Oct. 11, 1966 F. A. KIRSTEN ET AL 3,278,892

ACOUSTIC SPARK CHAMBER

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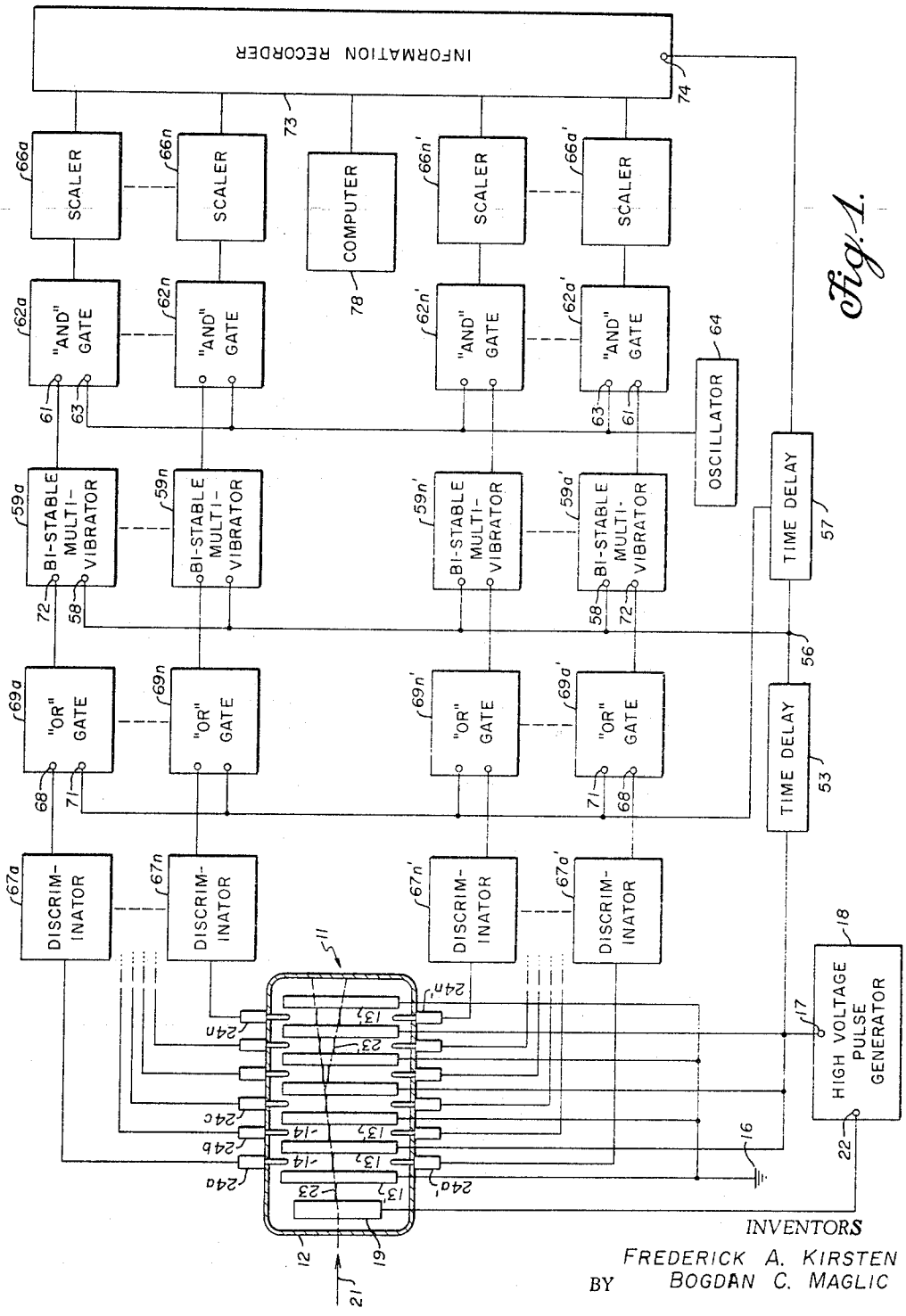


Fig. 1.

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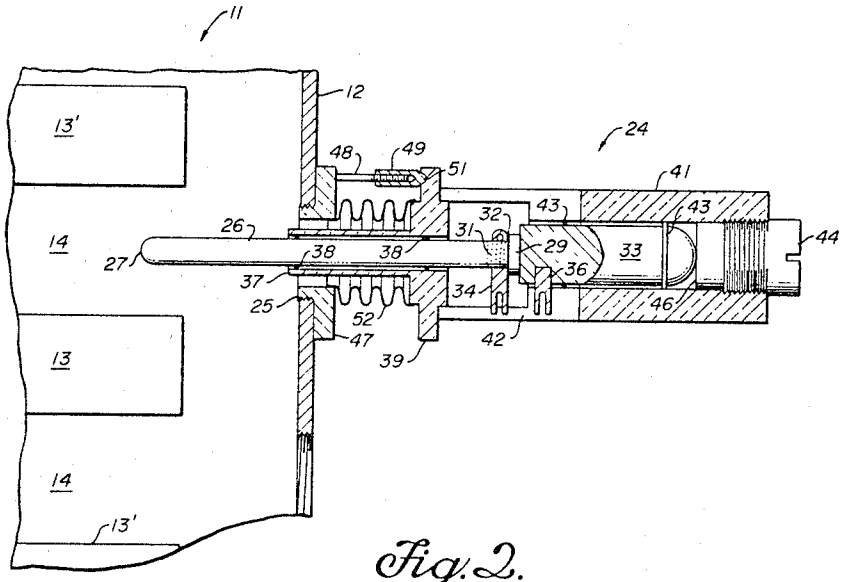


Fig. 2.

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ACOUSTIC SPARK CHAMBER

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5 Claims. (Cl. 340—15)

This application is a continuation-in-part of our co-pending application Serial No. 277,968, filed May 3, 1963, for Acoustic Spark Chamber and now abandoned.

The present invention relates to spark chamber devices for detecting charged particle trajectories and more particularly to a chamber having means for acoustically detecting the location of charged particle paths therein. The invention described herein was made in the course of, or under, Contract W–7405–eng–48 with the United States Atomic Energy Commission.

The conventional spark chamber consists essentially of a series of parallel plates within a gas-filled chamber. When a charged particle passes through the chamber and a charge is applied to the plates, the particle path is made visible by sparks occurring between the plates. The spark patterns are visible through the chamber windows and are customarily recorded by means of stereoscopic photographs.

The spark chamber has found increasing importance as a track detecting device in the study of the behavior of subatomic particles, as it inherently combines certain advantages found only separately in the cloud and bubble chamber. In particular, more selective timing and improved clarity in the photographic exposures is obtained. As is the case with these other instruments, however, the problem of handling, developing and scanning the rapidly accumulated quantities of photographic data is considerable. In general, such instruments have tended to produce nuclear data much faster than it can be analyzed with a practical investment in equipment and personnel.

Also inherent in the spark chamber however are characteristics which make other methods of track detection and recording plausible. The present invention provides a means for acoustically detecting the spark patterns by virtue of the shock waves produced thereby. Since the overall path is manifested in increments, i.e., by the sparks across the successive separate gaps in the chamber space, the sparks can be located acoustically within each separate gap. Computer operations on the acoustical information rapidly locate the sparks and reconstruct the particle paths. It can be seen that such a method completely circumvents the the cumbersome problems associated with the conventional photographic recording of such data.

The invention comprises a series of acoustic probes which extend through the spark chamber wall and terminate at known locations within each gap between the chamber plates. The probes act as wave guides and transmit along their length the sonic waves produced upon the occurrence of a spark in the associated gap. An electro-acoustic transducer element contacts the opposite end of each probe and produces an electrical signal in response to pressure increases exerted on it by the probe. Each transducer output is coupled to a separate channel of a time comparison circuit wherein the timespans between the occurrence of the spark in the chamber and the arrival of the resulting sonic wave at each of the probe tips are determined.

Given these separate times of travel of the spark sound event to the separate probe tips and knowing the velocity of sound in the particular chamber medium, the distance of the sound travel to the separate probes can be determined. By virtue of the fact that more than one probe

is present in each gap, which probes are positioned at known co-ordinate locations therein with respect to the gap, the solution of simultaneous equations of these co-ordinate distances in a particular gap reveals the co-ordinate location of the spark center of that gap.

The mathematical operations are programmed into a computer whereby the spark locations for each gap are calculated directly from the probe output data and the particle paths through the chamber are re-constructed from the spark locations in the successive gaps.

It is accordingly an object of the present invention to facilitate the study of high-energy nuclear charged particles.

It is another object of the invention to improve and implement spark chamber type charged particle detection.

It is a further object of this invention to provide a rapid and convenient means for locating and recording the path of charged particles within a spark chamber.

It is another object of this invention to provide a means for acoustically detecting charged particle paths in a spark chamber whereby the delay and effort required for photographic data detection may be avoided.

It is still another object of the invention to provide acoustic detection of charged particle paths in a spark chamber whereby the electronic form of the output information may be directly analyzed by a computer program.

The invention, both as to its organization and operation, together with further objects and advantages thereof, will be best understood with reference to the following specification taken in conjunction with the accompanying drawing, of which:

FIGURE 1 is a diagrammatic view of a spark chamber having acoustic particle track locating means incorporated therein and showing the electrical circuitry associated therewith, and

FIGURE 2 is a section view showing a portion of a spark chamber and the detailed structure of one of the acoustic probes shown diagrammatically in FIGURE 1.

Referring now to the drawing and more particularly to FIGURE 1 thereof, there is shown a spark chamber **11**. The spark chamber **11** comprises an air-tight rectangular housing **12** which encloses the chamber gas, typically argon or neon. A plurality of electrically conductive plates **13** are disposed within the housing **12**. The plates **13** are rectangular in shape and are arranged within the chamber in parallel and spaced apart relationship whereby a series of equal width gaps **14** are formed between successive plates. The outer plates of this arrangement and the alternate plates therebetween, indicated by primes in the drawing, are connected to a ground line **16** external to chamber housing **12**. The remaining plates **13**, intermediate to the grounded plates, are connected to a common output **17** of an external high voltage pulse generator **18**, whereby an electric field may be established simultaneously in all of the gaps **14** upon occurrence of a pulse from the generator.

A broad flat charged particle detector **19** is disposed in the chamber **11** near the end thereof and transverse to the path of the incoming charged particles, indicated in the drawing by arrow **21**, and has an output coupled to a trigger input **22** of pulse generator **18**. The counter **19** may be selectively adjusted to discriminate among the incoming particles to detect those having desired characteristics. Upon detecting an incoming particle of interest the counter **19** triggers an output pulse from the pulse generator **18** to apply a charge to the plates **13**. In the presence of the electric field thereby established in the gaps **14**, sparks occur along the lines of ionized gas particles left by each passing charged particle. A typical example

of such particle ionization trails is shown in FIGURE 1 by the broken lines **23**, while the resulting sparks along these paths are indicated by the heavy solid lines **23'** between the plates **13**.

The above described elements constitute the salient features of a conventional spark chamber in which it has heretofore been the practice to record the position of particle tracks by means of a camera situated to one side of the chamber and viewing the gaps **14**. While the data can be efficiently recorded by such means, the subsequent developing and analysis of the photos involves considerable effort and delay. To avoid these problems, the present invention provides a novel acoustic track detecting means which can supply track position data directly to a computer for immediate analysis.

Referring still to FIGURE 1 there is shown a plurality of rod-shaped acoustic probes **24***a* to **24***n* disposed in a bank along one wall of chamber **11** with one probe projecting into each of the gaps **14**. At least one additional bank of similar probes **24***a'* to **24***n'* is attached to the chamber **11** and arranged with one probe projecting into each gap **14**. In this way at least two probes are inserted into each of the gaps and are positioned at known locations therein. The probes **24** in each gap **14** respond separately to any spark shock wave that is produced in that gap. The relative times of arrival of the shock waves to each of the separate probes in a particular gap thus enables the position of the spark from which the shock wave emanated to be determined, as will hereinafter be more fully described.

Referring now to FIGURE 2 there is shown a detailed section view of one of the acoustic probes **24** as it is disposed with respect to the spark chamber **11**. The probe **24** comprises a slender glass (Pyrex) rod **26** which extends into the chamber **11**, through an opening **25** provided in the chamber wall **12**, in alignment with associated gap **14**. The rod **26** is positioned with its rounded detecting tip **27** located a short distance within the gap **14** where it is responsive to the shock waves therein. The rod **26** acts as a sonic wave guide and transmits the shock along its length, out of the chamber, to an electro-acoustic transducer **29** at the other end of the rod **26**. The transducer **29** may be a disc of barium-titanate, silver coated on both faces. The disc **29** is disposed coaxially with the rod **26** and is in abutment with the flat end thereof. For electrical conduction this end of rod **26** is provided with a platinum coating **31** and acoustic contact between the rod **26** and the disc face **29** is enhanced by a layer of apiezon grease **32** therebetween. The opposite face of the transducer disc **29** abuts the flat end surface of a large cylindrical lead damper **33**. The damper **33** presents sufficient inertial resistance to the system that the shock wave transmitted by the wave guide **26** will result in the necessary compression of the transducer **29** whereby the mechanical energy is converted to electrical energy therein. A first electrode **34** is connected to platinum coating **31** of rod **26** and a second electrode **36** is connected to lead damper **33** to conduct the output pulses of transducer **29**.

A portion of the length of the wave guide rod **26** external to the chamber **11** is enclosed in a Lucite sleeve **37**. The rod **26** is supported in the sleeve **37** and spaced therefrom to provide acoustical isolation by rubber O-rings **38**. A wide flange **39** at the end of sleeve **37** away from chamber **11** provides a connecting means for other elements of the probe housing. A tubular Lucite casing **41**, larger than sleeve **37**, fits over lead damper **33** and is affixed at one end to flange **39**. A cut-out section **42** near this end of the casing **41** provides access to the transducer electrodes **34** and **36**. The damper **33** is spaced from the casing **41** by O-ring supports **43**. The casing **41** extends beyond the end of the damper **33** and is internally threaded at this end to accommodate a threaded aluminum closure plug **44** therein. A rubber insulating cushion **46** is disposed between the end of damper **33** and plug **44**.

The probe **24** is mounted on the exterior chamber wall **12** by a threaded Lucite collar plate **47** engaged in opening **25** in the wall. A spacer screw **48** is mounted radially outward on collar plate **47** and has an elongated cap **49** threaded thereon. The conical head of cap **49** fits into an identation **51** provided therefor in the face of flange **39** whereby the flange is held adjustably outward from the chamber by the positioning of cap **49** on screw **48**. The variable positioning of the flange **39** is communicated through sleeve **37** and O-rings **38** to the wave guide rod **26** and thereby provides for minor adjustments of the wave guide position within the spark chamber gap **14**. A stainless steel bellows **52** flexibly encloses the sleeve **37** between collar plate **47** and flange **39**.

Referring again to FIGURE 1, there is shown the timing and data transmission circuitry associated with the probes **24**. The starting signal is taken from the pulse generator **18** which supplies the charge to the spark chamber plates **13**. This signal, originating with the detection of a charged particle by detector **19**, occurs simultaneously with the sparking and thus provides the initial time reference for measuring the shock wave travel.

The time reference signal from generator **18** to the counting circuitry is delayed in a first time delay **53**, which delay is of the one-shot type responding only to the leading edge of the incoming pulses thereto. This delay is provided to prevent premature energization of the subsequent circuitry due to electrical noise generated by the spark gap and the spark chamber. The time delay **53** output is branched at junction **56** and is connected to a second time delay **57** and to first inputs **58** of a plurality of bi-stable multivibrators **59***a* to **59***n'* associated with the output channels of probes **24***a* to **24***n'* respectively. The delayed reference signal energizes multivibrators **59**, simultaneously triggering continuous outputs therefrom which are applied to first inputs **61** of a plurality of "and" type gating circuits **62***a* to **62***n'*. A second input **63** of the gate circuits **62** continuously receives clock pulses from a two-megacycle oscillator clock **63**. The appearance of the multivibrator **59** signals as gate input **61** opens the gates **62** and transmits the clock pulses to a plurality of scalers **66***a* to **66***n'* separately coupled to the outputs of gating circuits **62***a* to **62***n*. Thus the scaler **66** of each probe **24** output channel simultaneously begins a count of the clock **63** pulses with the occurrence of the spark in the chamber gaps **14**.

Each of the probe **24** outputs is connected through a separate pulse height discriminator **67** to a first input **68** of an associated one of a plurality of "or" type gate circuits **69***a* to **69***n'*. A second input **71** of each gate **69** is coupled to the output of time delay **57**. The gate **69** output of each channel supplies a second input **72** of the respective channel bi-stable multivibrator **59** and provides the triggering-off pulse therefor. Thus, a shock wave signal from a probe **24** is transmitted by the "or" gate **69** to de-energize multivibrator **59**. This closes the "and" gate **62** and stops the count of clock **64** pulses in the channel scaler **66**. The count in the scaler **66** thus represents the acoustic time delay from the spark to the corresponding probe transducer **29**.

Where the particle path does not enter a gap **14** and there occurs no spark therein there will be no transducer output pulse to de-energize the multivibrator **59** of that channel and stop the scaler **66** count. For this reason a reset pulse from second time delay **57** is delivered to each of the "or" gates **69** whereby those which have not received a transducer signal will transmit the reset signal to trigger off the multivibrators **59**. Since the count accumulated in the scalers **66** in such cases is greater than the longest possible acoustic delay in the chamber, such scaler output information is readily recognized as invalid.

The output of each channel scaler **66** is connected to an information recording device **73** such as a print-out recorder or a magnetic-core buffer store. The reset pulse from time delay **57** supplies a read-out command signal

to the recorder **73** at input **74** thereof whereupon the counts contained in each scaler **66** are transferred thereto for storage and subsequent analytical computation by a suitable computer **78**.

These counts contained in the scalers **66** and transferred to the recorder **73** for each spark event represent the number of oscillator **64** pulses received by the particular probe channel during the time interval between the delayed reference signal from first delay **53** and the arrival of the shock wave at the particular probe transducer **29**. These counts thus correspond to a counted time of N/f, where N is the number of pulses received and f is the pulse frequency of the oscillator clock **64**.

In order to obtain the precise acoustic delay time T between the occurrence of the spark and the arrival of the shock wave at the probe detecting tip **27** the scaler **66** counts must be corrected. A first correction must subtract the travel time of the sound wave along the length of the wave guide rod **26** in order that the measured time be only to the detecting tip **27** rather than to the transducer **29** of the probes **24**. The amount of this correction is a unique constant for each probe channel and is dependent upon the length of the particular guide rod **26** of each probe **24**. A second correction adds to the counted time the artificial time delay introduced in the reference starting signal by time delay **53**. This correction is a constant of the circuit and the same amount applies to all the probe **24** channels. The third correction arises from the physics of shock wave behavior wherein in the immediate vicinity of a spark the shock wave velocity is several times greater than that of ordinary sound in the chamber medium. After a few centimeters of travel the wave velocity approaches the normal sound velocity C. The amount of this correction can be best determined experimentally by using a movable test spark in the gap **14** and measuring the sound travel time at varying spark distances from the probe tip **27**. Extrapolating from this data to zero distance will yield the correction time for this effect, which amount is then to be added to the counted time. Such correction is sufficiently accurate that the wave travel may be assumed at a constant velocity provided only that the detecting tips **27** are located beyond the shock wave region of the sparks. For this reason, and as can be seen in FIGURE 1, the area presented to the incoming particles **27** by the particle detector **19** is slightly smaller than the surface area of the conducting plates **13** and **13'** in order to prevent sparking in the peripheral regions of the gaps **14** where the probe tips **27** are located.

Given the corrected time delays T between the spark and the shock wave arrival at two probe tips within an individual gap **14**, the spark location within the gap can be determined. Let T_1 and T_2 represent the respective time delays of the two probes **24** and let C represent the established velocity of sound in the chamber gas. The spark coordinates x and y in the gap will be the point of intersection of two circles of radius

$$R_1=\frac{T_1}{C} \text{ and } R_2=\frac{T_2}{C}$$

respectively, the centers of which circles are at the known coordinate location of the probe tips **27**. If the probes are separated by a distance (a) along the assumed x-axis of the gap space, the spark center coordinates will follow the relationship:

$$x=\frac{R_2^2-R_1^2}{2a}+\frac{a}{2} \text{ and } y=\pm(R_1^2+x^2)^{1/2}$$

Thus it can be seen that from the acoustic time delay data stored in recorder **73**, subsequent computer operations can readily calculate the spark locations in each gap **14** for each spark occurrence of the chamber **11**, techniques for accomplishing this operation being apparent to those skilled in the art. From these locations the position and angle of the particle paths through the chamber **11** can be reconstructed by the computer program for analysis.

While the invention has been described with respect to a single embodiment thereof, it will be apparent to those skilled in the art that numerous variations and modifications may be made within the spirit and scope of the invention and it is not intended to limit the invention except as defined in the following claims.

What is claimed is:

1. In a charged particle sensitive instrument of the class having a plurality of electrically charged plates spaced apart within a gas filled chamber to form a series of spark gaps and having a detector indicating the passage of a charged particle therethrough, a means for electronically detecting the location of charged particle paths through said chamber comprising:

(a) a plurality of sonic wave guides with at least two thereof extending into each spark gap of said chamber at spaced apart positions in said gap, said wave guides being responsive to shock waves emanating from sparks therein,

(b) a like plurality of acoustical-electrical transducer elements of the piezoelectric class each being disposed at the end of a separate one of said wave guides and producing an electrical signal in response to pressure exerted thereon by said wave guide,

(c) a like plurality of bi-stable multivibrators each receiving the signal from said detector at a first input thereof and each having a second input coupled to the output of a separate one of said transducers, said multivibrators producing an output signal during the interval between said detector signal and said transducer signal,

(d) an oscillator,

(e) a plurality of coincidence gates each having a first input connected to the output of a separate one of said multivibrators and having a second input coupled to said oscillator, said gates transmitting said oscillator pulses during the input coincidence of said multivibrator signal therewith,

(f) a like plurality of scalers each coupled to the output of a separate one of said coincidence gates and counting the oscillator pulses therefrom, which counts correspond to the acoustic time delays between the spark of the particle path in a gap and the sonic wave arrival at the positions of the wave guides disposed therein, and

(g) a recording means having a plurality of inputs separately coupled to said scalers and receiving said counts therefrom.

2. In a charged particle sensitive device of the class having a plurality of electrically charged parallel plates spaced apart within a gas filled chamber to form a series of spark gaps and having a detector indicating the passage of a charged particle therethrough, a means for electronically detecting the location of charged particle paths through said chamber comprising:

(a) a plurality of sonic wave guides with at least two thereof extending into each spark gap of said chamber at spaced apart positions in said gap, said wave guides being responsive to shock waves emanating from sparks therein,

(b) a like plurality of acoustical-electrical transducer elements each being disposed at the end of a separate one of said wave guides and producing an electrical signal in response to pressure exerted thereon by said wave guide,

(c) a like plurality of amplitude discriminator circuits each having an input coupled to the output of a separate one of said transducers and discriminating against low amplitude noise signals therefrom,

(d) a like plurality of bi-stable multivibrators each receiving the signal from said detector at a first input thereof and each having a second input coupled to the output of a separate one of said discriminator

circuits, said multivibrators generating an output signal during the interval between said detector signal and said discriminator signal,

(e) a high frequency clocking oscillator,

(f) a like plurality of coincidence gates each having a first input connected to the output of a separate one of said multivibrators and having a second input coupled to said oscillator, said gates transmitting said oscillator pulses during the input coincidence of said multivibrator signal therewith,

(g) a like plurality of scalers each coupled to the output of a separate one of said coincidence gates and counting the oscillator pulses therefrom, which counts correspond to the acoustic time delays between the spark of the particle path in a gap and the sonic wave arrival at the positions of the wave guides disposed therein, and

(h) an information storage device having a plurality of inputs coupled to said scalers and receiving said counts therefrom.

3. In combination with a gas-filled parallel plate spark chamber of the class having a series of spark gaps defined by said plates, an acoustical probe for detecting charged particle passages across the gaps thereof, said probe comprising a tubular enclosure disposed adjacent the side of a gap of said chamber and directed theretowards, a wave guide rod longitudinally disposed in said enclosure and having a rounded sensing end extending into said spark gap of said chamber and having a flat opposite end, a disc-type piezoelectric transducer disposed against said flat end of said rod in said enclosure, a heavy damper element secured against said transducer disc, said damper being disposed and resiliently supported in said enclosure, and electrical terminal means coupled to said transducer for conducting current pulses generated in said transducer by sonic pressure exerted thereon from said wave guide.

4. In a charged particle sensitive instrument of the class having a plurality of spaced apart parallel plates and having a pulse source for applying a potential difference between neighboring ones of said plates whereby a spark is produced by the passage of a charged particle across the gap between said neighboring ones of said plates, the combination comprising:

(a) a pair of acoustic-electric transducers associated with each of said gaps and situated outside thereof, said pair of transducers each having an associated acoustic wave detecting element in said gap at spaced apart locations therein, said acoustic wave detecting elements being sonic waveguide rods extending from said transducers into the outer regions of said gaps,

(b) a plurality of timing circuits a separate one being coupled to each of said transducers and being coupled to said pulse source for determining the time intervals between the application of said potential difference to said plates and the detection of an acoustic wave by the associated transducer, and

(c) output means for transferring said time interval determinations to a computer for analysis whereby the position of said sparks in said gap may be determined.

5. In a charged particle sensitive instrument of the class having a plurality of spaced apart parallel plates and having a pulse source for applying a potential difference between neighboring ones of said plates whereby a spark is produced by the passage of a charged particle across the gap between said neighboring ones of said plates, the combination comprising:

(a) a pair of acoustic-electric transducers associated with each of said gaps, said pair of transducers each having an associated acoustic wave detecting element in said gap at spaced apart locations therein,

(b) a plurality of timing circuits a separate one being coupled to each of said transducers and being coupled to said pulse source for determining the time intervals between the application of said potential difference to said plates and the detection of an acoustic wave by the associated transducer,

(c) a particle detector disposed in the path of particles approaching said gap and connected to initiate operation of said pulse source and to initiate operation of said timing circuit upon detection of a charged particle,

(d) a reset signal source coupled to said timing circuits for cancelling the accumulated count thereof a predetermined interval after detection of a particle by said detector which interval exceeds the time required for said transducers to detect acoustic waves originating at the region of said gaps which is most remote from said transducers, and

(e) output means for transferring said time interval determinations to a computer for analysis whereby the position of said sparks in said gap may be determined.

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