has many advantages over the prior art. Also, since seal 31 overlaps the lower portion of the passage 24 and the table 30 fits loosely therein, the need for precision motion is relaxed. The manner of rotating the shutter-wheel 40 is such that a positive mechanical interlock has been provided which will override the motor 10 in the event of a malfunction such as a bottle being jammed in the shutter. The device of the invention also permits the use of a relatively inexpensive unidirectional motor, which can employ much simpler control circuitry and does not require the accurate braking required of the bidirectional motors of the prior art, since the elevator table 30 is moving very slowly when at the top and bottom extremities. The use of the photocell detectors avoids the problem of bounce associated with the limit switches employed in the prior art, permitting further simplification of the motor control circuitry.

Since the principles of the invention have now been made clear, modifications which are particularly adapted for specific situations without departing from those principles will be apparent to those skilled in the art. The appended claims are intended to cover such modifications as well as the subject matter described and to only be limited by the true spirit of the invention.

What is claimed is:

1. In a sample changing elevator and light sealing mechanism having an elevator shaft and table for lowering samples from a sample conveyor through an elevator passage to a detection chamber and returning them to the conveyor;

a unidirectional drive motor connected to said elevator shaft to drive it in a nonlinear manner;

a rotating shutter mechanism for opening and closing a shutter at the top of said passage,

interlocking means connecting said shutter mechanism for intermittent actuation by said motor to only open said shutter when said table has entered said passage at its lower end and to always close said shutter before said table leaves said passage at its lower end, and

a light seal cooperating with said shaft to withdraw with said table when it leaves the lower end of said passage and to extend from said shaft to a position overlapping the lower end of said passage to block light from going therebetween when said table enters or is in said passage.

2. The mechanism of claim 1 in which said unidirectional drive motor has a motor shaft and is connected to said elevator shaft by;

an elevator drive wheel mounted for rotation on said motor shaft,

a drive bearing connected at a point on said elevator drive wheel,

a guide rail having a channel therein connected to said elevator shaft at an angle therewith, said bearing being positioned to ride back and forth in said channel and upon linear rotation of said elevator drive wheel to cause said elevator shaft to go up and down in nonlinear motion.

3. The mechanism of claim 2 in which said angle is a right angle and said nonlinear motion is sinusoidal.

4. The mechanism of claim 2 in which photocell sensing means are positioned to cooperate with a portion of said guide rail to detect the upper and lower extremes of traverse of said elevator shaft and generate an elevator motor control signal.

5. The mechanism of claim 1 in which said rotating shutter mechanism includes;

a shutter wheel connected for rotation on a shutter drive shaft at the top of said passage,

a shutter drive wheel connected for rotation on said shutter drive shaft and containing two sets of teeth,

and in which said interlocking means includes;

a motor shaft on said motor,

an elevator drive wheel connected for rotation on said motor shaft,

at least one drive mechanism extending from said elevator drive wheel followed during rotation of said elevator drive wheel by a slot in the circumference of said elevator drive wheel, said drive mechanism positioned to contact a tooth in one of said sets of teeth during rotation of said elevator drive wheel and cause said shutter drive wheel and shutter drive shaft to rotate by inserting a tooth from the other of said sets of teeth into said slot to permit rotation of said shutter connecting wheel, said other set of teeth normally coacting against said elevator drive wheel to prevent said shutter drive wheel from rotating.

6. The mechanism of claim 5 in which said elevator drive wheel has two of said drive mechanisms, each formed by a pin extending from its circumference, each followed by one of said slots, for permitting rotation of said shutter twice during each revolution of said elevator drive wheel, said pins and slots being positioned at points on the circumference of said elevator drive wheel to rotate said shutter wheel, said shutter drive shaft and said shutter drive wheel after said table enters said passage from its lower end to open said shutter and before said table leaves said passage from its lower end to close said shutter.

7. The mechanism of claim 6 in which said two sets of teeth each contain four teeth extending radially outward from said shutter drive wheel and located 90 degrees apart around the circumference of said shutter drive wheel, said two sets of teeth being displaced 45 degrees around the circumference of said shutter drive wheel and axially along said shutter drive shaft, and

said shutter wheel having two holes therein located 180° apart for indexing with said elevator passage to alternately open and close the top of said passage.

8. The mechanism of claim 1 in which said light seal is biased against said table to withdraw with said table when it leaves the lower end of said passage, and

said light seal is biased against the lower end of said passage to extend from said elevator shaft overlapping the lower end of said passage to block light from going therebetween when said table enters or is in said passage.

9. In a sample changing elevator and light sealing mechanism having an elevator shaft and table for lowering samples from a sample conveyor through an elevator passage

to a detection chamber and returning them to the conveyor, a rotating shutter mechanism including;

a shutter wheel connected for rotation on a shutter drive shaft at the top of said passage,

a shutter drive wheel connected for rotation on said shutter drive shaft and containing two sets of teeth,

a unidirectional drive motor having a shaft,

an elevator drive wheel having a slot in the periphery thereof and a smooth surface over the remainder of the periphery connected for rotation on said motor shaft,

at least one drive mechanism extending from said elevator drive wheel followed during rotation of said elevator drive wheel by a slot in the circumference of said elevator drive wheel, said drive mechanism positioned to contact a tooth in one of said sets of teeth during rotation of said elevator drive wheel and cause said shutter drive wheel and shutter drive shaft to rotate by inserting a tooth from the other said sets of teeth into said slot to permit rotation of said shutter drive wheel, said other set of teeth normally coacting against said smooth surface of said elevator drive wheel to prevent said shutter drive wheel from rotating.

10. The mechanism of claim **9** in which said elevator drive wheel has two of said drive mechanisms, each formed by a pin extending from its circumference, each followed by one of said slots, for permitting rotation of said shutter twice during each revolution of said elevator drive wheel, said pins and slots being positioned at points on a circumference of said elevator drive wheel to rotate said shutter wheel, said shutter drive shaft and said shutter drive wheel after said table enters said passage from its lower end to open said shutter and before said table leaves said passage from its lower end to close said shutter.

11. The mechanism of claim **10** in which said two sets of teeth each contain four teeth extending radially outward from said shutter drive wheel and located 90 degrees apart around the circumference of said shutter drive wheel, said two sets of teeth being displaced 45 degrees around the circumference of said shutter drive wheel and axially along said shutter drive shaft, and

said shutter wheel having two holes therein located 180° apart for indexing with said elevator passage to alternately open and close the top of said passage.

12. In a sample changing elevator and light sealing mechanism having an elevator shaft and table for lowering samples from a sample conveyor through an elevator passage to a detection chamber and returning them to the conveyor;

a light seal,

means biasing said light seal against said table to withdraw it with said table when said table leaves the lower end of said passage, and

means biasing said light seal against the lower end of said passage to extend from said shaft overlapping the lower end of said passage to block light from going therebetween when said table is in said passage.

13. The mechanism of claim **12** in which said light seal is mounted in a cup having a hole larger than said shaft centrally located in its bottom through which said shaft moves,

said shaft is mounted for motion through an elevator guide bearing, and

a compression spring is connected between said cup and said elevator guide bearing to urge said seal against said table when said table is withdrawn from said passage and to urge said seal against the lower end of said passage, overlapping said passage, when said table is in said passage, said seal always fitting snugly to provide a light seal around said shaft.

14. An apparatus for scintillation counting and analogous purposes, comprising wall means defining a counting chamber and an elongated passage connecting said chamber with the exterior, said wall means having a shoulder portion between the counting chamber and the exterior, a sample platform moveable through a portion of said passage and into said counting chamber, a shaft coupled to said platform for positioning said platform within said passage and said counting chamber, and a sleeve moveable about said shaft, said sleeve having light-sealing means for engaging said shoulder portion of said wall means.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,626,190 Dated December 7, 1971

Inventor(s) Raymond E. Cannon

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, line 40, after "shutter" delete "connecting" and insert --drive--.

Signed and sealed this 30th day of May 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents