Dec. 19, 1967 V. PEREZ-MENDEZ ETAL 3,359,421

MAGNETOSTRICTIVE READOUT FOR WIRE SPARK CHAMBERS

Filed Oct. 20, 1965 2 Sheets-Sheet 1

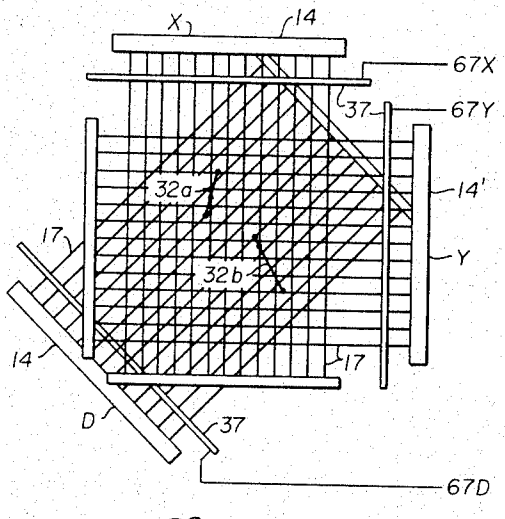


Fig. 5.

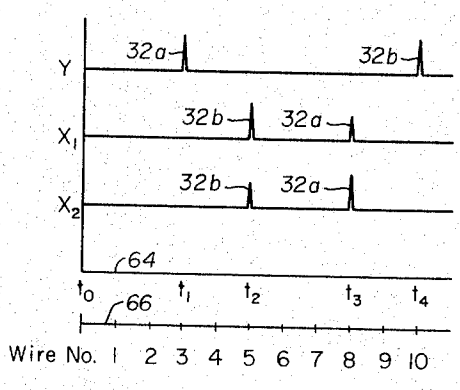


Fig. 4.

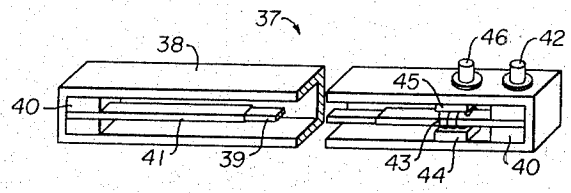


Fig. 3.

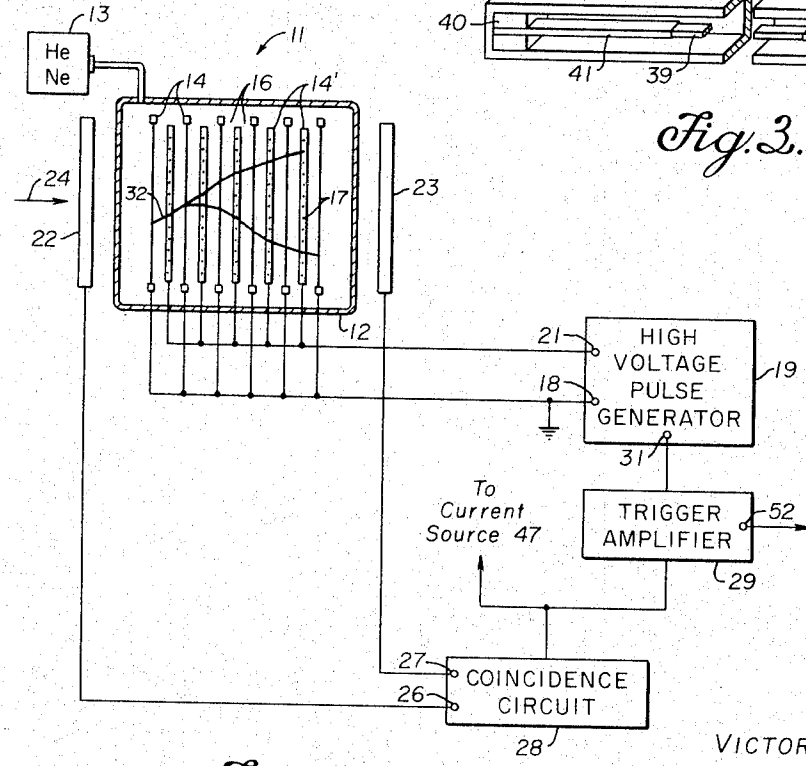


Fig. 1.

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MAGNETOSTRICTIVE READOUT FOR WIRE SPARK CHAMBERS

Filed Oct. 20, 1965 2 Sheets-Sheet 2

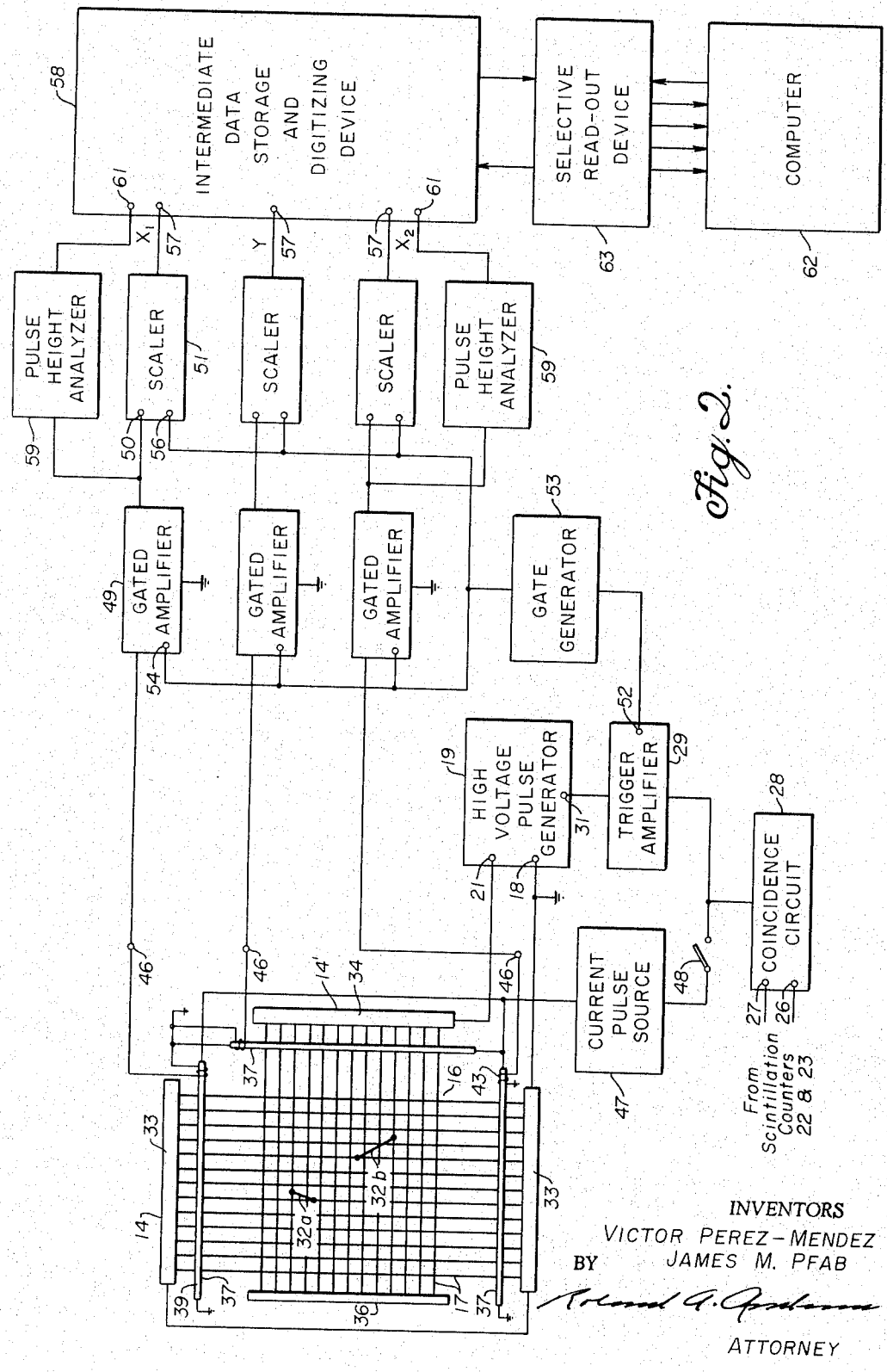


Fig. 2.

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MAGNETOSTRICTIVE READOUT FOR WIRE SPARK CHAMBERS

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12 Claims. (Cl. 250—83.6)

The present invention relates to spark chambers for detecting and locating the trajectories of charged particles and more particularly to an improved means for recording the spark discharge positions in a spark chamber of the type having wire electrodes.

As a charged particle track detector, the spark chamber has proven to be an extremely versatile and valuable tool in elementary-particle physics, particularly in connection with experiments at high energy accelerators. Spark chambers can be counter-controlled with time resolutions of less than 10^{-6} sec. and are therefore effective detectors in very intense particle beams providing high data rates. By virtue of the inherent flexibility in the chamber size, shape, and composition, the instrument lends itself to a wide diversity of particle investigations some of which are not necessarily limited to those involving accelerators. For instance, large volume low mass spark chambers are successfully being used in airplanes, balloons, and satellites for cosmic ray experiments.

Normally the spark chamber data has been obtained by photographing the spark discharge pattern of the particle paths. Various means for filmless data extraction are currently being advanced, however, due to some rather basic limitations of the photographic recording method. The quantity of film required to photographically record large experiments is costly and the subsequent processing is cumbersome and slow. Electronic methods are far simpler and faster, and the electronic techniques lend themselves better to direct correlation of the spark chamber and counter information. Also, the speed and form of the electronic data provides for prompt feedback of the experimental results.

The wire spark chamber is one of various filmless, electronic spark detection methods under refinement. Advantageously, the wire chamber requires a relatively small amount of discharge energy and thus operates with an inherently shorter spark-recovery time. The higher repetition rate resulting therefrom further increases the data accumulation capability and provides for even more versatile usage such as in rapid-cycling control or trigger systems for larger chamber installations.

In the wire spark chamber, the parallel-plate electrodes which normally define the chamber gaps are replaced by parallel planar arrays of many closely-spaced fine wires. Sparks across the chamber gaps are detectable by the resulting currents in the electrode wires coupled by the spark. These current pulses are then used to digitize the various spark locations in the chamber space.

The data extraction from such wire spark chambers has heretofore been accomplished by means of small ferrite cores which are separately threaded onto the chamber wires for the data signal input. Additional wires are also threaded onto each core for the data sensing and read-out functions. The minute detail of this ferrite coil assembly, wherein for every wire of the chamber a separate small core must be threaded with three leads, makes fabrication of the instrument extremely tedious and time-consuming. As a practical matter, the assembly problem limits the size of the wire chamber and thus precludes full exploitation of the advantages of the instrument. Very large chambers having many thousands of wires would be desirable for use in high energy experiments, but it can be seen that construction of the ferrite coil assembly in such size is hardly feasible. In addition, the amount of support circuitry necessarily associated with magnetic core operation virtually places such contemplated sizes out of the question.

The subject invention provides a novel and simplified means for data extraction from a wire spark chamber which avoids the complicated assembly and cumbersome circuitry associated with magnetic cores. The invention uses the property of magnetostriction of ferromagnetic materials to store and measure the time intervals of pulses magnetically impressed thereon and requires only a single read-out lead for each wire plane of the chamber.

A thin nickel ribbon is disposed along the side of each wire plane to cross, in close proximity, each wire of the plane. The nickel is magnetostrictive and the strips are magnetized to a suitable bias level to optimize this effect. Thus the magnetic field of a spark current in any of the chamber wires may be coupled to the nickel ribbon of the particular wire plane. As a spark current flows through the wire to a common ground lead, in passing near the nickel ribbon the magnetic field from the current pulse produces a local elongation in the ribbon in the immediate vicinity of the wire. This deformation pulse travels in both directions along the nickel ribbon at the velocity of sound in nickel and is damped at each end thereof by rubber support clamps. A small pick-up coil is located near one end of each ribbon. The arrival of the deformation pulse changes the magnetization in the ribbon increment within the coil and, by the inverse magnetostrictive effect, produces a small detectable voltage signal in the coil. The time interval between the onset of the chamber spark discharge and the output pulse from the pick-up coil indicates the location of the particular wire in the plane which carried the spark current. The wires in the alternate planes of the chamber may lie at right angles to those of the other planes. Thus, for any gap each plane thereof provides a respective rectangular coordinate position of the spark thereacross.

The pick-up coils of the chamber planes are coupled to the readout circuitry wherein timing circuits determine the intervals of the coil output pulses and logic circuits convert the time intervals to digitized form for subsequent operation by computer.

The circuitry for these read-out operations is far less complex than that required for the ferrite core method of data extraction. The amount of circuitry required is more directly related to the chamber size, as opposed to the rapid scaling with size in the other case, with no sacrifice in the spark chamber performance. The number of sparks that can be handled simultaneously is limited only by the distribution of the discharge current among sparks; by the capacity of the read-out circuit; and by the two-spark resolution. Through optimizing certain limiting factors, the two-spark resolution can be reduced to less than 2 mm. Multiple-spark ambiguities in the read-out data can be eliminated either by means of orienting some of the wire planes at 45° with respect to the others, or by employing an additional magnetostrictive read-out along the opposite side of the ground planes.

It is accordingly an object of the invention to provide a simplified means for automatically measuring the spark positions in a wire spark chamber.

It is an object of the invention to provide a wire spark chamber having improved means for detecting and recording the charged particle tracks therein.

It is an object of the invention to provide a data-extraction means for a wire spark chamber which is particularly suited to very large chambers.

It is another object of the invention to provide a wire spark chamber data-extraction means in which multiple-spark events are recorded without ambiguity.

It is a further object of the invention to provide a spark-event detector for use in a wire spark chamber which is simple to construct and which requires a minimum of support circuitry.

It is still another object of this invention to provide a spark chamber of the type having wire-plane electrodes in which only a single readout channel is required for each electrode.

It is a further object of the invention to provide a wire spark chamber in which a major portion of the read-out circuitry can be remotely located from the chamber.

The invention, both as to its organization and method of 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 wire spark chamber showing the chamber pulsing circuitry associated therewith,

FIGURE 2 is a schematic diagram of the magnetostrictive spark detectors of the subject invention as used on two orthogonal wire electrodes of the wire chamber of FIGURE 1 and showing the output circuitry therefor in block form,

FIGURE 3 is a view showing the detailed structure of the magnetostrictive spark detectors of FIGURE 2,

FIGURE 4 is a pulse display of the output signals from the magnetostrictive detectors of FIGURE 2, and

FIGURE 5 is a diagrammatic view showing the magnetostrictive spark detectors used on an alternate arrangement of the electrode planes of wire spark chamber.

Referring now to the drawing and more particularly to FIGURE 1 thereof, there is shown a wire spark chamber **11** comprising an air-tight enclosure **12** which is filled to approximately one atmosphere pressure with a noble gas from supply tank **13**. The gas might typically be argon or a mixture of helium and neon, as shown. Several planar electrodes **14** are disposed within the housing **12**, arranged in parallel and spaced-apart relationship whereby a series of equal-width gaps **16** is formed between successive electrodes **14**. Each of the rectangular electrodes **14** comprises a parallel array of many closely-spaced fine wires **17**, as will hereinafter be described in greater detail. The electrodes **14** are arranged in chamber **11** with the wires **17** of successive electrodes running in alternate orthogonal directions whereby in the subsequent digitization of the chamber data these vertical and horizontal directions in the chamber space may correspond to x, y coordinate reference axes.

The two outer electrodes **14** of the chamber **11** and the alternate electrodes therebetween are connected to a ground line **18** of the chamber pulsing source **19**. The remaining electrodes, intermediate to the grounded electrodes and indicated by primes in the drawing, are connected to a common high voltage output **21** of the chamber pulse source **19**. An electric field is thereby established simultaneously in all of the chamber gaps **16** upon the occurrence of a pulse from the high voltage pulse generator **19**.

A pair of flat rectangular particle detectors **22** and **23** are provided outside the chamber **11** at opposite ends thereof. The detectors **22** and **23** are disposed parallel to the electrodes **14** and transverse to the path of the incoming charged particles, indicated in the drawing by arrow **24**. The detectors **22** and **23** may be selected to discriminate among the incoming particles and respond to those having the particular characteristics desired for the investigation at hand. The outputs of the detectors **22** and **23** are coupled to separate inputs **26** and **27** of a coincidence circuit **28**. The passage of desired particles through the chamber **11** is detected by the counters **22** and **23** and the essentially simultaneous input signals to the coincidence circuit **28** produce a trigger pulse at the output thereof.

The trigger pulse from coincidence circuit **28** is coupled

through an amplifier **29** to the input **31** of the chamber pulse generator **19** whereby a high voltage charge (10 to 50 kv.) is applied to the wires **17** of the chamber electrodes **14'**. In the presence of the electric field thereby established in the gaps **16** between the wire planes, sparks occur along the lines of ionized gas particles left by each passing charged particle. A typical spark pattern from such a particle ionization trail is shown in FIGURE 1 by the heavy lines **32** between the affected wires **17** of the successive electrode planes. The spark **32** provides an instantaneous low resistance coupling and thus establishes a current path from the wire of the pulsed electrode **14'** to the wire of the grounded electrodes **14**. The spark current temporarily flowing in these two wires may be detected and, by virtue of the known locations of the wires, can be used to denote the spark position in the chamber **11**.

The elements of the invention as described up to this point constitute the salient features of a conventional wire spark chamber in which the previous practice has been to detect and record the spark positions by means of ferrite cores threaded onto the separate wires of each plane. The wire electrode planes of these chambers are often formed of copper-etched lines on a plastic plate, having as many as 50 lines per inch. This degree of detail for the core assembly and the related circuitry involved has prevented construction of very large chambers, therefore the advantages of the wire spark technique have not been fully realized. In the subject invention the novel magnetostrictive detection sufficiently reduces the number of read-out channels and the necessary electronics to be conveniently adaptable to chambers of any size.

With reference now to FIGURE 2, there is shown schematically two wire planes **14** and **14'** defining a chamber spark gap **16** therebetween. The figure includes one of two alternate means provided by the invention for resolving multiple-spark event ambiguities (the other to be described with reference to FIGURE 5) which means divides the spark current flowing in the ground plane electrode between two detectors whereby the respective x and y coordinate positions of simultaneous sparks may be properly paired. Thus, the vertical wires **17** of the grounded electrode **14** are shown coupled between a pair of spaced conducting bars **33** which bars, in turn, are connected to the ground line **18** of high voltage source **19**. The horizontal wires of the pulsed electrode **14'** are coupled at one end to a conducting bar **34** which is connected to the high voltage output **21** of source **19** and are open-circuited at the other end by a non-conducting support strap **36**. The incoming particle path in this figure would be into the plane of the drawing and the sample spark patterns **32** are seen to extend from a horizontal wire of plane **14'** to a vertical wire of plane **14**. The discharge current from the spark will diverge in the vertical ground wire and flow toward the two conducting bars **33**, the current magnitude dividing in direct proportion to the fractional wire lengths. Accordingly, two magnetostrictive detecting units **37** are each disposed near a grounded bar **33** of the wire plane **14** and a third unit **37** is disposed near the high voltage bar **34** of plane **14'**.

Referring now to FIGURE 3, the detector assembly **37** is contained in a long rectangular aluminum holder **38** having one side open. A sensing strip **39** is disposed along the open side of holder **38** and is spanned between two pairs of rubber damping pads **40** which are clamped at the ends thereof. The sensing strip **39** is formed of a magnetostrictive material such as nickel or a cobalt alloy thereof whereby magnetic pulses imposed thereon will produce a mechanical deformation therein. The strip **39** may be in the form of a fine wire or a very thin ribbon—a ribbon 0.005 in. by 0.025 in. is used in the present embodiment. These small dimensions of the strip relative to the wavelength of the deformation pulse produced makes it possible to establish a pure longitudinal mode of the pulse. The pulse

will travel along the strip with a velocity $V=(E/\rho)^{\frac{1}{2}}$ where E is Young's modulus of elasticity and ρ is the density of the material. For nickel, which has a high coefficient of magnetization, the longitudinal pulse velocity is approximately 5000 meters/sec.

A thin tape **41** insulates the nickel ribbon **39** from the aluminum holder **38** and from the electrode wires **17** near which it will be placed. Thus, a spark current flowing through a wire **17** to ground acts as a single-turn "send" coil to the ribbon **39**. The magnetic field of the spark current produces a local elongation in the magnetostrictive ribbon **39** in the immediate vicinity of the particular current-carrying wire **17**. An induced current is also established in the aluminum holder **38** and effectively doubles the magnetic pulse imposed on the ribbon **39**. The deformation pulse will travel along the ribbon **39** to both ends thereof whereupon it is damped by the rubber clamps **40**.

The properties of magnetostriction are enhanced when the materials involved are magnetized to the knee region of the B–H curve, since the magnetic domains will then have reached maximum size and will be most ready to align with an applied magnetic field. This magnetic biasing is necessary only in the regions where a magnetostrictive pulse is to be imposed or detected. Since in the invention, any portion of the sensing strip **39** may be used as a "send" coil, the entire length of the nickel ribbon should be uniformly biased. This may be done either by placing a current-carrying conductor closely parallel to the ribbon or by passing a current pulse along the ribbon itself (a pulse must be used since the equivalent D.C. current density would overheat the ribbon). Thus for the latter case, a plug-in terminal **42** is shown for coupling the ribbon **39** to a biasing current source as will hereinafter be described.

A very small pick-up coil **43** encircles the ribbon **39** near one end thereof to detect the arrival of the magnetostrictive deformation pulse. A small permanent magnet **44** is mounted in holder **38** opposite the coil **43** to bias magnetize the detecting region. The deformation pulse causes a change in the bias level of the ribbon **39** element which lies within the coil **43** and, by means of the Villari effect, produces a small voltage signal from the coil. A small emitter-follower amplifier stage **45** couples the coil **43** to an external jack-type terminal **46** on the holder **38** for connection to the output circuitry. The present embodiment of the invention uses a 600-turn coil, 3 mm. long, and a 2000-ohm input impedance in the amplifier stage. The aluminum holder **38** provides some electric shielding for the ribbon **39** and pick-up coil **43** to decrease induced signals from the spark-discharge noise.

The spark position in the wire electrode plane **14** can thus be determined along the coordinate reference direction of the sensing strip **39** by measuring the time interval between the onset of spark discharge in the chamber and the occurrence of the output pulse from the pick-up coil **43**. This time interval essentially corresponds to the travel time of the deformation pulse along the ribbon **39** from the point of origin, i.e., the wire position, to the coil **43**. Knowing the pulse velocity in the ribbon, the output circuitry converts travel time to the corresponding distance and digitizes the wire **17** position from which the pulse originated.

The open side of the holder **38** is provided in order that the detecting unit **37** may be disposed on the electrode plane with the detecting strip **39** facing the electrode wires **17** and spaced slightly apart therefrom. The units **37** are oriented along a side of the electrode such that each wire **17** of the plane is included within the free span of the sensing strip **39** and crosses at right angles thereto.

The detecting units **37** are shown schematically in FIGURE 2 as disposed on the two orthogonal wire planes **14** and **14'**. The arrangement of two detectors on the grounded plane **14** and one detector on the pulsed plane **14'** is repeated throughout the chamber **11**.

The bias magnetizing current for the nickel ribbons **39** is supplied from a current pulse source **47** which is triggered by the branched output of the chamber coincidence circuit **28**. The biasing has a relatively lasting effect in the ribbons **39** and the current pulse is only intermittently re-applied by means of a switch **48**.

The pick-up coils **43** of the detector units **37** are each coupled at the output **46** thereof, through a gated amplifier **49**, to a first input **50** of a scaler **51** in the respective output channels. A second output **52** of the main trigger amplifier **29** is coupled to a gate generator **53**. Upon sparking of the chamber **11**, the trigger amplifier **29** initiates a gating signal from generator the duration of which is equivalent to the longest possible travel time of a spark deformation pulse in the nickel ribbons **39**. A branched output of the gate generator **53** is coupled to second inputs **54** of the channel amplifiers **49** whereby the amplifiers are gated "on" during this time and random noise is otherwise blocked from the output circuitry. The branched output of generator **53** is also coupled to second inputs **56** of the channel scalers **51**. The gate input **56** provides a t_0 reference, concurrent with the onset of chamber sparking, whereupon the scalers **51** begin to count until pulsed-off and reset at the cessation of the gating signal. The instantaneous scaler **51** counts at the time of an input **50** detector signal thereto are then applied to separate channel inputs **57** of an intermediate data storage device **58**.

The scaler **51** count from the single detector **37** of the pulsed electrode **14'** is thus indicative of the digitized *y*-coordinate position of a spark terminating at a wire of this plane. The two detectors **37** of the grounded electrode **14** produce equal counts from the respective channel scalers **51** for a spark terminal position along a wire of this plane, since the deformation pulse travel distance from the current-carrying wire to the coils **37** is the same for each detector. However, the relative amplitudes of the pulses will differ according to the location of the spark along the wire **17**. As was mentioned earlier, the divergent spark current in the grounded wires **17** divides in direct proportion to the respective wire path lengths traveled thereby. Thus, the relative voltage outputs of the pick-up coils **43** are in the ratio $V_1/V_2=L_1/L_2$, where L is the distance along the wire **17** from the spark to the respective conducting bar. Accordingly, a pulse height analyzer **59** is included in each of the ground plane **14** output channels, coupled between the amplifier **49** output and a second channel input **61** of the intermediate data storage **58**. The paired inputs **61** and **57** of the two ground plane **14** channels to the data storage **58** are thus identified as the X_1 and X_2 data channels, while the single input **57** of the pulsed plane **14'** channel is the Y data channel.

Since most computer facilities have a limited capacity for parallel data entry, the spark position data arriving at the channel inputs X_1, X_2 and Y of the various chamber planes is held in the data storage **58** for digitization and subsequent transfer to a computer **62** by means of the selective read-out device **63**. The form of the spark position information provided by the invention, i.e., the counts from scalers **51** and the pulse height comparisons from analyzers **59** is readily convertible to digitized form by various means known to the art. Thus, the intermediate storage device **58** may be any of several presently available types, such as magnetic core or drum memory.

Referring now to FIGURE 4 in conjunction with FIGURE 2 for a description of the logic involved in identifying the chamber spark positions from X_1, X_2 and Y output channel information, there is shown a pulse display of sample signals therefrom. A common horizontal time reference **64** to the three-channel display has the t_0 of chamber spark onset as the origin. A second common horizontal reference **66** is calibrated in the successive wire positions of an electrode plane from which the magnetostrictive deformation pulse would travel in the corresponding time scale of reference **64**. Accordingly, the

origin of wire reference 66 corresponds to the upper right corner of the electrode grid pattern of FIGURE 2.

Considering a multiple-spark event such as that exemplified by the two sample spark patterns 32*a* and 32*b* in the chamber gap of FIGURE 2, a first deformation pulse will be imposed on the nickel ribbon 39 of the pulsed *y*-coordinate electrode 14' at the point of the third wire thereon at t_0 of spark discharge. This pulse will arrive at pick-up coil 43 after a travel time t_1, as measured by scaler 51 in the output circuitry. A second deformation pulse from spark 32*b* is simultaneously impressed further along on the ribbon 39 at the point of the tenth wire of the electrode 14'. The longer travel time of this second pulse to the pick-up coil 43 is also measured in the channel scaler 51 and the two Y-channel output signals from sparks *a* and *b* are seen in FIGURE 4 at times t_1 and t_4 respectively.

The discharge current from spark 32*b* at the fifth wire of the grounded *x*-coordinate electrode 14 will diverge at the spark terminal point on this wire and flow toward the two grounded conducting bars 33, the current magnitude dividing in direct proportion to the respective to the respective lengths of the divergent paths. Thus, deformation pulses of differing amplitude will simultaneously be imposed on the respective ribbons 39 of the two X-plane detectors 37 at corresponding points thereon. The travel time and amplitude of these pulses are measured in the respective scalers 51 and pulse analyzers 59 of X_1 and X_2 output channels. The slightly larger X_1 pulse and the smaller X_2 pulse of spark 32*b* are seen in the display, occurring at time t_2 which corresponds to the location of this wire. Similarly, the terminal of spark 32*a* at the eighth vertical wire produces second deformation pulses in the X-plane nickel ribbons 39, arriving at the slightly later time t_3. The amplitudes of the two t_3 pulses are also seen to differ in accordance with the relative location of the spark 32*a* along this wire.

It can be seen that the output pulses from the X and Y plane output channels do not necessarily occur in a correct time sequence and, thus, for such multiple-spark events it is initially ambiguous as to which pair of simultaneous X_1 and X_2 pulses belongs with the separate Y-plane pulses. The pulse height data from the X-plane output channel analyzers 59 is therefore used by the computer 62 logic to resolve this multiple-spark ambiguity.

By virtue of the current division in the X-plane wires, for any single spark, the ratio of the X_1 output voltage to the combined X_1 and X_2 output voltages is directly proportional to the ratio of the X_1 current path to the entire wire length. This voltage ratio is therefore indicative of the spark terminal position on the X-plane wire, relative to the *y*-coordinate reference axis. Accordingly, the terminal position of the spark on the X-plane can be located in both the *x* and *y* reference directions, and this derived *y* position provides the necessary redundancy to properly pair the four spark terminal points. Given the gap width between electrodes and the wire spacing within electrodes, there is only a limited and predictable range of lateral deviation from the normal to the electrode plane that a spark path may have in the space of a single gap for even the most oblique particle paths. The other terminal of the spark, in the Y-plane wire, must therefore be in the vicinity of the derived *y*-coordinate spark position along the X-plane wire. Thus, the computer 62 can compare the ambiguous Y-plane output data with the derived *y*-coordinate information from the X-plane data and match the acceptable Y-plane signal with its appropriate X-plane pair counterpart.

The accuracy of the derived redundant data may be only in the range of a centimeter, while that obtained directly from the magnetostrictive strips is limited only by the spacing of the wires and is thus in the range of 1 or 2 millimeters. In order to eliminate or balance this asymmetry in accuracy between the two reference directions,

the successive ground electrodes 14 throughout the chamber 11 may be arranged with the respective wire arrays thereof alternating between the *x* and *y* coordinate directions.

The wire grid electrode arrangement of an alternate means for resolving multiple-spark ambiguities is shown schematically in FIGURE 5 wherein each orthogonal pair of X and Y plane electrodes is followed by a diagonal D-plane electrode in which the wire grid is oriented at 45° to the X and Y plane reference axes. Coupling to the chamber high voltage source 19 with the alternation of grounded and pulsed electrodes 14 and 14' throughout the chamber 11 is the same as was previously described. In the arrangement of FIGURE 5, however, only one magnetostrictive detecting unit 37 is used on each electrode plane. Accordingly, the pulse height analyzers 59 of FIG. 2 are eliminated from the output circuitry and the respective single output channels 67_X, 67_Y, and 67_D of each electrode correspond exactly in structure and operation to the Y-plane read-out channel of FIGURE 2.

The sample spark patterns *a* and *b* are shown in FIGURE 5 to continue across the second gap formed between the Y-plane and the D-plane. The wire 17 locations of each of the sparks *a* and *b* are detected by the three magnetostrictive units 37 respectively associated with the planes X, Y, and D. As in the previous case, the time sequence of the two output signals appearing in each of the read-out channels 67_X, 67_Y, and 67_D is not in itself indicative of the spark locations. The ambiguity of which three pulses belong with which spark still persists. Due to the geometry of the pattern presented by the three grids X, Y, and D, however, it can be seen that a spark path across the two intervening gaps which is directed essentially normal to the grid planes will intersect a different combination of wires 17 in the respective grids at all points about the pattern. Thus, the computer 62 is programmed with all the possible X and Y plane wire intersections that lie along the vicinity of each diagonal wire 17 of the D-plane. For each of the two spark terminal wire locations indicated by the D-plane output signals, the computer 62 can thereby determine which combination of the X and Y plane signals could possibly coincide with that particular diagonal wire and the logic will properly group the appropriate *x*, *y* and *d* wire positions of each spark, *a* and *b*.

The wire spark chambers 11 are often compiled of pre-assembled units of paired orthogonal electrode planes 14. In such cases the alternate two-plane units throughout the chamber may be disposed at the 45° orientation and the output data from both planes may be similarly used in the ambiguity resolution.

While the diagonal plane method of resolving ambiguity in the data from multiple-spark events involves greater complexity in the computer 62 programming and requires more computer time for particle-track analysis, the electronics of the output circuitry is simpler than that required for the pulse-height comparison of the previously described dual-detector plane method. The relative advantages of the two systems are therefore dependent on the circuitry facilities or the computer capacity of the particular installations at which the spark chamber is used. Both methods are readily adaptable to various commonly used means for processing the data into digitized form for entry into the computer 62. Thus the intermediate storage and digitizing device 58 may be either in the form of the magnetic core stack, a recirculating magnetostrictive delay line, or a rotating magnetic disk or drum.

While either of the above-described embodiments of the invention handles ambiguous data from multiple sparks better than has heretofore been the case, it should be noted that in the instances of simultaneous sparks occurring very close together in the chamber gaps 16 or of two sparks terminating at the same wire 17 of an electrode 14, the ambiguity cannot be resolved. The known

probability of these occurences is small, however, and presents no significant practical limitation to the track measuring ability of the device.

In addition to the superiority of the invention in resolving ambiguous data, the simplicity of the magnetostrictive data-extraction technique lends itself most advantageously to the photo-etch method of wire chamber construction which is applicable to both planar and non-planar chamber configurations. Some common examples of such usage in multiple-plate chambers are in gamma ray investigations wherein the wire grids **17** are etched directly on lead plates or in polarization analyses of nucleons wherein the grids are etched on carbon plates. As a further advantage of the invention, the relatively high output level from the pick-up coils **43** allows the main portion of the read-out electronics to be remotely located, providing wide potential application in space physics research in which balloon or satellite experiments can have the data telemetered to a ground-based computer.

While the invention has been described with respect to certain particular embodiments thereof, it will be apparent to those skilled in the art that numerous other variations and modifications are possible within the spirit and scope of the invention and thus it is not intended to limit the invention except as defined in the following claims.

What is claimed is:

1. In combination with a spark chamber charged particle detector of the type having electrodes formed of wire grids wherein the current from a particle initiated spark between successive electrodes is discharged through a separate wire of each of said electrodes, a means for locating the position of said spark in said chamber comprising, a magnetostrictive delay line disposed along each of said electrodes and across the wires comprising the grid thereof in close proximity thereto for magnetic coupling to each wire of said grid upon the occurrence of a spark discharge current in said wire, sensing elements disposed near one end of each of said delay lines and responsive to magnetostrictive deformation pulses established in said delay line by the spark discharge currents in said wires, and means coupled to each of said sensing elements for timing the arrival of said deformation pulses at said sensing elements relative to the time of said chamber spark discharge whereby the position of said spark in the direction of said delay line may be computed.

2. In a charged particle sensitive spark chamber of the class having a gas-filled enclosure surrounding a plurality of spaced-apart parallel wire grid electrodes, alternate ones of which electrodes are coupled to a pulse source for applying a potential difference between successive pairs of said electrodes whereby passage of a charged particle through said chamber produces sparks between specific individual wires of neighboring electrodes, the wire grids of certain ones of said electrodes being disposed in a first direction and the wire grids of the remaining electrodes being disposed in a second direction, the combination comprising a plurality of magnetostrictive delay lines, one of said delay lines being disposed along a side of each of said electrodes and across each of the component wires thereof in close proximity thereto whereby the spark discharge current flowing in an individual wire of said electrode produces a deformation pulse in the magnetostrictive delay line associated with said electrode at a point thereon in the immediate vicinity of said wire, a plurality of sensing coils, one of said sensing coils being disposed near one end of each of said magnetostrictive delay lines and producing an output pulse in response to said deformation pulses in said delay line arriving thereat, a plurality of timing circuits each coupled at a first input thereof to a separate one of said sensing coils and coupled at a second input to said chamber pulse source for determining the time delay between the occurrence of said chamber spark pulse and the detection of said deformation pulse by the associated sensing coil, and output means for transferring said time delays from timing circuits to a computer for analysis whereby the position of said sparks in said chamber may be determined.

3. A charged particle sensitive spark chamber as described in claim **2** wherein said output means comprises a data storage device for accumulating a quantity of said time delay determinations for subsequent analysis by a computer.

4. A charged particle sensitive spark chamber as described in claim **2** and comprising the further combination of a gate generator having an input coupled to said chamber pulse source and an output, said generator being of the class producing a gate signal at the output thereof which signal is of duration equal to the longest possible time required for a deformation pulse in said magnetostrictive delay lines to arrive at said sensing coils, and a plurality of amplifiers each having a gate input coupled to said output of said gate generator, each of said amplifiers being coupled between the output of a separate one of said sensing coils and said first input of the particular one of said timing circuits associated therewith.

5. A wire spark chamber for locating the position of charged particle paths directed therethrough comprising, a gas-filled enclosure, a pulse source external to said enclosure having a high voltage terminal and a ground potential terminal, a first plurality of spaced-apart parallel electrodes disposed in said enclosure, each of which electrodes is formed of a closely-spaced parallel array of many fine wires, alternate ones of said electrodes being coupled at both ends of said wire array to the ground terminal of said pulse source and the intermediate ones of said electrodes being coupled at one end of said wire array to the high voltage terminal of said pulse source whereby the potential difference established between successive electrodes produces a spark pattern along said charged particle path and whereby the discharge current from a spark terminating at a wire of said grounded electrodes diverges at a point on the wire where the spark terminates with the spark current magnitude dividing in proportion to the distances from said point to each of said end ground connections thereof, a plurality of magnetostrictive delay lines, two of said delay lines being disposed along opposite sides of each of said grounded electrodes transverse to the wire arrays thereof and one of said delay lines being disposed along one side of each of said high voltage electrodes transverse to the wire arrays thereof whereby said spark currents discharging through any wire of said electrodes produce a local deformation pulse in the magnetostrictive delay lines associated with said electrodes, a plurality of sensing coils each disposed at one end of a separate one of said delay lines, said sensing coils being responsive to deformation pulses arriving at the end of the associated one of said delay lines, a plurality of timing circuits each coupled at a first input thereof to said pulse source and coupled at a second input thereof to a separate one of said sensing coils and producing an ontput indicative of the time delay between signals arriving at said first and second inputs thereof, a plurality of pulse height analyzing circuits separately coupled to the ones of said sensing coils which are associated with said grounded electrodes, a computer, and output means for transferring the outputs from said timing circuits and said pulse height analyzing circuits to said computer for analysis whereby the position of said sparks in said wire chamber may be determined.

6. A wire spark chamber as described in claim **5** wherein the wires said grounded ones of said electrodes extend in a direction which is orthogonal to that of the wires of the high voltage ones of said electrodes.

7. In a spark chamber for locating the paths of charged particles passing therethrough of the class having a gas-filled enclosure surrounding a plurality of spaced-apart parallel wire grid electrodes alternate ones of which are

coupled to electrical ground and the intermediate ones of which are coupled to a pulse source for applying a potential difference across the gaps between neighboring electrodes with the wires of said alternate and said intermediate electrodes extending in orthogonal directions, the combination comprising a plurality of magnetostrictive rods each of said rods being disposed along a separate one of said electrodes transversely with respect to one end of the wires thereof and in proximity thereto for detecting the spark discharge from any wire of said electrode associated therewith, a plurality of sensing means each being coupled to a separate one of said magnetostrictive rods at an end thereof for producing an electrical pulse in response to a magnetostrictive deformation pulse traveling along said rod, a scaler circuit coupled to the output of each of said sensing means and coupled to said pulse source for determining the time interval between the application of said potential difference to said electrodes and the receipt of an input pulse from said sensing means associated therewith which time interval is indicative of the particular wire location in said electrode plane from which said spark discharge originated, and a data digitizing device coupled to said scaler circuits whereby the outputs of said scaler circuits respectively associated wtih each of said orthogonal pairs of electrodes in said chamber may be converted into the corresponding coordinate locations of a spark across the gap defined therebetween.

8. A spark chamber as described in claim 7 wherein the wires of alternate pairs of said electrodes are directed at an angle with respect to the orientation of the wires of the intervening electrode pairs whereby ambiguities in said coordinate data arising from multiple spark events in said chamber may be resolved in said data digitizing device.

9. A spark detector as described in claim 7 and further characterized by a thin electrically-insulative material encircling said magnetostrictive rods.

10. A spark detector as described in claim 7 wherein

the cross-sectional dimensions of said magnetostrictive rods are substantially smaller than the characteristic wavelength of magnetic deformation pulses produced therein.

11. A spark location detecting means for use on an electrically-charged parallel wire grid electrode of a wire spark chamber comprising, a long holder having a chamber therein with one side open, a pair of damping pads disposed in said holder at each end thereof, a thin strip of ferromagnetic magnetostrictive material disposed in said holder and having a length at least greater than the dimension of said electrode which is transverse to the component wires thereof, said strip being suspended between said damping pads to lie along the open side of said holder, a first coupling terminal disposed on said holder at one end thereof to connect said magnetostrictive strip to an external current pulse source, a small electrical coil encircling said strip and disposed near one end thereof, a small permanent magnet mounted in said holder directly opposite said coil to bias magnetize said strip in the vicinity of said coil, an amplifier means disposed in said holder and coupled to the output of said coil, and means for mounting said holder along one side of said electrode with said magnetostrictive strip proximal to the component wires thereof in substantially transverse relationship thereto whereby a spark current established in a wire of said electrode produces a deformation pulse in said strip in the vicinity of said wire which deformation pulse is detected upon arrival at the end of said strip by said coil and the travel time of which pulse in said strip is indicative of the wire location at the origin of said spark.

12. A spark detector means as described in claim 11 wherein said holder is composed of an electrically conductive material.

No references cited.

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