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SENSITIVE RADIATION DETECTOR HAVING ALTERNATE CATHODE
AND ANODE MEMBERS IN CHAMBER CONTAINING IONIZING GAS
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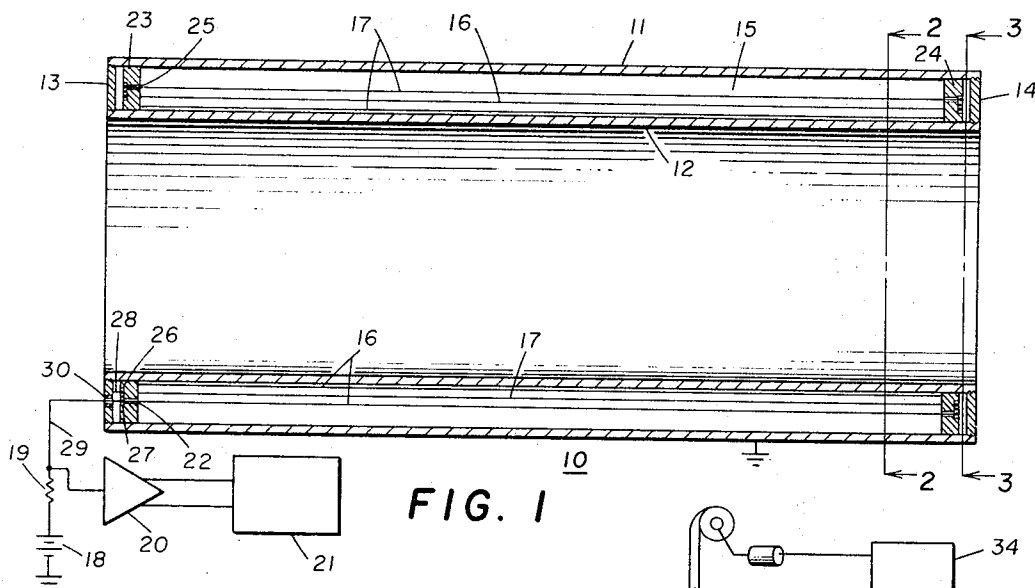


FIG. 1

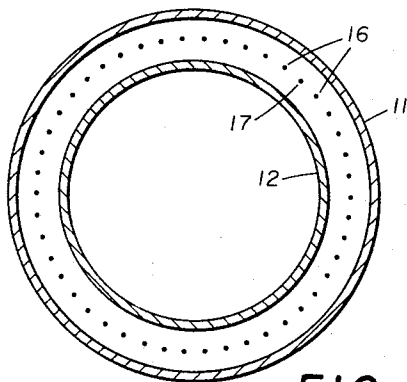


FIG. 2

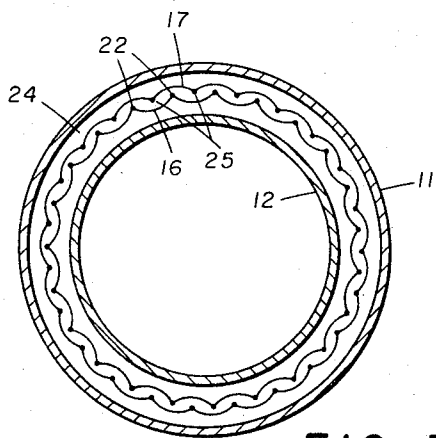


FIG. 3

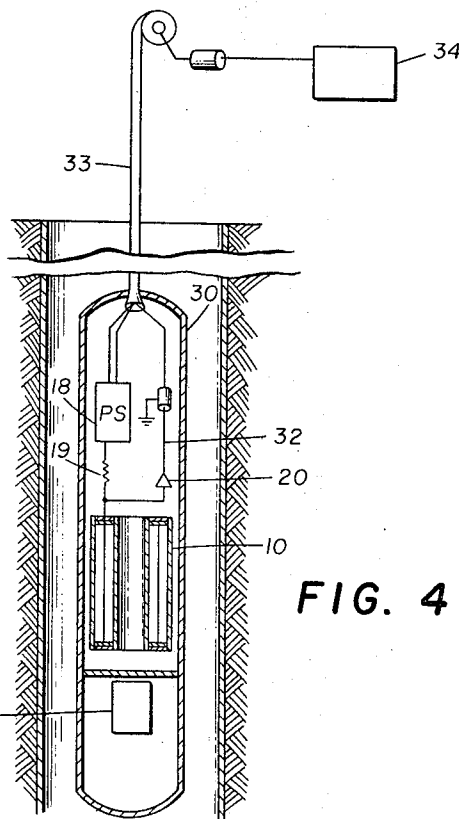


FIG. 4

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SENSITIVE RADIATION DETECTOR HAVING ALTERNATE CATHODE AND ANODE MEMBERS IN CHAMBER CONTAINING IONIZING GAS

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ABSTRACT OF THE DISCLOSURE

A radiation detector comprising two spaced cylindrical members forming an annular chamber filled with an ionizing gas and having a plurality of anode and cathode wires alternately disposed in the chamber. The cathode wires are coupled together and to the cylindrical members to form the cathode of the detector while the anode wires are coupled together and insulated from the cathode to form the anode. In the chamber, all of the wires are spaced from each other and from the cylindrical walls. High pressure helium-3 gas is injected into the chamber to form a proportional counter for detecting thermal neutrons or epithermal neutrons.

This invention relates to the detection of radiation and more particularly to a sensitive proportional counter for detecting neutrons.

The commercially available detector or counter of the proportional type generally comprises a cylindrical-shaped container filled with an ionizing gas and having an anode wire extending through the center thereof. For detecting thermal neutrons, the ionizing gas employed may be helium-3 or boron trifluoride. In applications such as in well logging, a plurality of such detectors is employed in a borehole tool, generally in an annular manner, in order to increase the counting efficiency. Due to the shape of the detectors and the small size of the borehole tools, a relatively large amount of space exists between the detectors and hence maximum counting efficiency is not realized.

It has been found that the counting efficiency may be increased further by providing the detector in an annular shape of large diameter and employing a plurality of spaced anode wires in the annular chamber. Such a detector utilizes all of the space in the annular region for ionizing gas and hence presents an increased volume of gas for interaction with the radiation of interest.

It is an object of the present invention to increase further the efficiency of a radiation detector, having a plurality of spaced anode wires disposed in a chamber, by employing cathode wires between the anode wires. More particularly, it has been found that when anode wires alone are employed, a relatively large region exists between the anode wires wherein the electrostatic field is relatively weak. The presence of the weak field reduces the collection process of electrons by the anode wires since it increases the probability of electrons, formed between the anode wires, recombining with ions rather than being collected. This, of course, reduces the efficiency of the detector since the electrons which recombine will not contribute to a pulse. The presence of the cathode wires increases the electrostatic field and hence increases the efficiency of the detector.

In accordance with the present invention, the radiation detector comprises a container having wall members forming a pressure-tight chamber. An ionizing gas is provided within the chamber. A plurality of spaced first wires extends through the chamber and is disposed intermediate the walls of the chamber. These wires and the walls of the chamber are connected together to form

a first electrode. A plurality of second wires extends through the chamber and is disposed intermediate the walls of the chamber and the second wires. The second wires are connected together and are insulated from the first electrode to form a second electrode. Circuit connections extend from the first and second electrodes for application of a potential voltage.

In a further aspect, the detector comprises a pressure-tight annular chamber having walls formed by a pair of spaced cylindrical members disposed concentrically and connected together. The first wires extend through the chamber and are disposed intermediate the walls of the chamber. In addition, the second wires extend through the chamber and are disposed between the walls of the chamber and the first wires. Preferably, the ionizing gas employed consists substantially of helium-3 at superatmospheric pressure greater than about 2 atmospheres absolute.

For a more complete understanding of the present invention and for further objects and advantages thereof, reference may now be had to the following detailed description taken in conjunction with the accompanying drawings wherein:

FIGURE 1 is a cross-sectional view of the detector of the present invention;

FIGURE 2 is a sectional view taken along the lines 2-2 of FIGURE 1;

FIGURE 3 is a sectional view taken along the lines 3-3 of FIGURE 1; and

FIGURE 4 illustrates a radioactive well logging system employing the detector of the present invention.

Referring now to FIGURE 1, there is illustrated a detector 10 of the proportional counter type which comprises concentric cylindrical members 11 and 12 having ring-shaped end plates 13 and 14 internally threaded to the members 11 and 12 to form an annular chamber 15. Sealed within the chamber is an ionizing gas, which preferably is helium-3 at superatmospheric pressures. Extending through the chamber in an annular arrangement intermediate the wall members 11 and 12 is a plurality of parallel-spaced first wires 16 and a plurality of alternately-spaced second wires 17 located between wires 16. Wires 17 are connected together and with wall members 11 and 12 to form the cathode, while wires 16 are connected together and insulated from the cathode to form the anode.

A voltage source illustrated at 18 is coupled across the anode and cathode by way of resistor 19. Coupled from resistor 19 is an amplifier 20 and a measuring device 21 for obtaining an indication of the number of counts detected per unit time.

In the present system, the use of alternate cathode wires provides an attractive force at a point intermediate the anode wires and hence results in an increase in the number of lines of force or electrostatic field in this region. Furthermore, the use of the cathode wires results in a more uniform distribution of lines of force from the anode wires. In effect, the volume between the inner and outer cylinders is divided into n distinct counters where n is the number of cathode or anode wires. Infinitely thin walls between the successive counters are formed by equal potential lines (at cathode potential) passing through the cathode wires in a direction normal to the inner and outer cylindrical walls. Particles resulting from interaction of radiation with the gas, however, are able to pass from one counter to another and hence will contribute to the detection process.

In a more detailed description, the wires 16 comprise a continuous wire which is threaded through apertures 22 (FIGURE 3) formed in a circular path in ceramic end members 23 and 24 (see also FIGURE 1). Wires 17 also

comprise a continuous wire threaded through apertures 25 formed in the same circular path intermediate apertures 22 in ceramic end members 23 and 24. Thus, wires 16 and 17 extend through the chamber in an annular arrangement in an alternate pattern.

Arc-shaped grooves 26 and 27 (see FIGURE 1) are formed in the outer surfaces of members 23 and 24 to insure that wires 16 and 17 are insulated from each other. Wires 17 are connected to the cylindrical members 11 and 12 by way of connection 28 extending to end plate 13 (FIGURE 1). A positive potential is applied to the wires 16 from the source 18 by way of resistor 19 and conductor 29 which extends to wires 16 by way of pressure-tight insulating member 30 located in end plate 13.

In a preferred embodiment, the chamber 15 has a narrow cross section, preferably having an inner diameter of at least 2 inches and an outer diameter of about 2½ inches. The narrow cross section of the annular chamber has advantages since it allows the ions, resulting from the interaction of the radiation with the gas, to be formed in close proximity to the anodes. This is desirable, especially when employing helium-3 at superatmospheric pressures, since less voltage is required in order to minimize the electron collection time and hence response time of the detector.

In the preferred embodiment, the longitudinal dimension of the detector 10 is of the order of 6 inches. The cylindrical members 11 and 12 are stainless steel and respectively have outside diameters of 2.75 inches and 2 inches. The wall thickness of the cylinders 11 and 12 is of the order of ¼ of an inch. The end plates 13 and 14 are also of stainless steel. Wires 16 and 17 are of tungsten. The number of wires 16 and 17 employed are 23 each. All of the wires 16 and 17 are equally spaced along an annular path that extends midway between the outside diameter of cylinder 12 and the inside diameter of cylinder 11. The ceramic end plates 23 and 24 are sealed to cylinders 11 and 12 by a suitable seal (not shown).

In the preferred embodiment, the detector is employed for detecting thermal neutrons or epithermal neutrons (by providing a cadmium shield around the detector). In this embodiment, the gas employed is substantially helium-3 at superatmospheric pressures. There also may be included a quenching gas such as carbon dioxide.

Helium-3 at superatmospheric pressures is preferred since, as disclosed in U.S. Patent No. 3,102,198, at superatmospheric pressures, which may be from about 2 atmospheres absolute to about 20 atmospheres absolute, helium-3 has a high-capture cross section for thermal and epithermal neutrons by the reaction of $\text{He}^3(n,p)\text{H}^3$.

In the annular-shaped detector of narrow cross section, as described above, the gas preferably is employed at a pressure of at least 6 atmospheres. At such pressures, substantially all thermal neutrons and epithermal neutrons will be absorbed. At a pressure of 6 atmospheres, the voltage applied across the anode and cathode will be less than 1000 volts, i.e., of the order of 700 volts.

Referring now to FIGURE 4, there is illustrated a borehole logging system employing the detector of the present invention. As illustrated, the detector 10 is employed in a borehole logging tool 30 which also includes a neutron source 31 which may be a pulsed neutron source or a steady-state source. The output of the detector is applied to the surface by way of amplifier 20 and coaxial cable 32 of logging cable 33.

At the surface, detector pulses are applied to a readout 34 which may be a continuous recorder having its chart driven in correlation with depth by means not shown.

While the invention has been described in connection with a certain specific embodiment thereof, it will be understood that further modifications will suggest themselves to those skilled in the art, and it is intended to cover such modifications as fall within the scope of the appended claims.

What is claimed is:

1. A neutron detector of the proportional type, comprising:
 - a pressure-tight annular chamber having walls formed by a pair of spaced cylindrical members disposed concentrically,
 - said members being formed of stainless steel,
 - an ionizing gas within said chamber and consisting substantially of helium-3 at superatmospheric pressures greater than about 2 atmospheres absolute,
 - a plurality of first wires extending through said chamber in spaced relation with each other and disposed intermediate said walls of said chamber,
 - said first wires and said walls of said chamber being connected together electrically to form a cathode,
 - a plurality of second wires extending through said chamber and disposed intermediate said walls of said chamber and said first wires,
 - said second wires being connected together electrically and insulated from said cathode to form an anode, and
 - circuit connections extending from said anode and from said cathode for application thereto of a direct current potential.
2. The detector of claim 1 wherein:
 - said chamber has an inner diameter of the order of 2 inches,
 - said ionizing gas consisting substantially of helium-3 at superatmospheric pressures of the order of 6 atmospheres absolute.
3. The detector of claim 1 wherein:
 - said chamber has an inner diameter of at least 2 inches and an outside diameter of the order of 2½ inches,
 - said ionizing gas consisting substantially of helium-3 at superatmospheric pressures of at least 6 atmospheres absolute.
4. In a radioactive well logging system having a logging tool containing a source of neutrons, the combination therewith of a neutron detector of the proportional type, comprising:
 - a pressure-tight annular chamber having walls formed by a pair of spaced cylindrical members disposed concentrically,
 - said chamber having an inner diameter of at least 2 inches and an outer diameter less than 3 inches,
 - said members being formed of stainless steel,
 - an ionizing gas within said chamber and consisting substantially of helium-3 at superatmospheric pressures of at least 6 atmospheres absolute,
 - a plurality of first wires extending through said chamber in spaced relation with each other and disposed intermediate said walls of said chamber,
 - said first wires and said walls of said chamber being connected together electrically to form a cathode,
 - a plurality of second wires extending through said chamber and disposed intermediate said walls of said chamber and said first wires,
 - said second wires being connected together electrically and insulated from said cathode to form an anode, and
 - circuit connections extending from said anode and from said cathode for application thereto of a direct current potential.
5. A radiation detector comprising:
 - a container having two spaced ends,
 - enclosing wall structure between said ends forming a pressure-tight chamber,
 - an ionizing gas within said chamber,
 - a plurality of elongated first wire members having substantially circular cross sections extending through said chamber and directly exposed to said enclosing wall structure,
 - a plurality of elongated second wire members having substantially circular cross sections extending through

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said chamber and directly exposed to said enclosing wall structure,
 said first and second elongated wire members being arranged to extend through said chamber with their elongated axes substantially parallel and forming a series of wire members disposed in a predetermined pattern,
 said first and second wire members being disposed alternately in said series,
 said first and second wire members being spaced from each other in said chamber and from said enclosing wall structure,
 said first wire members and said enclosing wall structure being coupled together electrically to form a cathode,
 said second wire members being coupled together electrically to form an anode for collecting electrons upon the ionization of said gas and resulting from the interaction of radiation with said detector, and circuit connections extending from said anode and said cathode for application thereto of a source of voltage.
 6. The detector of claim 5 comprising:
 means including an impedance means coupled electrically between said cathode and said anode for obtaining an indication of radiation detected.
 7. The detector of claim 6 wherein said chamber is formed by spaced wall members, the distance between adjacent wire members of the same kind being about equal to the distance between said spaced wall members.
 8. A radiation detector comprising:
 two spaced hollow members, one positioned within the other forming inner and outer wall members, respectively, defining a chamber surrounding an interior central region,
 an ionizing gas within said chamber,
 a plurality of first members disposed in said chamber in spaced relation with each other and with said inner and outer wall members,
 said first members throughout most of their length within said chamber being directly exposed to the surfaces of said inner and outer wall members forming said chamber,
 said first members and said inner and outer wall members being connected together electrically to form a cathode, and
 a plurality of second members disposed in said chamber in spaced relation with each other and with said inner and outer wall members,
 said second members being directly exposed throughout most of their length within said chamber to the surfaces of said inner and outer wall members forming said chamber,
 said second members being connected together electrically to form an anode,
 said first and second members being spaced from each other in said chamber,
 said first and second members being alternately disposed within said chamber.
 9. A radiation detector comprising:
 a pressure-tight annular chamber having walls formed by a pair of spaced cylindrical members disposed concentrically,
 an ionizing gas within said chamber,
 a plurality of first members disposed in said annular chamber about the axis of said annular chamber and in spaced relation with each other and with said cylindrical members,
 said first members being connected together electrically to form a cathode, and

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a plurality of second members disposed in said annular chamber about the axis of said annular chamber and in spaced relation with each other and with said cylindrical members,
 said first and second members being spaced from each other in said chamber,
 said second members being connected together electrically to form an anode,
 said first and second members being alternately disposed within said chamber.
 10. The detector of claim 9 wherein:
 said first members and said cylindrical members are coupled together electrically to form said cathode.
 11. The detector of claim 9 wherein:
 said first and second members are elongated and extend through said annular chamber with their elongated axes substantially parallel with the central axis of said annular chamber.
 12. The detector of claim 11 wherein:
 said first and second members are disposed in said annular chamber substantially in a circular path concentric with the central axis of said chamber,
 said members being equally spaced along said circular path.
 13. The detector of claim 9 wherein:
 said first and second members are directly exposed to the surfaces of said cylindrical members forming said annular chamber.
 14. The detector of claim 9 wherein:
 said first and second members are disposed in said annular chamber at substantially the same distance from the central axis of said annular chamber.
 15. The detector of claim 9 wherein:
 said first and second members comprise metallic wire members,
 said first members and said cylindrical members being coupled together electrically to form said cathode,
 said first and second members throughout most of their length within said chamber being directly exposed to the surfaces of said cylindrical members forming said annular chamber.
 16. The detector of claim 15 wherein:
 said ionizing gas consists substantially of helium-3 confined in said chamber at superatmospheric pressures greater than about two atmospheres absolute.
 17. The detector of claim 15 comprising:
 means including impedance means coupled electrically between said cathode and said anode for obtaining an indication of radiation detected.
 18. The detector of claim 15 wherein:
 said first and second members are elongated and extend through said annular chamber with their elongated axes substantially parallel with the central axis of said annular chamber.
 19. The detector of claim 15 wherein:
 the distance between adjacent wire members of the same kind is about equal to the radial distance between said spaced cylindrical members disposed concentrically forming said annular chamber.

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