Ames

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

(NASA-Case-ARC-10516-1) HIGH SPEED SHUTTER Patent (NASA) 7 p CSCL 20F

N74-21300

Unclas
00/23 33970

REPLY TO ATTN OF: GP

TO: KSI/Scientific & Technical Information Division
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,797,919

Government or Corporate Employee : U.S. Government

Supplementary Corporate Source (if applicable) : ——

NASA Patent Case No. : ARC-10516-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES [ ] NO [X]

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "... with respect to an invention of ..."

Bonnie L. Woerner

Bonnie L. Woerner
Enclosure

United States Patent [19]
McClenahan

[11] **3,797,919**
[45] **Mar. 19, 1974**

[54] **HIGH-SPEED SHUTTER**

[75] Inventor: **James O. McClenahan,** Milpitas, Calif.

[73] Assignee: **The United States of America as represented by the Administrator of the National Aeronautics and Space Administration,** Washington, D.C.

[22] Filed: **June 30, 1972**

[21] Appl. No.: **267,768**

[52] **U.S. Cl.** **350/270,** 354/234
[51] **Int. Cl.** **G03b 9/08,** G02f 1/30
[58] **Field of Search** .... 95/53 E; 350/270, 271, 350/269

[56] **References Cited**

UNITED STATES PATENTS

3,654,846	4/1972	Wernikoff et al.	95/53 E
3,553,364	1/1971	Lee	350/269 X
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OTHER PUBLICATIONS

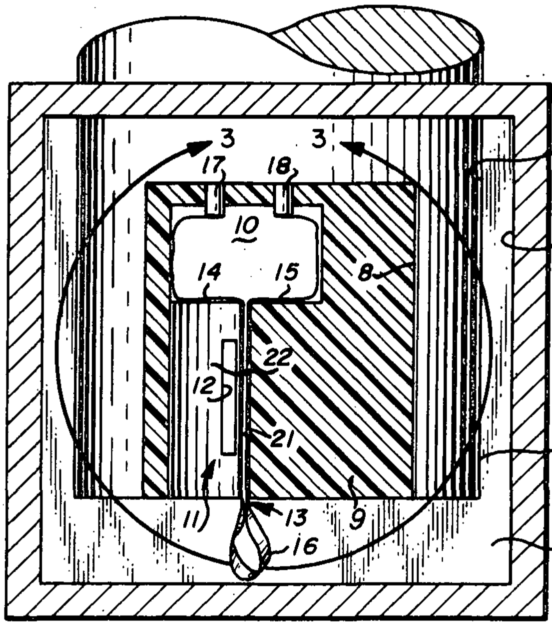
R. J. Dike & E. L. Kemp, "Quick Closing Shutter," The Review of Scientific Instruments, Vol. 36, No. 8, August 1965.

Primary Examiner—Joseph F. Peters, Jr.
Attorney, Agent, or Firm—Darrell G. Brekke; Armand G. Morin, Sr.; John R. Manning

[57] **ABSTRACT**

A shutter element is formed by a loop of an electrically conductive ribbon disposed adjacent to the end of a passageway to be shuttered. The shuttered end of the passageway is cut at an acute angle. The two leg portions of the ribbon loop are closely spaced to each other and disposed in a plane parallel to the axis of the passageway. A pulse of high current is switched through the loop to cause the current flowing in opposite directions through adjacent leg portions of the ribbon to produce a magnetically induced pressure on one of the legs of the ribbon forcing the leg over the end of the passageway in gas tight sealing engagement therewith, thereby blocking same.

5 Claims, 9 Drawing Figures



3,797,919

Fig_1

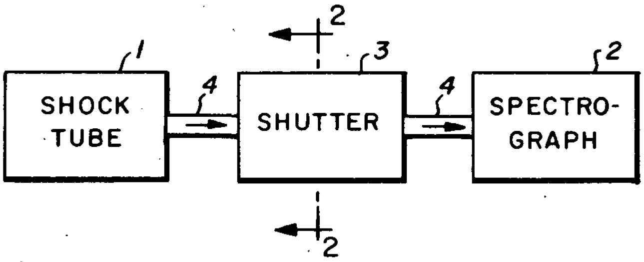


Fig_2

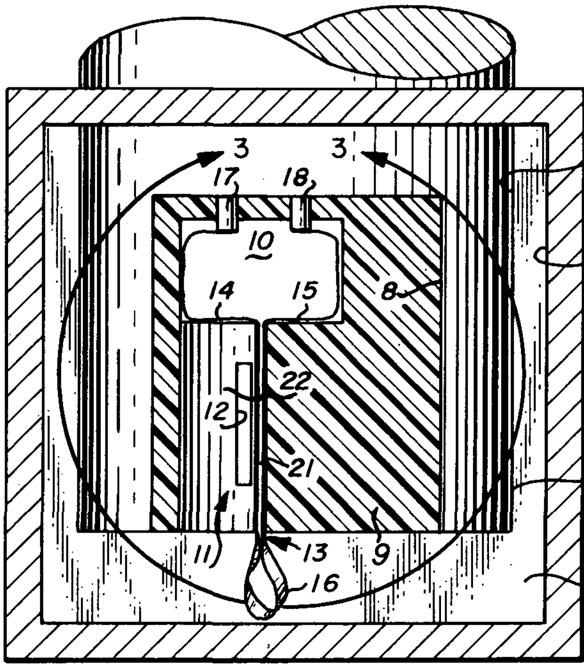
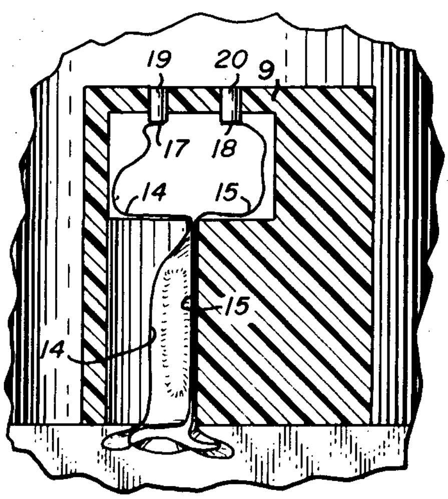


Fig_3



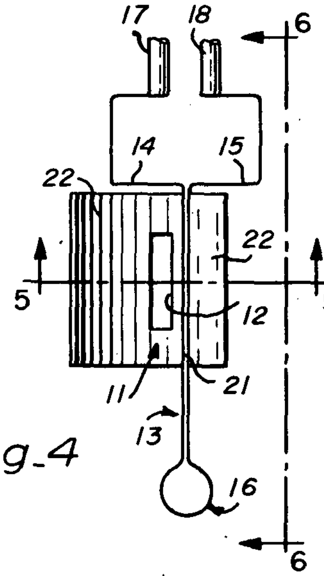


Fig_4

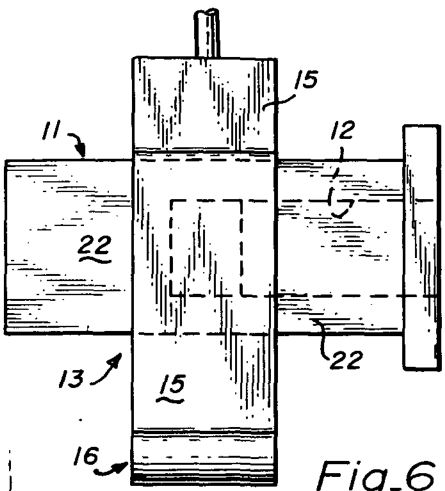


Fig_6

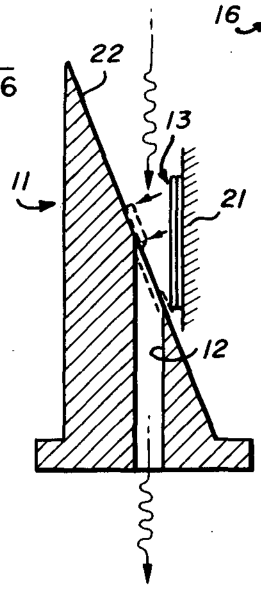


Fig_5

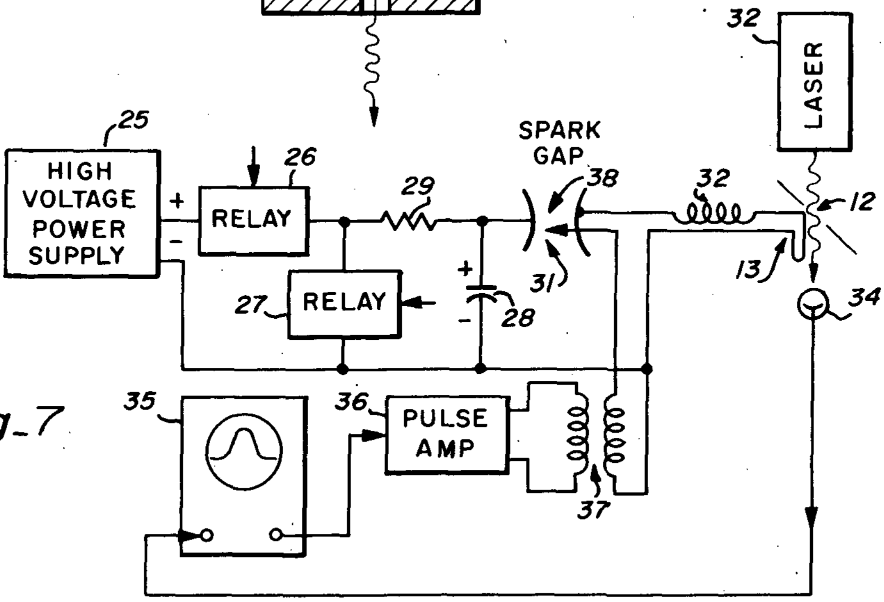


Fig_7

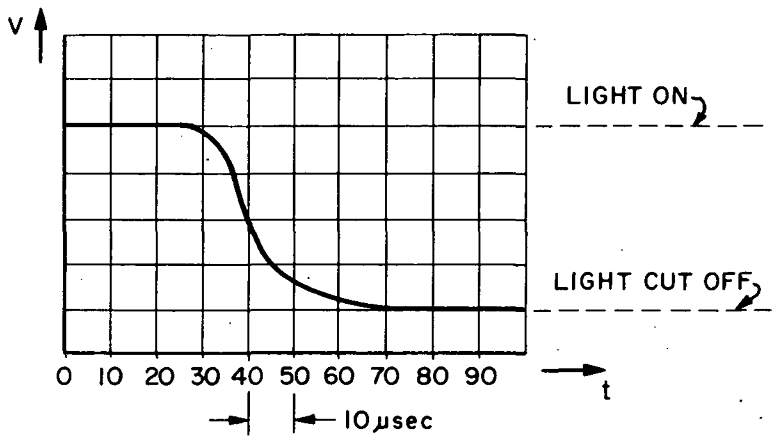

V
LIGHT ON
LIGHT CUT OFF
0 10 20 30 40 50 60 70 80 90
t
10 µsec

Fig_8

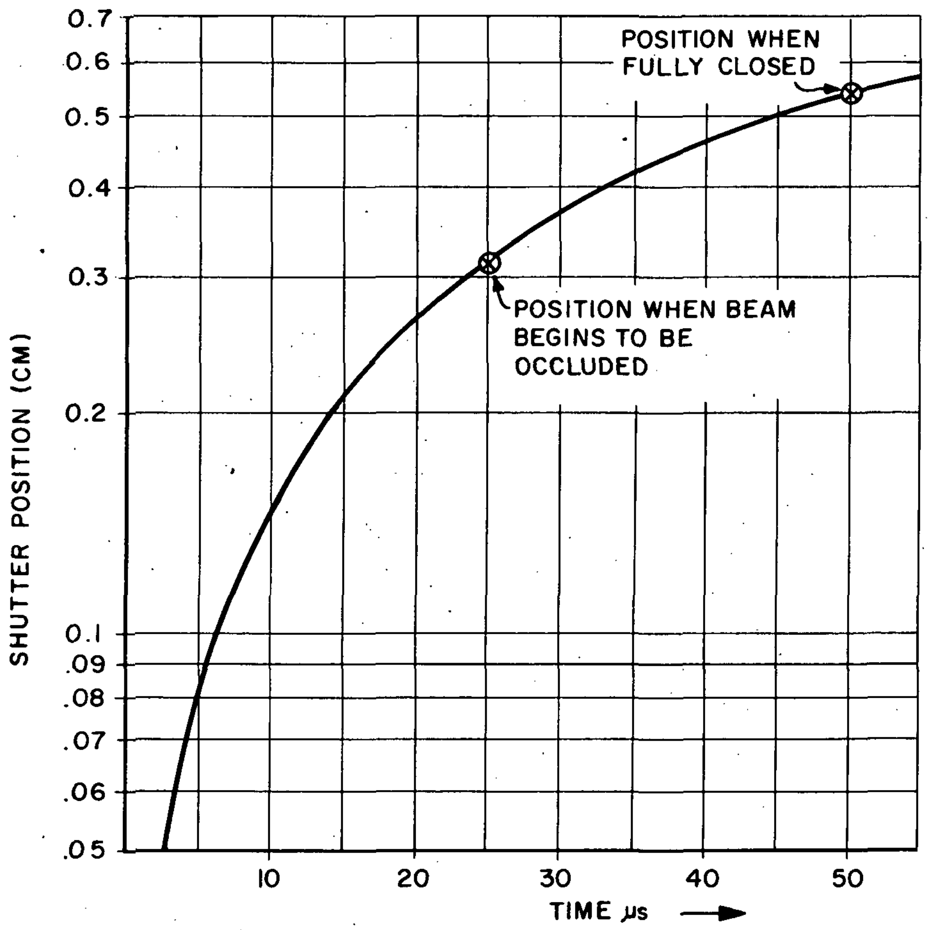

SHUTTER POSITION (CM)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
.09
.08
.07
.06
.05
POSITION WHEN FULLY CLOSED
POSITION WHEN BEAM BEGINS TO BE OCCLUDED
10
20
30
40
50
TIME µs

Fig_9

HIGH-SPEED SHUTTER

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

DESCRIPTION OF THE PRIOR ART

Heretofore, high-speed optical shutters have been proposed wherein a high-current pulse in an electrical circuit produces an associated magnetic field for forcing a shutter element across a path to be blocked.

In one prior art high-speed shutter, as exemplified by U.S. Pat. No. 3,049,982, Aug. 21, 1962, the shutter actuating wire is formed into a loop having two closely spaced leg portions, one of the leg portions being constrained and the other being coupled to a movable shutter element. A high-current pulse, applied to the terminals of the loop, causes current to flow in opposite directions through adjacent leg portions of the loop, thereby producing bucking magnetic fields forcing the coupled shutter element across the optical path for blocking same.

The problem with a high-speed shutter, wherein the magnetically induced pressure on the actuating conductor is transmitted to a movable shutter element separate from the actuating conductor, is that the actuating force is not evenly distributed over the movable shutter element. Shear stresses are produced which limit the amount of force that may be applied to the shutter element and therefore limits the speed of the shutter.

In another prior art magnetically-actuated shutter, an electrically-conductive cylindrical foil shutter element is disposed coaxially of an optical path to be shuttered. A magnetic solenoid is disposed coaxially of the shutter cylinder and externally thereof. A pulse of high current is applied to the solenoid for generating a first magnetic field which induces an eddy current in the cylindrical foil which in-turn produces a counteractive magnetic field for producing a magnetically induced pressure on the cylinder. The pressure is sufficient to collapse the central portion of the cylinder while leaving the end portions in a relatively uncollapsed state. The centrally collapsed shutter element blocks the optical path.

The advantage to this latter type of high-speed shutter is that the magnetic forces are distributed generally uniformly over that portion of the conductive shutter element to be moved or crushed. As a consequence, much larger forces can be exerted on the shutter element and therefore higher shutter speeds may be obtained without producing a rupture of the shutter element. Such a shutter element is disclosed in U.S. Pat. No. 3,185,063 issued May 25, 1965.

One problem with such a cylindrical shutter element is that when it is employed between a shock tube and a spectrograph quite often particulate contaminant material, associated with the shock tube, will pass with the shock wave through the closed shutter into the spectrograph. It would be desirable to have a shutter that not only blocks the optical path but forms a gas tight seal over the shuttered passageway, such that particulate contaminants and gas contaminants cannot pass through the closed shutter to the instruments monitoring the radiation emanating from the shock tube or the like.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved high-speed shutter.

In one feature of the present invention, a foil electrical conductor is disposed adjacent the end of the passageway to be shuttered and a rapidly changing magnetic field is produced adjacent the conductive foil for producing a magnetic pressure on the foil to force same across the end of said passageway, thereby shuttering same.

In another feature of the present invention, the conductive foil is ductile and deformable and is extruded by the magnetically induced pressure into and over the end of the shuttered passageway to form a dust tight closure over same.

In another feature of the present invention, the conductive foil, which forms the shutter element, is made of a ribbon shaped conductor formed into a generally U-shaped member having a pair of adjacent parallel leg portions, one of which is constrained and the other of which is free to move and which is to form the shutter element such that, when a current is passed through the U-shaped member, current flowing in opposite directions in adjacent legs causes the unconstrained leg to move across and to close the passage being shuttered.

In another feature of the present invention, the shuttered end of the passageway has a lip which lies in a plane disposed at an acute angle to the longitudinal axis of the passageway and at an acute angle to the plane of the conductive foil forming the shutter element, such that the distance that the foil must move in order to block the passageway is reduced to a minimum, thereby increasing the shutter speed.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram of a radiation analysis system incorporating a shutter of the present invention,

FIG. 2 is an enlarged cross-sectional view of the shutter portion of FIG. 1 taken along line 2—2 in the direction of the arrows and showing the shutter element in the open position,

FIG. 3 is a fragmentary detail view of a portion of the structure of FIG. 2 delineated by line 3—3 and showing the shutter element in the closed position,

FIG. 4 is a simplified view of the shutter similar to that of FIG. 2,

FIG. 5 is a sectional view of the shutter of FIG. 4 taken along line 5—5 in the direction of the arrows,

FIG. 6 is a view of the shutter of FIG. 4 taken along line 6—6 in the direction of the arrows,

FIG. 7 is a schematic circuit diagram, partly in block diagram form, depicting a circuit for actuating and testing the closure time of the shutter of FIGS. 2–6.

FIG. 8 is a plot of voltage vs. time in microseconds depicting the detected light intensity vs. time during the closure of the shutter, and

FIG. 9 is a plot of shutter position in centimeters vs. time in microseconds showing the movement of the shutter and depicting the position of the shutter when the beam is beginning to be occluded and when the beam is fully occluded.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown a typical radiation monitoring system employing the shutter of the present invention. The system includes a shock tube **1** connected to a spectrograph **2** via the intermediary of a shutter **3**. The shutter **3** is disposed in a tubulation **4** which provides a line of sight optical path between the shock tube **1** and the spectrograph **2**, such that optical radiation emanating from an experiment within the shock tube **1** can be monitored by the spectrograph **2**.

The optical radiation, which it is desired to monitor, occurs within **100** microseconds after an event occurs within the shock tube. A pressure wave follows the radiation of light and brings with it certain particulate contaminants, which it is desired to prevent from entering the spectrograph. Accordingly, the shutter is actuated with a timing pulse synchronized with the experiment within the shock tube **1** such that after a suitable delay, as of 40 microseconds, the shutter **3** is closed to isolate the shock tube **1** from the spectrograph **2**.

Referring now to FIGS. **2–6** there is shown the shutter of the present invention. The shutter assembly **3** includes a cylindrical housing member **5**, as of steel, inserted transversely into the tubulation **4** via a circular opening, not shown, provided in the upper wall of the tubulation **4**. The cylindrical body **5** is inserted within a transverse cylindrical bore **6** in a transverse wall **7** of the tube **4**. The wall **7** has a thickness substantially smaller than the diameter of the cylindrical body portion **5**.

The inner end of the cylindrical body portion **5** abutts the lower end of the bore **6**. A rectangular chamber **8** is formed at the inner end of the cylindrical body **5**. An insulative block **9**, as of teflon, is captured within the rectangular chamber **8**. A receiver body **11**, as of steel, and of rectangular cross section is carried transversely of the cylindrical shutter body **5** within a rectangular bore in the insulative block **9**. A rectangular bore **12** extends longitudinally in the receiver member **11** to define a passageway to be shuttered. The central axis of the passageway **12** is coaxially aligned with the optical path between the shock tube **1** and the spectrograph **2**.

A generally U-shaped shutter element **13** is disposed within a hollowed-out portion **10** of insulating block **9**. The shutter element **13** includes a ribbon of electrically conductive foil having a pair of generally parallel leg portions **14** and **15** interconnected by a generally cylindrical end loop portion **16**. The element **13** is connected to electrical terminals **17** and **18** at the upper ends of the legs **14** and **15**, respectively.

In a typical example, the shutter element **13** is made of a ribbon of annealed copper foil 0.005 inches thick and 2.0 centimeters wide. The legs **14** and **15** are disposed to one side of the open end of passageway **12** and approximately 0.3 centimeters from the plane of the legs **14** and **15** to the axis of the passageway **12**.

One of the legs **15** of the shutter element **13** is constrained from movement transversely away from the axis of the passageway **12** by being disposed along an abutting edge of the insulative block **9** at **21**. The other leg **14** of the shutter **13** is free to move away from the constraining face **21** of the block **9** toward the passageway **12**. In a typical example, the passageway **12** which is to be shuttered has a width, parallel to the shutter element **13** of approximately 1.0 centimeters and a height transverse to the plane of the shutter element **13**, as of 0.25 centimeters. The end face **22** of the receiver block **11** which faces the shutter element is inclined at an acute angle, as of 30°, to the plane of the shutter element and to the axis of the passageway **12** for reducing the total distance that the shutter element must move in order to cover over the open end of the passageway **12**.

In operation, a pulse of current is applied across the terminals **17** and **18** to drive a high current pulse through the U-shaped conductive shutter element **12**. The current flowing in opposite leg portions **14** and **15** in the region adjacent the passageway **12** produces opposing magnetic fields which exert opposing pressures on the leg portions **14** and **15** of the shutter element **13** causing the legs to be forced apart. Due to the constraint of leg **15** by face **21** of block **9**, the opposed leg **14** is caused to move across the optical path and over the end of the passageway **12**, thereby blocking the passageway.

In addition, the magnetically induced force is sufficient on leg **14** to actually extrude the foil into and over the end of the passageway at the lip thereof, thereby forming a gas tight seal over the passageway **12** to exclude dust and other particulate contaminants that might tend to pass through the passageway following the burst of radiant energy. The shutter element is shown in the closed position in FIGS. **3** and **5**.

The operation of the shutter has been analyzed to determine its speed and other properties as follows: The force on a charge moving in a magnetic field may be determined from:

$$F = vQB \quad (1)$$

where

F = force (newtons)
v = velocity of charge (meter/sec)
Q = charge on particle (coulomb)
B = flux density (weber/meter^2)

The whole system has been analyzed and an expression for the movement of the shutter as a function of the physical and electrical properties has been derived using equation (1) and Newtons second law:

$$x^2 = x_0^2 + \frac{u_0 V_0^2 C}{L\pi\rho wh}\left[\int_0^t \int_0^t e^{-2\alpha t} \sin \omega t dt^2\right] \quad (2)$$

where

x = the separation between the two current carrying parts at any time t (meters)
x_o = initial separation (meters)
u_o = permeability of air (henry/meter)
α = damping constant (sec^{-1})
ω = frequency of current discharge (radian/sec)
V_o = initial voltage on energy-storage capacitor (volts)
C = capacitance of energy-storage capacitor (farad)
ρ = density of movable bus (kilograms/meter^3)
w = width of the movable bus (meter)
h = thickness of the movable bus (meter)
L = inductance of system (henry)
t = time (seconds)

The expression of equation (2) has been evaluated and is plotted in FIG. **9**. More particularly, FIG. **9** shows the shutter position as a function of the time elapsing after application of the high current pulse to the shutter element **13**. The actual data, as obtained from an oscilloscope trace, is shown in FIG. **8** utilizing a testing circuit of the type shown in FIG. **7**. The observed movement of the shutter position corresponded accurately with the computed curve of FIG. **9**. Since the results of the trial agree quite closely with the prediction of FIG. **9**, equation (2) accurately predicts the behavior of the shutter and it may be used to design a system to fulfill any requirements. For example, to obtain a certain delay time or closure time, certain of the physical or electrical parameters may be varied. It should be noted that a much faster response is obtainable by increasing V_o.

Referring now to FIG. **7**, there is shown a circuit for actuating and testing the response of the shutter **3** of the present invention. More particularly, the output of a high voltage power supply **25** is applied to the high-voltage, energy-storage capacitor **28** through isolation relay **26** and current limiting resistor **29**. When the energy-storage capacitor **28** is charged to a predetermined voltage V_o, the isolation relay **26** opens and energy is "dumped" through the spark gap switch **31**, through the coaxial cable **32** to the shutter element **13**. The spark gap switch **31** is fired on command by means by a high-voltage pulse applied to the trigger gap **38**. After firing the device, the ground relay **27** is closed to safely discharge the capacitor **28**.

A laser **33** directs its light beam to a photodetector **34** through the shuttered passageway **12**. An output signal as derived from the detector **34** is fed to the vertical deflection plates of an oscilloscope **35**. A pulse generator within th oscilloscope **35** generates a trigger pulse at the start of its horizontal sweep scan.

The trigger pulse is fed to the input of a pulse amplifier **36** which amplifies the pulse to produce a high-current pulse for energizing the primary winding of a high-voltage transformer **37**. The high-voltage output pulse of the secondary of transformer **37** is applied across a trigger gap **38** of the spark gap **31** for breaking down the spark gap **31** and allowing the capacitor **28** to discharge a high-current pulse through the coaxial cable **32** and shutter element **13** for closing the shutter **13** in the manner as previously described with regard to FIGS. 2–6.

A typical oscilloscope trace is shown in FIG. **8** wherein it is seen that after a delay of approximately 30 microseconds the light beam begins to be occluded. Upon an elapse of approximately 50 microseconds the light beam is fully occluded or cut off.

Although the shutter **3** of the present invention has been described, thusfar, for cutting off a light beam be-

tween a source of light and a spectograph it may be utilized to advantage in systems where the passageway to be shuttered is merely a gas passageway for isolating two atmospheres, one from the other.

What is claimed is:

1. In a shutter apparatus, means having a passageway therein, shutter means for selectively blocking said passageway, THE IMPROVEMENT WHEREIN, said shutter means includes an electrically conductive sheet disposed adjacent an end portion of said passageway, and means for providing a rapidly changing magnetic field adjacent said electrically conductive sheet and for providing for the flow of a counteractive electrical current in said sheet productive of a magnetically-induced pressure of predetermined direction and strength on said sheet to force said sheet across the end of said passageway for blocking same, and said conductive sheet is ductile and deformable and is extruded by the magnetically-induced pressure at least partially into said passageway around the lip portion of the blocked end thereof to form a gas tight seal over said passageway.

2. The apparatus of claim **1** wherein said passageway is a passageway for radiant energy, and wherein said conductive sheet is opaque to the radiant energy for blocking the flow of radiant energy through said passageway.

3. The apparatus of claim **1** wherein said conductive sheet is a copper foil.

4. The apparatus of claim **1** wherein said means for providing a rapidly-changing magnetic field adjacent said conductive sheet and for the flow of a counteractive current in the sheet for producing the pressure on said sheet includes, an electrical circuit means having a pair of adjacent conductive leg portions conductively interconnected at one end and having a pair of electrical terminals at the other end so that a potential applied across the terminals of said leg portions causes an electrical current to flow in opposite directions through said adjacent leg portions, one of said leg portions being formed by said conductive sheet, said sheet being free to move away from said other leg portion of said circuit and across said passageway by the magnetically-induced pressure on said sheet caused by opposite directions of current flow through said adjacent leg portions of said electrical circuit means.

5. The apparatus of claim **1** wherein said lip of said shuttered end of said passageway lies in a plane disposed at an acute angle to the longitudinal axis of said passageway at the shuttered end thereof, and said conductive sheet prior to being forced over said passageway lies generally in a plane parallel to said longitudinal axis of said passageway.

* * * * *