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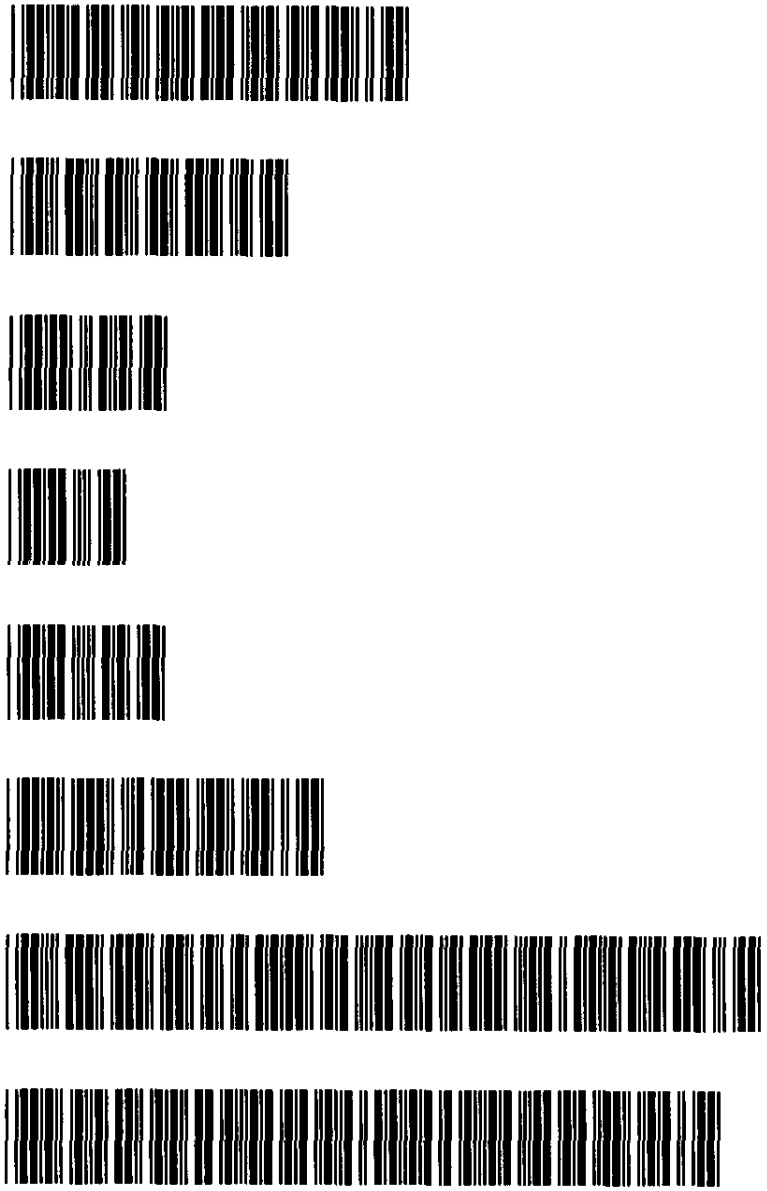

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3:00-CV-00701 GAMMA METRICS INC V. ANALYSER SYSTEMS
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AMDCMP.

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UNITED STATES DISTRICT COURT

SOUTHERN DISTRICT OF CALIFORNIA

GAMMA-METRICS, INC., a California corporation, Plaintiff, v. ANALYSER SYSTEMS COMPANY, INC., a California corporation, Defendant.	Case No. 00cv0701 L (LAB) **FIRST AMENDED COMPLAINT FOR PATENT INFRINGEMENT** **DEMAND FOR JURY TRIAL**

Pursuant to Rule 15(a) of the Federal Rules of Civil Procedure, Plaintiff GAMMA-METRICS, INC. ("Gamma-Metrics") submits this First Amended Complaint for Patent Infringement and hereby complains and alleges against Defendant ANALYSER SYSTEMS COMPANY, INC. ("ASYS" or "Defendant") as follows:

1. Plaintiff Gamma-Metrics is a corporation organized and existing under the laws of the State of California, with its principal place of business in San Diego, California.

2. On information and belief, Defendant ASYS is a corporation organized and existing under the laws of the State of California, with a principal place of business in Escondido, California.

ORIGINAL

JURISDICTION

3. This is a civil action for patent infringement arising under the patent laws of the United States of America, and more specifically, under Title 35, United States Code, Sections 271, 281, 283, 284 and 285. Jurisdiction in this Court is founded upon 28 U.S.C. §§ 1331 and 1338(a).

4. Venue is proper in this district under 28 U.S.C. § 1391(b) on the grounds that Defendant ASYS resides and has a principal place of business in this district.

5. On information and belief, Defendant ASYS is engaged in the business of manufacturing, offering for sale, and selling in interstate commerce analyzers which infringe Gamma-Metrics' intellectual property rights.

PATENT INFRINGEMENT
Count 1
(Patent No. 4,682,043)

6. Gamma-Metrics realleges and incorporates the allegations of paragraphs 1-5 as if fully set forth herein.

7. Gamma-Metrics is the owner of the entire right, title and interest in and to United States Patent No. 4,682,043 of J. Howard Marshall (the "Marshall patent"), entitled "Obtaining Uniformity of Response in Analytical Measurement in a Neutron-Capture-Based On-Line Bulk-Substance Elemental-Analyzer Apparatus", which issued July 21, 1987. The Marshall patent covers a technology known as prompt gamma-neutron activation analysis ("PGNAA"). A copy of the Marshall patent is attached as Exhibit "A" to this Complaint.

8. The Marshall patent was the subject of a reexamination in the U.S. Patent and Trademark Office ("the Patent Office"),

which reexamination was filed on January 28, 1999. On February 29, 2000, the Patent Office issued a Notice of Intent to Issue Reexamination Certificate confirming patentability of all claims of the original patent. A copy of relevant pages of this Notice is attached as Exhibit "B" to this Complaint. Issuance of a Reexamination Certificate is imminent.

9. On June 27, 2000, the Patent Office issued the Reexamination Certificate for the Marshall patent. This Certificate is attached as Exhibit "C" to this Complaint.

10. Gamma-Metrics manufactures and sells a Cross Belt Analyzer (CBA) system for bulk elemental analysis of cement raw mix, which system uses the PGNAA technology that is covered by the Marshall patent.

11. Defendant ASYS has manufactured, offered for sale, sold and delivered in the United States a CBA system for bulk elemental analysis of cement raw mix under the trade name "FULL STREAM ANALYZER FSA", which system infringes the claims of the Marshall patent in violation of 35 U.S.C. Section 271.

12. Gamma-Metrics has been damaged and has suffered irreparable injury due to acts of infringement by Defendant ASYS and will continue to suffer irreparable injury unless Defendant's activities are enjoined.

13. Gamma-Metrics has suffered and will continue to suffer substantial damage to its business in the form of loss of profits by reason of Defendant's acts of patent infringement as alleged above and Gamma-Metrics is entitled to recover from Defendant the damages sustained as a result of Defendant's acts. Gamma-Metrics is at present unable to estimate the full extent of the monetary

damages suffered by reason of Defendant's acts of patent infringement but will provide such at trial.

14. Defendant has willfully infringed Patent No. 4,682,043 in disregard of Gamma-Metrics' rights.

PATENT INFRINGEMENT
Count 2
(Patent No. 5,732,115)

15. Gamma-Metrics realleges and incorporates the allegations of paragraphs 1-14 as if fully set forth herein.

16. Gamma-Metrics is the owner of the entire right, title and interest in and to United States Patent No. 5,732,115 of Thomas L. Atwell, et al. (the "Atwell patent"), entitled "Enhancement of Measurement Accuracy in Bulk Material Analyzer", which issued March 24, 1998. The Atwell patent discloses a CBA with improved uniformity. A copy of the Atwell patent is attached as Exhibit "D" to this Complaint.

17. Thomas L. Atwell ("Atwell") was employed by Gamma-Metrics from June, 1981, to April, 1995. During his employment by Gamma-Metrics, Atwell participated in and made major contributions to the design and development of the Gamma-Metrics CBA.

18. Gamma-Metrics is informed and believes and on that basis alleges that Atwell, along with Victor Lanz, another former Gamma-Metrics employee, and Anton Lucchin founded ASYS.

19. Gamma-Metrics is informed and believes and on that basis alleges that Atwell made major contributions to the design and development of the ASYS "FULL STREAM ANALYZER FSA".

20. The ASYS "FULL STREAM ANALYZER FSA" infringes claims of the Atwell patent in violation of 35 U.S.C. Section 271.

21. Gamma-Metrics has been damaged and has suffered irreparable injury due to acts of infringement by Defendant ASYS and will continue to suffer irreparable injury unless Defendant's activities are enjoined.

22. Gamma-Metrics has suffered and will continue to suffer substantial damage to its business in the form of loss of profits by reason of Defendant's acts of patent infringement as alleged above and Gamma-Metrics is entitled to recover from Defendant the damages sustained as a result of Defendant's acts. Gamma-Metrics is at present unable to estimate the full extent of the monetary damages suffered by reason of Defendant's acts of patent infringement but will provide such at trial.

23. Defendant has willfully infringed Patent No. 5,732,115 in disregard of Gamma-Metrics' rights.

PRAYER FOR RELIEF

a) That the Court find that Defendant ASYS has infringed United States Patent No. 4,682,043;

b) That the Court find that Defendant ASYS has infringed United States Patent No. 5,732,115;

c) That the Court preliminarily and permanently enjoin ASYS and each of its officers, agents, servants, employees and attorneys, and all persons acting in concert or participation with them, from further infringement of United States Patent No. 4,682,043;

d) That the Court preliminarily and permanently enjoin ASYS and each of its officers, agents, servants, employees and attorneys, and all persons acting in concert or participation with

them, from further infringement of United States Patent No. 5,732,115;

e) That the Court award damages sufficient to compensate Gamma-Metrics for the past infringement of Patent No. 4,682,043 by ASYS;

f) That the Court award damages sufficient to compensate Gamma-Metrics for the past infringement of Patent No. 5,732,115 by ASYS;

g) That the Court find that Defendant's infringement of Patent No. 4,682,043 was willful;

h) That the Court find that Defendant's infringement of Patent No. 5,732,115 was willful;

i) That the Court find this to be an exceptional case and award Gamma-Metrics its attorneys fees and costs; and

j) That Gamma-Metrics be awarded such other relief as the Court may deem just and proper.

DEMAND FOR JURY TRIAL

Plaintiff Gamma-Metrics hereby demands a jury trial as to all issues that are so triable.

Dated: July 7, 2000

FISH & RICHARDSON P.C.

By: Juanita R. Brooks

Juanita R. Brooks
David S. Shuman

Attorneys for Plaintiff
GAMMA-METRICS, INC.

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United States Patent [19]
Marshall

[11] Patent Number: 4,682,043
[45] Date of Patent: Jul. 21, 1987

[54] OBTAINING UNIFORMITY OF RESPONSE IN ANALYTICAL MEASUREMENT IN A NEUTRON-CAPTURE-BASED ON-LINE BULK-SUBSTANCE ELEMENTAL-ANALYZER APPARATUS

[76] Inventor: J. Howard Marshall, 145 Hurlbut, Apt. 305, Pasadena, Calif. 91105

[21] Appl. No.: 61,833

[22] Filed: Jul. 30, 1979

Related U.S. Application Data

[63] Continuation of Ser. No. 866,488, Jan. 3, 1978.

[51] Int. Cl.⁴ G01F 23/00
[52] U.S. Cl. 250/358.1; 250/359.1; 250/390
[58] Field of Search ..... 250/358 R, 358 P, 359, 250/390, 391, 392, 432, 435, 453

[56] References Cited

U.S. PATENT DOCUMENTS

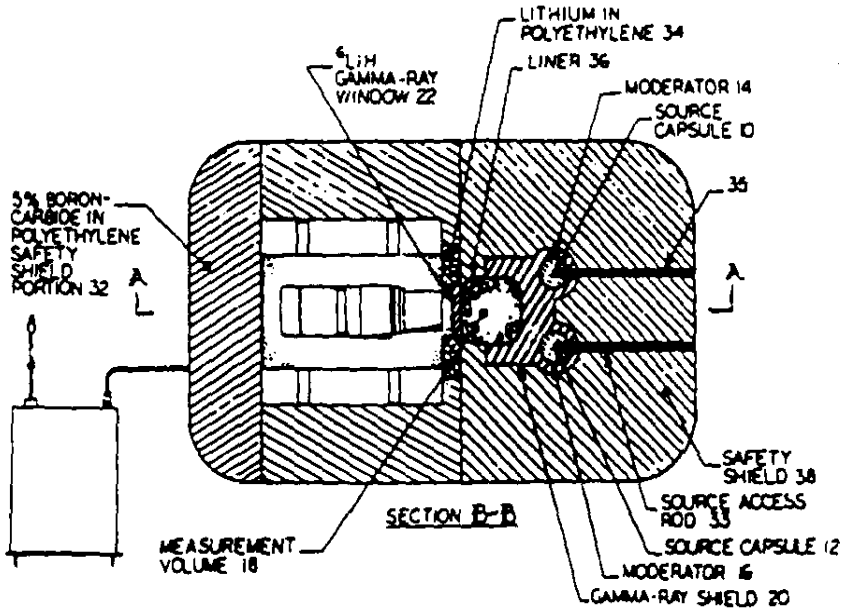
3,053,388	9/1962	Tittle	250/359
3,082,323	3/1963	Chope et al.	250/358 R
4,028,267	6/1977	Christell et al.	250/359

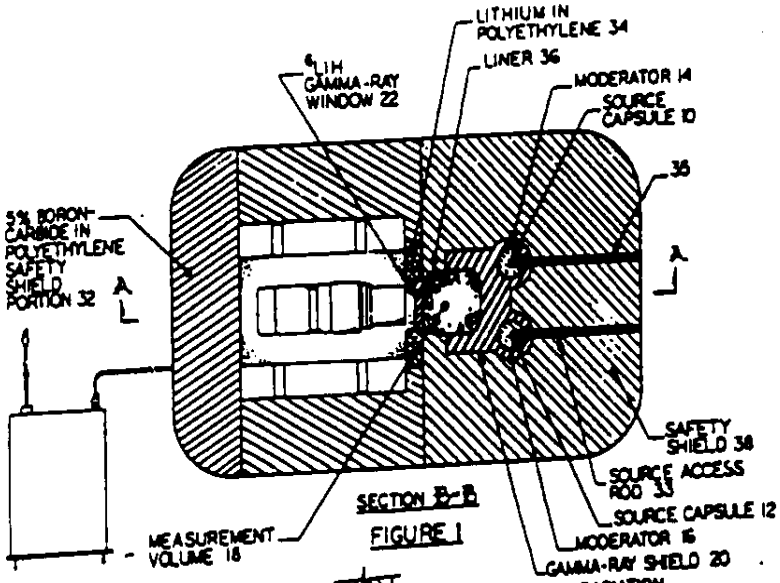
Primary Examiner—Janice A. Howell
Attorney, Agent, or Firm—James E. Brunton

[57] ABSTRACT

In an apparatus for neutron-capture-based on-line elemental analysis of bulk substances, an improved uniformity of response of analytical measurement will make the apparatus less sensitive to segregations that occur in moving streams of the bulk substance. The apparatus incorporates a measurement volume having a substantially-square cross-section with rounded corners in the plane perpendicular to the direction of flow in order to exclude the bulk substance from regions of unusual sensitivities and to facilitate the orientation of the instrument for minimum sensitivity to segregations in the bulk substance. The apparatus also includes a plurality of neutron sources which expose the analyzed bulk substance momentarily contained within the apparatus to a flux of neutrons. The apparatus also provides for the use of neutron reflectors to increase the neutron flux near the sides of the measurement volume, further improving the uniformity of measurement. The analyzed substance captures some of the neutrons by (n,γ) reactions, producing prompt gamma rays which are detected to provide the composition measurement. The use of multiple sources causes the neutron flux to rise instead of fall near the sides of the volume containing the bulk substance compared to the center of the volume, and flux variations can be made to cancel solid-angle variations to produce a more-uniform response over a substantial portion of the measurement volume. Similarly the use of multiple gamma-ray detectors can also reduce these solid-angle variations, improving measurement uniformity, particularly if the measurement volume is large because of material-flow requirements.

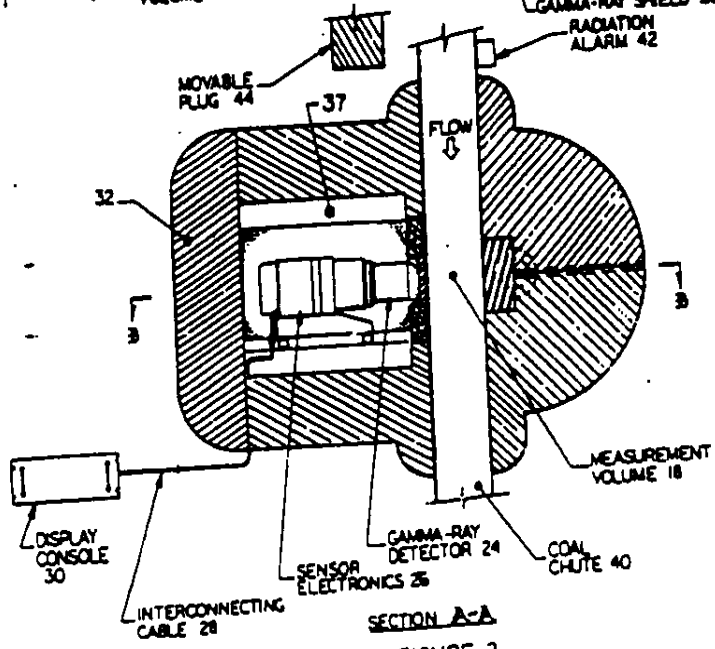
8 Claims, 2 Drawing Figures





SECTION B-B

FIGURE 1



SECTION A-A

FIGURE 2

OBTAINING UNIFORMITY OF RESPONSE IN ANALYTICAL MEASUREMENT IN A NEUTRON-CAPTURE-BASED ON-LINE BULK-SUBSTANCE ELEMENTAL-ANALYZER APPARATUS

This is a continuation of application Ser. No. 866,488, filed Jan. 3, 1978.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention generally relates to nuclear meters, and more particularly to improvements in neutron-capture-based elemental analyzers leading to an increased uniformity of response in on-line analytical measurements of bulk substances.

2. Description of the Prior Art

The rising cost of fuels, coupled with the need to avoid atmospheric pollution when burning them, has led to the requirement that their composition be known at various points in the fuel-preparation cycle. For example, because of the scarcity of low-sulfur crude oils and the cost of sulfur removal, the value of fuel oil increases significantly as its sulfur content becomes lower, indicating that accurate fuel-oil blending to a fixed sulfur level consistent with allowable amounts of pollution is both cost effective and an efficient utilization of increasingly-scarce hydrocarbons. Furthermore, precise knowledge of the heat content of fuel oil allows furnaces and boilers to be operated in a more-efficient manner. In addition, knowledge of the amount of sulfur and other contaminants such as vanadium and nickel in various hydrocarbon streams can help prevent the poisoning of catalysts used in oil refineries, avoiding costly shut downs.

In the case of coal, sulfur content is generally higher than that of oil, making the pollution problem even more severe. As a result, expensive coal-cleaning plants, stack-gas scrubbers and precipitators are necessary, all of which can be operated more efficiently if the coal composition is known on a real-time, on-line basis. Efficient boiler operation also benefits from this composition measurement, and knowing the composition of the ash in the coal can be used to avoid boiler slagging, which is a costly problem that is generally absent for fuel oil.

Particularly in the case of coal, but also for oil, these composition measurements have to be made on inhomogeneous substances with high mass flow rates and variable compositions. Thus, this measurement should continuously reflect the average composition of the bulk substance, and response times should be fast enough to permit effective process control. Generally the latter requirement implies a speed of response ranging from a few minutes up to an hour.

A technique which can satisfy these requirements can often be used in applications which do not involve fuels or their derivatives. For example, it could measure the nitrogen content of wheat in order to determine the amount of protein present, which in turn is related to food value. Thus, the measurement of fuels is illustrative only and is not essential to this invention, which applies to all measurements of bulk substances by the techniques to be described hereinafter.

Several methods for composition measurement are known in the prior art, the most obvious one being sampling following by chemical analysis. This technique provides most present data on the composition of various bulk substances. Unfortunately sampling is inherently inaccurate because of the lack of homogeneity of bulk materials, and large continual expenditures for manpower, sampling devices and chemical-analysis equipment are required to provide response times which at best could approach one hour. These disadvantages lead to the consideration of other techniques which are faster, more subject to automatic operations and more of an on-line continuous bulk measurement.

One technique often used in industrial environments for elemental analysis involves X-ray fluorescence. This technique relies on the fact that each atom emits X-rays with distinct and well-known energies when external radiations disturb its orbital electrons. Unfortunately, sulfur, which is an interesting element from the standpoints of air pollution and catalyst poisoning, emits mostly 2-keV X-rays, which can only traverse about 0.1 mm of a typical fuel. Iron, which is one of the elements generating the highest-energy X-rays in coal, produces mostly a 6-keV X-ray, which also cannot escape from any appreciable amount of coal or other nongaseous fuel. Thus, the use of X-ray fluorescence for other than gaseous materials requires either the preparation of very clean surfaces truly representative of the bulk material or the vaporization of a sample in an atmosphere which does not confuse the measurement. In either case, a difficult sample-preparation problem compounds the errors associated with X-ray fluorescence itself.

A second technique usually involving X-rays which are more penetrating is X-ray absorption. In this case one measures the differences in the absorption or scattering of X-rays caused by changes in the amounts of certain elements. In the case of relatively-pure hydrocarbons such as refined fuel oil, this technique can provide a useful measurement of sulfur content because sulfur at X-ray energies near 22 keV can have a predominant effect on the X-ray absorption. This predominance, however, is dependent on the lack of most of the metals which are present in coal and may also be present in oil. In addition, 22-keV X-rays only penetrate about 2 mm in most non-gaseous fuels, making sampling still a requirement. Moreover, this technique is generally limited to measuring only one of several potentially-interesting elements, and the measurement of the relative amount of many different elements in a complex mixture such as coal becomes difficult.

Nonetheless, nuclear techniques in general remain attractive because they often can be automated and in principal do not require actual manipulation of the bulk material itself. The problems with X-ray fluorescence and absorption arise partly because the Associated radiations are not sufficiently penetrating. However, because the energetic gamma rays produced by the capture of thermal neutrons will penetrate over 100 mm of most fuels, an analysis technique based on them can provide an accurate, continuous, on-line measurement of the elemental composition of bulk substances without sampling.

This technique is based on the fact that almost all elements when bombarded by slow neutrons capture these neutrons at least momentarily and form a compound nucleus in an excited state. Usually the prompt emission of one or more gamma rays with energies and intensities which are uniquely characteristic of the capturing nucleus dissipates most of this excitation energy. Because these prompt gamma rays often have energies in the 2- to 11-MeV range, they can penetrate substan-

tial quantities of material. Thus, for those isotopes with significant capture cross sections and prominent gamma-ray lines, measurement of prompt gamma rays can be used to determine in an on-line, real-time manner the quantity of most of the elements present in bulk substances, which can be flowing through the analyzer.

The above emphasis on thermal neutrons reflects the fact that for most elements the cross section for neutron capture is approxiately proportional to the reciprocal of the square root of the neutron energy. Thus, almost all neutron capture occurs at the lowest neutron energies, which happen when the neutrons are in thermal equilibrium with the nuclei of the surrouding medium. As a result, the thermal-neutron-capture cross sections characterize the expected prompt-gamma-ray spectra. These gamma-ray spectra are particularly amenable to simple theoretical interpretation using well-known thermal-neutron-capture cross sections, making automatic operation a feasible concept.

However, because isotopic and other neutron sources generally produce neutrons with average energies of at least several MeV, "moderation" or "thermalization" processes must reduce neutron energies by over eight orders of magnitude in order for them to reach the thermal region near 0.025 eV. Collisions with hydrogen nuclei, which have a mass essentially the same as that of the neutron and a large scattering cross section, are the most effective means for neutron moderation, although collisions with other elements will moderate neutrons to some degree. Because the neutrons move between collisions, the volume of material exposed to significant neutron fluxes can have a considerable extent, which depends mostly on the amount of hydrogen present. Because the thermal neutrons are produced continuously by moderation of the more-energetic neutrons and then diffuse throughout this moderation volume, the substance being measured is sampled over a large extent, providing the bulk measurement.

Although these techniques have been used in the laboratory under controlled conditions, their implementation in an automatic, on-line instrument placed in an industrial environment presents unique problems which prior-art instruments have not solved. One of these problems arises when the instrument must measure accurately substances with compositions which vary within the measurement volume. One such non-uniform material may occur when coal with various particle sizes of different compositions flows through a chute or channel passing through the instrument. Often in this case the coal particles will differentially segregate along the chute walls so that the elemental composition depends upon position within the measurement volume. Only if the instrument has a response which is independent of position within the measurement volume will it measure correctly the average composition of the bulk substance. Incomplete mixing of fluids or slurries could produce the same problems as illustrated above for solid coal, again leading to the need for a uniform response or measurement sensitivity.

In the known prior art, a single neutron source was located in the center of a coal chute passing through the measurement volume, and a single gamma-ray detector, which was located outside of the chute, was used to measure the energy spectrum of the capture gamma rays. In the plane passing through the center of the source and detector, the measurement sensitivity in this configuration varied both along the source-detector line and perpendicular thereto. Three major effects led to these sensitivity variations.

First, the neutron flux decreased as the distance from the source increased, and this flux had to fall substantially at the sides of the chute compared to its center in order to have an acceptable number of neutrons escaping into the detector. Because the probability of producing a gamma ray is proportional to the flux of thermal neutrons, the production probability per unit volume therefor also had to be substantially less at the sides of the chute than at its center.

Second, the solid angle subtended by the detector for each small volume in the coal chute is less for those volumes distant from the detector than for those closer to the detector. As a result, the probability that a gamma ray emitted from such a volume reached the detector decreased for volumes near the source or the far wall of the chute, and for those volumes removed from the source-detector line, compared to volumes on the source-detector line and near the detector side of the chute.

Third, the probability that a gamma ray moving toward the detector can travel from the region where it was produced to the detector without interacting decreases as the distance which it must travel increases. Thus, the measurement sensitivity, which was determined primarily by the gamma rays which did not interact, was less for regions near the source of the far wall of the coal cute compared to regions near the detector.

In these prior-art instruments all of these effective combined to make the sensitivity at the side of the chute on the opposite side of the source as the detector considerably less than the sensitivity in the volume between the source and the detector. However, if the neutron source is located outside of the measurement volume as described in another application for a U.S. patent, Ser. No. 808,106, filed on June 21, 1977 by the inventor herein, then the measurement can be confined to the volume between the source and the detector, resulting in improved uniformity. However, unless the techniques of this invention are also employed, the uniformity of sensitivity may still be insufficient to measure accurately segregated, inhomogeneous substances.

For example, if only a single source and detector are used, both the neutron flux and the solid angle are lowest at the sides of the chute compared to its center along a direction perpendicular to the source-detector line. Furthermore the amount of scattering material through which the gamma rays produced at the sides of the chute must travel to reach the detector is greater, adding to reduced sensitivities at the chute sides compared to its center. This effect becomes more severe as the chute becomes larger, particularly if neutron-absorbing materials or open spaces surround the chute and further depress the thermal-neutron flux at the chute sides. Large chute sizes may result from high mass flow rates or from other geometrical constraints imposed by the industrial environment and various properties of the substance being analyzed.

SUMMARY OF THE INVENTION

Applicant herein has conceived of several improvements for reducing these sensitivity variations in the elemental-analyzer apparatus, and these improvements can be applied either separately or in combination. One technique involves the use of two or more neutron sources which are located such that the neutron flux increases at the sides of the measurement volume com-

pared to the flux at the center. If the number and spacing of the sources are correctly chosen, then this flux increase can compensate for the reduced solid angle and gamma-ray transmission which occur at the sides. As a result, the sensitivity along lines parallel to the face of the detector can be made more uniform.

Similarly multiple gamma-ray detectors can also be used to accomplish the same result. In this case the solid angle and gamma-ray transmission can be enhanced near the sides of the measurement volume compared to its center. The combination of multiple sources with multiple detectors can produce an even-more-uniform measurement sensitivity particularly for large measurement volumes. In addition multiple detectors will measure more of the capture gamma rays and can tolerate higher total counting rates, leading to a more efficient use of neutrons and to a faster speed of response.

The flux at the sides of the measurement volume can be increased by still other means. For example, a smaller measurement volume has a smaller sensitivity variation than one with a larger cross-sectional area. Eliminating low-sensitivity regions, such as the corners of a coal chute, from the measurement volume also improves uniformity. In addition surrounding the measurement volume with a material which scatters neutrons without absorbing many of them will reflect neutrons back into the measurement volume, thus increasing the flux at the sides and improving the efficiency of neutron use. Typical neutron reflectors contain berrylium, carobon, oxygen or bismuth, with the latter also having the advantage of being a good absorber of background gamma rays.

Making the sensitivity uniform along the source-detector direction is more difficult, because the neutron flux must be allowed to decrease substantially near the detector, although a neutron-absorbing gamma-ray window can reduce the required amount of this flux decrease as described in U.S. patent application, Ser. No. 808,103, filed on June 21, 1977 by the inventor herein. Fortunately in this direction solid-angle and gamma-ray-transmission effects tend to compensate for the flux variations reducing the sensitivity non-uniformities, although perfect cancellation of these effects can only be fortuitous. In addition as one of the techniques of this invention, the orientation of the source-detector line can be chosen to lie along the direction of minimum concentration variation, reducing the inaccuracies resulting from sensitivity changes within the measurement volume. A symmetrical configuration for the measurement volume will then facilitate the adjustment of the instrument orientation in order to obtain optimum accuracies for nonuniform materials flowing through the instrument.

The present invention has several features of novelty over the known prior art, including the use of a plurality of neutron sources and detectors, the presence of neutron reflectors and the proper choice of the configuration and orientation of the measurement volume, in order to obtain a uniform measurement sensitivity throughout the measurement volume so that segregated, inhomogeneous bulk materials can be measured accurately.

It is an object of this invention to provide an improvement in a neutron-capture-based, on-line, bulk-substance elemental-analyzer apparatus for obtaining uniformity of response throughout the measurement volume.

It is another object of this invention to provide an improvement in an elemental-analyzer apparatus of the foregoing type for making the apparatus insensitive to segregations that may occur in moving streams of the bulk substance being analyzed.

It is an additional object of this invention to provide an elemental analyzer of the foregoing type having a symmetrical chute which has rounded corners through which the bulk substance being analyzed flows to improve uniformity of measurement.

It is another object of this invention to provide an elemental analyzer of the foregoing type having multiple neutron sources located outside of the chute through which the bulk substance being analyzed passes to improve uniformity of measurement.

It is another object of this invention to provide in an elemental analyzer of the foregoing type the capability for accommodating the placement therein of a multiple number of detectors to improve uniformity of measurement.

It is a further object of this invention to surround the measurement volume of an elemental analyzer of the foregoing type with a neutron-reflecting material in order to improve the uniformity of measurement.

For a better understanding of the present invention, together with other and further objects thereof, reference is made to the following description taken in connection with the accompanying drawings in which preferred embodiments of the invention are illustrated, the scope of the invention being pointed out and contained in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a cross-sectional view of the neutron sources, the gamma-ray detector, the measurement volume, the shielding and other structure associated with a meter for the elemental analysis of coal, which forms a preferred embodiment of this invention.

FIG. 2 shows further details of the same instrument as that shown in FIG. 1, but in this case the sectional view has been taken along the line A—A in FIG. 1. The line B—B of FIG. 2 shows the sectioning line used for producing FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The application of these considerations to an apparatus for the elemental analysis of coal forms one of the preferred embodiments of this invention, as shown in FIGS. 1 and 2. Other embodiments involve the on-line measurement of coal-water mixtures, coal-oil mixtures, crude oil, fuel oil, gasoline, wheat and most other bulk substances containing some hydrogen. Thus, the portions of the preferred embodiment shown in FIGS. 1 and 2 which are specific to the measurement of coal are illustrative only and are not intended to limit the scope of this invention.

The instrument includes means for containing the bulk substance to be analyzed, which may flow through the instrument in order to provide a continuous, on-line measurement of bulk composition. In the embodiment shown in FIGS. 1 and 2, this means encloses the centrally-located measurement volume 18, in which the coal being analyzed is confined. Measurement volume 18 is the region throughout which the composition measurement takes place. Coal passing through the coal chute 40 continuously fills the measurement volume 18 with a

current coal sample, facilitating the desired continuous, on-line bulk measurement.

In the embodiment of FIGS. 1 and 2, the means for containing the analyzed substance consists of the liner 36, which is partly surrounded by the bismuth gamma-ray shield 20. Because bismuth has a low probability for neutron absorption but does scatter neutrons, those portions of the gamma-ray shield 20 near the liner 36 reflect some of the escaping neutrons back into the measurement volume 18. As a result the gamma-ray shield 20 also acts as a neutron reflector, which increases the neutron flux along the sides of the measurement volume 18 in order to improve measurement uniformity and to use the neutrons more efficiently. Other elements besides bismuth are well known in the art to function as good neutron reflectors, including beryllium, oxygen, deuterium and carbon, and the use of any neutron-reflecting element for these purposes forms a part of this invention.

As shown in FIG. 1, the cross-section of the measurement volume 18 in the plane perpendicular to the flow of the bulk substance is a square with rounded corners. This symmetrical configuration provides several advantages compared to other configurations when measurement uniformity is important. First, this symmetry allows the instrument to be oriented easily such that the axis of the detector can lie along any desired direction without substantial modifications to the coal chute 40. Thus, the choice of the instrument orientation to minimize the sensitivity to composition segregations can be made relatively late in the installation process. Second, both the square cross section and the rounded corners exclude coal from regions of reduced measurement sensitivity. Because the configuration shown in FIG. 1 confines the coal to the region where neutron fluxes and detector 24 solid angles are relatively constant, the sensitivity throughout this plane will be more uniform than that provided by a wider measurement volume 18 or one permitting coal to enter square corners. These techniques also form a part of this invention, and they can be used separately or in combination with the other techniques described herein.

The instrument also includes neutron-producing means for providing neutrons. In the embodiment shown in FIG. 1, said neutron-producing means consists of two source capsules 10 and 12 containing the isotope Californium-252. In other embodiments of this invention the source could contain different isotopes, such as plutonium mixed with beryllium, or could contain a neutron generator, such as that using the $^{3}H(d,n)^{4}He$ reaction. Additionally the instrument could contain several other neutron sources, which could all be the same type or could be various combinations of source types. The neutronproducing means can be located either outside of the volume containing the bulk substance to be analyzed, as shown in FIGS. 1 and 2, or within this volume. If several neutron sources are present, some of these sources may be within this measurement volume, while other sources are external thereto. The principles forming a part of this invention apply to all of these variations of the embodiment shown in FIGS. 1 and 2.

The use of two neutron sources 10 and 12 as shown in FIG. 1 illustrates one of these principles. Because these two sources 10 and 12 are located near the corners of the measurement volume 18, the neutron flux is higher along the sides of the measurement volume 18 compared to its center. Because this flux increase compensates for the reduced detector 24 solid angle and gamma-ray transmission at the sides, the sensitivity uniformity is improved over the single-source case. Additional sources could be used to improve the uniformity even further, particularly if flow properties and flow rates of the bulk substance required a larger measurement volume 18 than that shown in FIG. 1.

In the embodiment of FIGS. 1 and 2 neutron moderators 14 and 16 surround the source capsules 10 and 12 in order to reduce neutron energies before the neutrons enter the measurement volume 18. A gamma-ray shield 20 then surrounds the moderators 14 and 16 to absorb gamma-rays produced by the source and the moderators and to provide a material with low neutron absorption through which neutrons can diffuse away from the source. The use of the moderators and gamma-ray shield is not essential to this invention, and their use in the embodiment shown in FIGS. 1 and 2 is not intended to limit the scope of the invention.

In the preferred embodiment shown in FIGS. 1 and 2, the neutron sources 10 and 12 are outside of the measurement volume 18, indicating that most neutrons will not enter the measurement volume 18. In order to control these unused escaping neutrons to avoid a radiation hazard and background in the measured energy spectrum, the preferred embodiment shown in FIGS. 1 and 2 includes the ^{6}LiH gamma-ray window 22, the boron-doped-polyethylene safety shields 30 and 32 with the source access rods 33 and 35, and the lithium in polyethylene 34. The existence of these neutron-absorbers in the preferred embodiment of FIGS. 1 and 2 is not intended to limit the scope of this invention.

In order to avoid a radiation hazard from escaping neutrons when the measurement volume 18 is empty, in the preferred embodiment the shield 32 on the detector side of the measurement volume 18 has been placed behind the sensor electronics 26 such that the gamma-ray detector 24 and the sensor electronics 26 are located with a chamber 37 in the neutron absorber. Even in this configuration some scattered radiation can leave the top and the bottom of the coal chute 40 passing through the measurement volume 18 when it is empty, because this region is not covered by shielding. A radiation alarm 42 and a movable plug 44 for the coal chute 40 when no coal is present provide the necessary protection to personnel when the coal chute is empty. If the movable plug 44 is constructed out of appropriate known materials, it can also be used for instrument calibration. The existence of the radiation alarm 42 and the movable plug 44 and the presence of a chamber 37 for the sensor electronics 26 in the preferred embodiment are not intended to limit the scope of this invention.

Some neutrons will diffuse through the gamma-ray shield 20 into the measurement volume 18. There hydrogen present in the coal being analyzed will moderate them further, and then they often will be captured by the various nuclei present in the analyzed coal. These neutron-capture reactions generally produce gamma ray, which travel through the measurement volume 18 and the neutron-absorbing gamma-ray window 22 and enter the gamma-ray detector 24, which in this embodiment forms a means for gamma-ray detection.

In the embodiment shown in FIGS. 1 and 2, this detector 24 is a large NaI(Tl) crystal, although other detectors such as CsI(Tl), CsI(Na), Ge or Ge(Li) could be used in instruments incorporating the features of this invention. For convenience, FIGS. 1 and 2 show a single detector 24, which is located near the side of the

measurement volume 18 opposite the side near the source capsules 10 and 12, but this invention is not intended to be limited to the use of a single gamma-ray detector nor to its location across the measurement volume from the neutron source. In fact the use of a plurality of detectors with possibly some along the other sides of the measurement volume 18 would be beneficial in improving the measurement uniformity.

For example, multiple detectors placed at different points along the perimeter of the measurement volume 18 would provide a composite solid angle and gamma-ray transmission which are more uniform throughout the measurement volume 18 than those obtained with a single detector. As a result, measurement uniformity is improved, and in addition the total allowable counting rate, and thus the speed of response, become higher, because each detector can tolerate the same counting rate as a single detector. Such a multiple-detector array is particularly justified when high mass flow rates or other properties of the bulk substance result in a large measurement volume 18, which a single detector cannot view with sufficient uniformity. The combination of multiple detectors with multiple sources and/or neutron reflectors can improve the measurement uniformity still further, and the detectors could also be usefully placed along more than one side of the measurement volume.

When the gamma rays interact in the gamma-ray detector 24, they produce electrical signals indicative of their energy. The sensor electronics 26 convert these electrical signals into digital information, which is transmitted over an interconnecting cable 28 to the display console 30. The display console 30 processes this information using the fact that neutron capture produces an energy spectrum which depends on the amounts of the various elements capturing the neutrons. The result of this processing is information concerning the relative concentrations of the various elements of interest in the measurement volume 18 and any other properties, such as density, which may be usefully obtained from the measured spectrum. The interface between the sensor electronics 26 and the display console 30 and the methods used therein also do not form a part of this invention.

What I claim as new is:

1. An improved apparatus for the on-line analysis of the composition of a bulk substance in a measurement volume, wherein said analysis includes the production and capture of neutrons and the detection of the resulting capture gamma rays, said apparatus comprising, in combination:

(a) means for containing the bulk substance to be analyzed, said means comprising a bulk substance receiving passageway substantially square in cross-section having first, second, third and fourth interconnected sides said means for containing the bulk substance being at least partly surrounded by a neutron-reflecting substance;

(b) neutron-producing means for providing neutrons which generate gamma rays by neutron-capture reactions with the nuclei in the bulk substance being analyzed, the neutron-producing means being operably associated with the means for containing the bulk substance; and

(c) means for gamma-ray detection operably associated with the neutron-producing means and the means for containing the bulk substance being analyzed, the means for gammaray detection producing electrical signals indicative of the gamma-ray energies to provide for the measurement of the energy spectrum of the capture gamma rays.

2. An apparatus as defined in claim 1 in which said neutron-producing means comprises a pair of neutron sources located externally of said passageway near the corners of said first side thereof whereby the neutron flux produced is relatively higher along the sides of said passageway disposed perpendicular to said first side thereof as compared with that produced by one source diposed exteriorly of said passageway at a location equidistant from said corners of said first side.

3. An apparatus as defined in claim 1 in which said means for gamma ray detection comprises a plurality of gamma ray detectors located along the side of said passageway disposed opposite from the first side thereof and along the sides disposed adjacent to said first side of said passageway.

4. An improved apparatus for the on-line analysis of the composition of a bulk substance flowing through a measurement volume, wherein said analysis includes the production and capture of neutrons and the detection of the resulting capture gamma rays, said apparatus comprising, in combination:

(a) means for containing the bulk substance to be analyzed, said means comprising an elongated passageway adapted to contain said bulk substance as it flows through said apparatus, said passageway being at least partly surrounded by a neutron-reflecting substance;

(b) neutron-producing means for providing neutrons which generate gamma rays by neutron-capture reactions with the nuclei in the bulk substance being analyzed, said neutron-producing means comprising at least one neutron source located externally of said passageway;

(c) means for gamma-ray detection operably associated with the neutron-producing means and the means for containing the bulk substance being analyzed, the means for gamma-ray detection producing electrical signals indicative of the gamma-ray energies to provide for the measurement of the energy spectrum of the capture gamma rays, said means comprising at least one gamma-ray detector disposed externally of said passegeway.

5. An apparatus as defined in claim 4 including a plurality of neutron sources located externally of said passageway.

6. An apparatus as defined in claim 4 including a plurality of gamma ray detectors located externally of said passageway.

7. An apparatus as defined in claim 4 in which said passageway is substantially rectangular in cross-section wit the corners thereof rounded to direct the flow of the bulk substance toward said region of maximum sensitivity.

8. An apparatus as defined in claim 4 in which said passageway is substantially square in cross-section with the corners thereof rounded to direct the flow of the bulk substance toward said region of maximum sensitivity.

* * * * *

Notice of Intent to Issue Reexamination Certificate	Control No. 90/005,237	Patent Under Reexamination 4682043 ET AL
	Examiner Constantine Hannaher	Art Unit 2878

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

1. ☒ Examination has been terminated in this reexamination proceeding, and a Certificate will be issued in view of
   (a) ☒ Patent owner's communication(s) filed: *18 November 1999 and 03 December 1999 an*.
   (b) ☐ Patent owner's late response filed: _____.
   (c) ☐ Patent owner's failure to file an appropriate response to the Office action mailed: _____.
   (d) ☐ Patent owner's failure to timely file an Appeal Brief (37 CFR 1.192).
   (e) ☐ *Other*:

   Status of Reexamination:

   (f) Change in the Specification: ☒ Yes, ☐ No
   (g) Change in the Drawing: ☐ Yes, ☒ No
   (h) Status of the Claim(s):
      (1) Patent claim(s) confirmed: *3,5,6 and 8*.
      (2) Patent claim(s) amended (including dependent): *1,2,4 and 7*.
      (3) Patent claim(s) cancelled: _____.
      (4) Newly presented claim(s) patentable: 9-17.
      (5) Newly presented cancelled claims _____.

2. ☒ Note the attached statement of reasons for patentability and/or confirmation. Any comments considered necessary by patent owner regarding reasons for patentability and/or confirmation must be submitted promptly to avoid processing delays. Such submission(s) should be labeled: "Comments On Statement of Reason for Patentability and/or Confirmation."
3. ☐ *Note attached* NOTICE OF REFERENCES CITED (PTO-892).
4. ☒ Note attached LIST OF REFERENCES CITED (PTO-1449).
5. ☐ The drawing correction request filed on _____ is: ☐ approved ☐ disapproved.
6. ☐ Acknowledgment is made of the priority claim under 35 U.S.C. § 119.
   a)☐ All b)☐ Some c)☐ None of the certified copies have
      ☐ been received.
      ☐ not been received.
      ☐ been filed in Application No. _____.
      ☐ been filed in reexamination Control No. _____.
      ☐ been received by the International Bureau in PCT Application No. _____.
7. ☐ *Note attached Examiner's Amendment*.
8. ☒ *Other: Note attached statement regarding Notification of Non-Compliance With 37 CFR 1.192(c) in Reexamination, Information Disclosure Statement(s), and Response to Submission(s).*

cc: Requester (if third party requester)

DETAILED ACTION

Reexamination

Notification of Non-Compliance With 37 CFR 1.192(c) in Reexamination

1. The Appeal Brief filed February 11, 2000 is defective for failure to comply with one or more provisions of 37 CFR 1.192(c). See MPEP § 1206. Because with this action the Examiner terminates the proceeding and prepares a Notice of Intent to Issue Reexamination Certificate with a favorable conclusion as to all claims, no further requirement on Patent Owner is made with respect to the brief. A TIME PERIOD of ONE MONTH would have been given to file a complete new brief.

2. The brief does not contain a concise explanation of the claimed invention referring to the specification by page and line number. 37 CFR 1.192(c)(5). The brief does not contain a concise statement of the issues presented for review because the stated issues do not correspond to separate grounds of rejection. 37 CFR 1.192(c)(6). There are seven issues corresponding to the separate grounds of rejection presented in the final rejection of August 13, 1999, should appellant have chosen all of them for the Board of Patent Appeals and Interferences to review. It is appellant's *argument* that the applied reference common to all of the rejections (the Gozani *et al.* document) can be removed. The statement required by 37 CFR 1.192(c)(7) has not been made with respect to any claims subject to a single applied ground of rejection. More specifically, appellant has not included a statement regarding whether claims 10 and 11 stand or fall together with claim 2, the only other claim in the rejection which applies to a group of two or more claims which includes claims 10 and 11. See paragraph 7 of the final rejection of August 13, 1999. Indeed, the statement that claims 10 and 11 do not stand or fall together with claim 9 is not relevant as no ground of rejection applies to a group of two or more claims that includes claims 9, 10, and 11. The argument states that "Claims 7 and 8 have been indicated to be allowable" even though section 3 of the brief correctly states the

status of these claims as having their patentability confirmed. The argument under 37 CFR 1.192(c)(8) presents no argument in support of the statement that claims 10 and 11 are believed to be separately patentable. As pointed out in the rule 37 CFR 1.192(c)(7): "Merely pointing out differences in what the claims cover is not an argument as to why the claims are separately patentable." With respect to 37 CFR 1.192(c)(9) the use of "sources" in claim 12, line 1 is original to the amendment filed July 21, 1999. The fee for filing an appeal brief is given by 37 CFR 1.17(c).

Information Disclosure Statement(s)

3. A paper styled "INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.97(e) and 1.98" bearing a group stamp of November 10, 1999 is noted. A paper styled "PETITION FOR CONSIDERATION OF INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.97(e)"[1] bearing a group stamp of December 3, 1999 is noted. The Examiner notes that 37 CFR 1.97 by its plain language[2] has no relevance in a reexamination proceeding. 37 CFR 1.555 is the relevant rule for reexaminations.

Response to Submission(s)

4. The specification of application 05/866,488 filed January 3, 1978 which led by continuation to the United States Patent No. 4,682,043 includes a description at column 7, lines 3-19 regarding the operation of gamma-ray shield **20** made of bismuth as a neutron reflector. The presence of this description is sufficiently different from the other specifications filed by applicant describing the invention that the specification retains the statement made in the other applications that gamma-ray shield **20** is dispensable. More specifically, there is a conflict between claiming a neutron-reflecting substance and describing the sole embodiment of such a neutron-reflecting substance (gamma-ray

[1] The double section marks appear in the original even though only one rule section is identified.

shield 20 by virtue of the selection of the material for its construction) as "not essential."[3] However, it is noted that column 9, lines 42-45 states that the methods used in the sensor electronics 26 and display console 30 do not form a part of the invention, either. This statement supports the intent to label subject matter as not essential to the invention when it was not recited in the claims at the end of the respective specification.

5. The response to the final rejection filed November 18, 1999 (and the appeal brief filed February 11, 2000) contends that the Examiner has "at least a partial misunderstanding of the physics of neutron interaction with materials." In view of the declaration of Raymond J. Proctor and exhibits attached thereto, which the Examiner has found very helpful, the source of that misunderstanding can be located. Exhibit F of the declaration under 37 CFR 1.131 submitted July 15, 1999 presented page 939 of *Modern College Physics* by James A. Richards, Jr. *et al.* because of its statement that "[a]ny material that has a low neutron absorption cross section can be used as a neutron reflector." See paragraph 9 of the declaration by Marshall to see the emphasis by quotation of this solitary sentence; the reliance thereon by the Examiner was to be expected. The paragraph of the declaration concluded that on the basis of this one characteristic (low neutron absorption material) that the gamma-ray shield 20 acted as a neutron reflector. As is apparent from the final rejection and advisory action, the sentence from Richards, Jr. is at best an inadequate statement[4] of what is needed for a neutron reflector in view of the many contradictions such an understanding leads to. The comments made by the Examiner regarding magnesium and aluminum based on the graphs found on pages 66-67 of Weinberg and Wigner attached as exhibit C to the declaration of

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[2] 37 CFR 1.97(a) states "In order for an applicant for a patent or for a reissue of a patent to have an information disclosure statement in compliance with § 1.98 considered by the Office during the pendency of the application, it must satisfy...." The reexamination is not an application and Patent Owner is not an applicant.

[3] Note that it is the "use of the... gamma-ray shield" that is "not essential to this invention", not the use of the gamma-ray *shielding property* of the shield.

Marshall filed September 27, 1999 are an example. When Duderstatdt and Hamilton (attached as Exhibit 2 to the declaration of Proctor) state at page 165 that "[s]uch material used to reduce neutron leakage are known as *reflectors*" and that "[a]ny material with a large scattering cross-section and low absorption cross section would make a suitable neutron reflector" the misunderstanding based on the reliance on the declaration of Marshall filed July 15, 1999 as specifically supported by Exhibit F attached thereto is clarified. Low neutron absorption cross section as stated in paragraph 9 of the declaration of Marshall filed July 15, 1999 is *not enough*. The neutron must be scattered sufficiently before the failure to absorb it makes the scattering material a reflector! Accordingly, the reliance and weight the Examiner afforded this explicit statement and conclusion, in compliance with the guidance of *Ex parte Ovshinksy*, led to any misunderstanding.

6. Note that column 7, lines 6-7 of the 4,682,043 patent states "Because bismuth has a low probability for neutron absorption *but does scatter neutrons...*" (emphasis supplied). In view of the declaration of Proctor and the excerpt from Duderstatdt and Hamilton, it is agreed that this is a fair description of what is necessary for a substance to be neutron reflecting. The declarations of Marshall and others and the exhibits attached thereto, it is accepted, provide sufficient evidence that inventor Marshall recognized that the material bismuth possessed these two, necessary properties to be a neutron reflecting substance as recited in the claims, and that this recognition was present prior to the effective date of the Gozani *et al.* reference.

7. The Examiner notes that the failure on the part of the requester to show that the Gozani *et al.* reference is a printed publication means that the request failed to meet the requirements of 35 U.S.C. 302 and 37 CFR 1.510(a) in addition to the failure to comply with 37 CFR 1.510(b)(4). See paragraphs 5 and 12 of the order granting request for reexamination.

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[4] The same inadequacy is seen at page 490 of Weinberg and Wigner.

8. The Examiner has a continuing obligation under 35 U.S.C. 305 and 37 CFR 1.550(a). See MPEP § 2261. A final rejection was prepared July 23, 1999 (see the last page thereof and the Form PTO-892 accompanying the final rejection) in reaction to the submissions of July 15, 1999. The mailing of the final rejection had to be postponed because of: (1) a "Supplemental Amendment" received July 28, 1999 that contained no amendment of the specification, claims, or drawings; and (2) a "Certificate of Service" received August 9, 1999 reflecting belated compliance with 37 CFR 1.550(e).

Conclusion

9. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Constantine Hannaher whose telephone number is (703) 308-4850. The examiner can normally be reached on Monday-Friday with flexible hours.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Seungsook (Robyn) Ham can be reached on (703) 308-4090. The fax phone numbers for the organization where this application or proceeding is assigned are (703) 308-7722 for regular communications and Not Established for After Final communications.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is (703) 308-0956.

ch
February 29, 2000

CONSTANTINE HANNAHER
PRIMARY EXAMINER

UNITED STATES DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

REEXAMINATION

REASONS FOR PATENTABILITY / CONFIRMATION

Reexamination Control No. 90/005,237 Attachment to Paper No. 26.

Art Unit 2878.

The declaration of Raymond J. Proctor filed on November 18, 1999 under 37 CFR 1.131 is sufficient to overcome the Gozani et al. reference.

CONSTANTINE HANNAHER
PRIMARY EXAMINER

(Examiner's Signature)

PTOL-476 (Rev. 03-98)

PTO/SB/08A (10-98)
Approved for use through 10/31/98. OMB 0651-0031
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449B/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT (use as many sheets as necessary)				Complete if Known	
				Reexam Control Number	90/005,237
				Filing Date	January 28, 1999
				First Named Inventor	J. Howard Marshall, III
				Group Art Unit	2878
				Examiner Name	Constantine Hannaher
Sheet	1	of	1	Attorney Docket Number	6851-RE01

OTHER PRIOR ART – NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
CH	A	SUPPLEMENTAL DECLARATION OF JOHN R. RHODES IN SUPPORT OF DEFENDANTS' MOTION FOR INVALIDITY OF U.S. PATENT NO. 4,689,043, filed October 13, 1998 in United States District Court, Southern District of California, Gamma-Metrics, Inc. v. Scantech Limited, et al., Case No. 97-CV-1767TW (CGA)	
CH	B	DECLARATION OF JOHN R. RHODES IN SUPPORT OF DEFENDANTS' MOTION FOR INVALIDITY OF U.S. PATENT NO.4,689,043, filed August 17, 1998 in United States District Court, Southern District of California, Gamma-Metrics, Inc. v. Scantech Limited, et al., Case No. 97-CV-1767TW (CGA)	

Examiner	CONSTANTINE HANNAHER	Date Considered	FEB 28 2000

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Unique citation designation number. [2]Applicant is to place a check mark here if English language Translation is attached.

PTO/SB/08A (10-98)
Approved for use through 10/31/99. OMB 0651-0031
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Substitute for form 1449B/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT (use as many sheets as necessary)				Complete if Known	
				Reexam Control Number	90/005,237
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				First Named Inventor	J. Howard Marshall, III
				Group Art Unit	2878
				Examiner Name	Constantine Hannaher
Sheet	1	of	1	Attorney Docket Number	6851-RE01

OTHER PRIOR ART – NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
CH	A	TRANSCRIPT OF THE DEPOSITION OF J. HOWARD MARSHALL, March 9, 1998, in Case No. 97-CV-1767 H (CGA), Gamma-Metrics, Inc. v. Scantech Limited, et al., in the United States District Court, Southern District of California.	
CH	B	FILE HISTORY OF U.S. APPLICATION SERIAL NO. 05/808,106 (abandoned) of J. Howard Marshall, filed June 20, 1977.	

Examiner	CONSTANTINE HANNAHER	Date Considered	FEB 28 2000

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Unique citation designation number. [2]Applicant is to place a check mark here if English language Translation is attached.

EXHIBIT C

US004682043B1

REEXAMINATION CERTIFICATE (4105th)

United States Patent [19] [11] B1 4,682,043

Marshall [45] Certificate Issued Jun. 27, 2000

[54] **OBTAINING UNIFORMITY OF RESPONSE IN ANALYTICAL MEASUREMENT IN A NEUTRON-CAPTURE-BASED ON-LINE BULK-SUBSTANCE ELEMENTAL-ANALYZER**

[75] Inventor: J. Howard Marshall, Pasadena, Calif.

[73] Assignee: Gamma-Metrics, San Diego, Calif.

Reexamination Request:
No. 90/005,237, Jan. 28, 1999

Reexamination Certificate for:

Patent No.:	4,682,043
Issued:	Jul. 21, 1987
Appl. No.:	06/061,833
Filed:	Jul. 30, 1979

Related U.S. Application Data

[63] Continuation of application No. 05/866,488, Jan. 3, 1978.

[51] Int. Cl.[7] G01N 23/222

[52] U.S. Cl. 250/358.1; 250/359.1; 250/390.04

[58] Field of Search 376/159; 250/359.1, 250/358.1, 390.04

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,053,338	9/1962	Tittle	209/3.1
3,582,647	6/1971	Piguet et al.	378/52
3,832,545	8/1974	Bartko .	
4,152,596	5/1979	Marshall, III .	
4,171,485	10/1979	Marshall .	
4,266,132	5/1981	Marshall, III .	

OTHER PUBLICATIONS

Stewart, R.F. et al., "Nuclear Meter for Monitoring the Sulfur Content of Coal Streams," *Advancing Energy Utilization Program—Bureau of Mines Technical Progress Report*, Jan. 1974, TPR 74, Int.–Bureau of Mines, Pittsburgh, PA 19127.

Rhodes, J.R., "Neutron–Gamma Techniques for On–Stream Analysis of Coal," American Chemical Society Symposium *"New Techniques in Coal Analysis,"* Aug. 28–Sep. 7,1977, Chicago, IL.

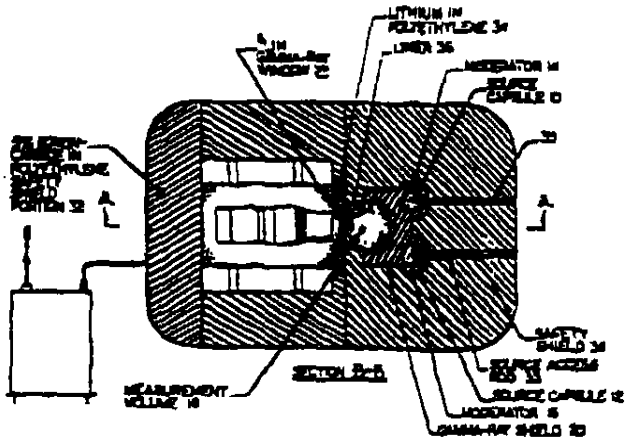
Reynolds, G.M. et al., "4. System Optimization for Prompt–Neutron Activation Analysis of Coal," *Nuclear Techniques in Geology, Transactions of the American Nuclear Society*, 1977 Winter Meeting, Nov. 27–Dec. 2, 1977, San Francisco, CA.

(List continued on next page.)

Primary Examiner—Constantine Hannaher

[57] **ABSTRACT**

In an apparatus for neutron-capture-based on-line elemental analysis of bulk substances, an improved uniformity of response of analytical measurement will make the apparatus less sensitive to segregations that occur in moving streams of the bulk substance. The apparatus incorporates a measurement volume having a substantially-square cross-section with rounded corners in the plane perpendicular to the direction of flow in order to exclude the bulk substance from regions of unusual sensitivities and to facilitate the orientation of the instrument for minimum sensitivity to segregations in the bulk substance. The apparatus also includes a plurality of neutron sources which expose the analyzed bulk substance momentarily contained within the apparatus to a flux of neutrons. The apparatus also provides for the use of neutron reflectors to increase the neutron flux near the sides of the measurement volume, further improving the uniformity of measurement. The analyzed substance captures some of the neutrons by (n,γ) reactions, producing prompt gamma rays which are detected to provide the composition measurement. The use of multiple sources causes the neutron flux to rise instead of fall near the sides of the volume containing the bulk substance compared to the center of the volume, and flux variations can be made to cancel solid-angle variations to produce a more-uniform response over a substantial portion of the measurement volume. Similarly the use of multiple gamma-ray detectors can also reduce these solid-angle variations, improving measurement uniformity, particularly if the measurement volume is large because of material-flow requirements.



OTHER PUBLICATIONS

Mihai Borsaru and Ralph J. Holmes, "Determination of Aluminum in Bulk Ore Samples by Neutron Activation Analysis." *Analytical Chemistry*, vol. 48, No. 12, pp. 1699–1701. Oct. 1976.

J. R. Rhodes, P. F. Berry, and R. D. Sieberg, "Nuclear Techniques in On-Stream Analysis of Ores and Coal." (Report), ORO-2980-18, for Division of Isotopes Development, United States Atomic Energy Commission, pp. 1–88. Sep. 1968.

T. Gozani et al., "Coal Stream Composition Analysis for Porcess [sic] Control Using Prompt Neutron Activation Analysis," Proceedings of the 1977 Symposium on Instrumentation and Process Control for Fossil Demonstration Plants, Jul. 13–15, 1977, Chicago, Illinois, published as Argonne National Laboratory, Illinois Publication No. ANL-78-7, 1977, pp. 162–193.

Anonymous, "Field Analysis Technique for Plastic Concrete," *California-252 Progress*, No. 17 (May 1974) pp. 17–20.

Anonymous, "Dartmouth College," *California-252 Progress*, No. 11 (Apr. 1972) pp. 42–43.

REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

ONLY THOSE PARAGRAPHS OF THE SPECIFICATION AFFECTED BY AMENDMENT ARE PRINTED HEREIN.

Column 2, lines 11–29:

One technique often used in industrial environments for elemental analysis involves X-ray [fluorescence] *fluorescence*. This technique relies on the fact that each atom emits X-rays with distinct and well-known energies when external radiations disturb its orbital electrons. Unfortunately, sulfur, which is an interesting element from the standpoints of air pollution and catalyst poisoning, emits mostly 2-keV X-rays, which can only traverse about 0.1 mm of a typical fuel. Iron, which is one of the elements generating the highest-energy X-rays in coal, produces mostly a 6-keV X-ray, which also cannot escape from any appreciable amount of coal or other nongaseous fuel. Thus, *the use of* X-ray fluorescence for other than gaseous materials requires either the preparation of very clean surfaces truly representative of the bulk material or the vaporization of a sample in an atmosphere which does not confuse *the measurement. In* either case, a difficult sample-preparation problem compounds the errors associated with X-ray fluorescence itself.

Column 2, lines 48–59:

Nonetheless, nuclear techniques in general remain attractive because they often can be automated and in principal do not require actual manipulation of the bulk material itself. The problems with X-ray fluorescence and absorption arise partly because the [Associated] *associated* radiations are not sufficiently penetrating. However, because the energenic gamma rays produced by the capture of thermal neutrons will penetrate over 100 mm of most fuels, an analysis *technique based on them can provide an accurate,* continuous, on-line measurement of the elemental composition of bulk substances without sampling.

Column 3, lines 7–19:

The above emphasis on thermal neutrons reflects the fact that for most elements the cross section for neutron capture is [approximately] *approximately* proportional to the reciprocal of the square root of the neutron energy. Thus, almost all neutron capture occurs at the lowest neutron energies, which happen when the neutrons are in thermal equilibrium with the nuclei of the [surrouding] *surrounding* medium. As a result, the thermal-neutron-capture cross sections characterize the expected prompt-gamma-ray spectra. These gamma-ray spectra are particularly amenable to simple theoretical interpretation using well-known thermal-neutron-capture cross sections, making automatic operation a feasible concept.

Column 4, lines 30–43:

In these prior-art instruments all of these [effective] *effectively* combined to make the sensitivity at the side of the chute on the opposite side of the source as the detector considerably less than the sensitivity in the volume between the source and the detector. However, if the neutron source is located outside of the measurement volume as described in another application for a U.S. patent, Ser. No. 808,106, filed on June 21, 1977 by the inventor herein, then the measurement can be confined to the volume between the source and the detector, resulting in improved uniformity. However, unless the techniques of this invention are also employed, the uniformity of sensitivity may still be insufficient to measure accurately segregated, inhomogeneous substances.

Column 5, lines 18–32:

The flux at the sides of the measurement volume can be increased by still other means. For example, a smaller measurement volume has a smaller sensitivity variation than one with a larger cross-sectional area. Eliminating low-sensitivity regions, such as the corners of a coal chute, from the measurement volume also improves uniformity. In addition surrounding the measurement volume with a material which scatters neutrons without absorbing many of them will reflect neutrons back into the measurement volume, thus increasing the flux at the sides and improving the efficiency of neutron use. Typical neutron reflectors contain [berrylium, carobon] *beryllium, carbon,* oxygen or bismuth, with the latter also having the advantage of being a good absorber of background gamma rays.

Column 5, lines 33–54:

Making the sensitivity uniform along the source-detector direction is more difficult, because the neutron flux must be allowed to decrease substantially near the detector, although a neutron-absorbing gamma-ray window can reduce the required amount of this flux decrease as described in U.S. [patent application, Ser. No. 808,103] *Patent No. 4,266,132,* filed on June [21] *20,* 1977 by the inventor herein. Fortunately in this direction solid-angle and gamma-ray-transmission effects tend to compensate for the flux variations reducing the sensitivity non-uniformities, although perfect cancellation of these effects can only be fortuitous. In addition as one of the techniques of this invention, the orientation of the source-detector line can be chosen to lie along the direction of minimum concentration variation, reducing the inaccuracies resulting from sensitivity changes within the measurement volume. A symmetrical configuration for the measurement volume will then facilitate the adjustment of the instrument orientation in order to obtain optimum accuracies for nonuniform *materials* flowing through the instrument.

Column 6, lines 25–31:

For a better [understanding] *understanding* of the present invention, *together with other and further objects thereof,* reference is made to the following description taken in connection with the accompanying drawings in which preferred embodiments of the invention are illustrated, the *scope of the invention being pointed out and contained* in the appended claims.

Column 7, lines 3–19:

In the embodiment of FIGS. 1 and 2, the means for *containing the analyzed substance consists of the liner* 36, which is partly surrounded by the bismuth gamma-ray shield 20. Because bismuth has a low probability for neutron absorption but does scatter neutrons, those portions of the gamma-ray shield 20 near the liner 36 reflect some of the escaping neutrons back into the measurement volume 18. As a result the gamma-ray shield 20 also acts as a neutron reflector, which increases the neutron flux along the sides of the measurement volume 18 in order to improve measurement uniformity and to use the neutrons more efficiently. Other elements besides bismuth are well known in the art to

function as good neutron reflectors, including [beryllium] *beryllium*, oxygen, deuterium and carbon, and the use of any neutron-reflecting element for these purposes forms a part of this invention.

Column 7, lines 43–62:

The instrument also includes neutron-producing means for providing neutrons. In the embodiment shown in FIG. 1, said neutron-producing means consists of two source capsules 10 and 12 containing the isotope, Californium-252. In other embodiments of this invention the source could contain different isotopes, such as plutonium mixed with beryllium, or could contain a neutron generator, such as that using the $^3H(d,n)^4He$ reaction. Additionally the instrument could contain several other neutron sources, which could all be the same type or could be various combinations of source types. The [neutronproducing] *neutron producing* means can be located either outside of the volume containing the bulk substance to be analyzed, as shown in FIGS. 1 and 2, or within this volume. If several neutron sources are present, some of these sources may be within this measurement volume, while other sources are external thereto. The principles forming a part of this invention apply to all of these variations of the embodiment shown in FIGS. 1 and 2.

Column 9, lines 29–45:

When the gamma rays interact in the gamma-ray detector 24, they produce electrical signals indicative of their energy. The sensor electronics 26 convert these electrical signals into digital information, which is transmitted over an interconnecting cable 28 to the display console 30. The display console 30 processes this information using the fact that neutron capture produces an energy [spectrum] *spectrum* which depends on the amounts of the various elements capturing the neutrons. The result of this processing is information concerning the relative concentrations of the various elements of interest in the measurement volume 18 and any other properties, such as density, which may be usefully obtained from the measured spectrum. The interface between the sensor electronics 26 and the display console 30 and the methods used therein also do not form a part of this invention.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claims 1, 2, 4 and 7 are determined to be patentable as amended.

Claims 3, 5, 6 and 8, dependent on an amended claim, are determined to be patentable.

New claims 9–17 are added and determined to be patentable.

1. An [improved] apparatus for the on-line analysis of the composition of a bulk substance in a measurement volume, wherein said analysis includes the production and capture of neutrons and the detection of the resulting capture gamma rays, said apparatus comprising, in combination:

(a) means for containing the bulk substance to be analyzed, said means comprising a bulk substance receiving passageway substantially square in cross-section having first, second, third and fourth interconnected sides said means for containing the bulk substance being at least partly surrounded by a neutron-reflecting substance;

(b) neutron-producing means for providing neutrons which generate gamma rays by neutron-capture reactions with the nuclei in the bulk substance being analyzed, the neutron-producing means being operably associated with the means for containing the bulk substance; and

(c) means for gamma-ray detection operably associated with the neutron-producing means and the means for containing the bulk substance being analyzed, the means for [gammaray] *gamma ray detection producing* electrical signals indicative of the gamma-ray energies to provide for the measurement of the energy spectrum of the capture gamma rays.

2. An apparatus as defined in claim 1 in which said neutron-producing means comprises a pair of neutron sources located externally of said passageway near the corners of said first side thereof whereby the neutron flux produced is relatively higher along the sides of said passageway disposed perpendicular to said first side thereof as compared with that produced by one source [diposed] *disposed* exteriorly of said passageway at a location equidistant from said corners of said first side.

4. An [improved] apparatus for the on-line analysis of the composition of a bulk substance flowing through a measurement volume, wherein said analysis includes the production and capture of neutrons and the detection of the resulting capture gamma rays, said apparatus comprising, in combination:

(a) means for containing the bulk substance to be analyzed, said means comprising an elongated passageway adapted to contain said bulk substance as it flows through said apparatus, said passageway being at least partly surrounded by a neutron-reflecting substance;

(b) neutron-producing means for providing neutrons which generate gamma rays by neutron-capture reactions with the nuclei in the bulk substance being analyzed, said neutron-producing means comprising at least one neutron source located externally of said passageway;

(c) means for gamma-ray detection operably associated with the neutron-producing means and the means for containing the bulk substance being analyzed, the means for gamma-ray detection producing electrical signals indicative of the gamma-ray energies to provide for the measurement of the energy spectrum of the capture gamma rays, said means comprising at least one gamma-ray detector disposed externally of said passageway.

7. An apparatus as defined in claim 4 in which said passageway is substantially rectangular in cross-section [wit] *with* the corners thereof rounded to direct the flow of the bulk substance toward said region of maximum sensitivity.

9. An apparatus for on-line elemental analysis of a bulk substance comprising a plurality of elements flowing through a measurement volume within the apparatus, the apparatus comprising:

an elongated passageway extending through the apparatus, the passageway adapted to enclose the measurement volume and direct the bulk substance flowing through the measurement volume;

a neutron-reflecting substance at least partially surrounding the passageway adjacent the measurement volume;

at least one neutron source disposed external to a source side of the passageway for providing thermal neutrons which interact with nuclei of the elements in the bulk substance within the measurement volume to generate prompt gamma rays having a plurality of energies; and

at least one gamma ray detector disposed external to a detector side of the passageway opposite the source side, the gamma ray detector producing electrical signals indicative of the plurality of energies of the prompt gamma rays to provide for measurement of an energy spectrum of the prompt gamma rays corresponding to the plurality of elements within the bulk material.

10. The apparatus of claim 9, wherein the measurement volume has a four-cornered cross-section and the at least one neutron source comprises two neutron source capsules disposed at locations corresponding to two corners of the measurement volume on the source side of the passageway, each source capsule containing a neutron-producing isotope.

11. The apparatus of claim 10, wherein the neutron-producing isotope is californium-252.

12. The apparatus of claim 9, wherein the at least one neutron sources comprises a neutron generator.

13. The apparatus of claim 9, wherein the at least one detector comprises a multi-detector array.

14. The apparatus of claim 13, where the multi-decector array comprises at least two sodium iodide crystals.

15. The apparatus of claim 9, wherein the neutron-reflecting substance is selected from the group consisting of bismuth, beryllium, oxygen, deuterium and carbon.

16. The apparatus of claim 9, wherein the passageway is a chute having a substantially square cross-section.

17. The apparatus of claim 9, wherein the passageway is a chute having a substantially rectangular cross-section.

* * * * *

US005732115A

United States Patent [19]

Atwell et al.

[11] Patent Number: 5,732,115

[45] Date of Patent: Mar. 24, 1998

[54] **ENHANCEMENT OF MEASUREMENT ACCURACY IN BULK MATERIAL ANALYZER**

[75] Inventors: **Thomas L. Atwell**, La Jolla; **Raymond J. Proctor**; **Chaur-Ming Shyu**, both of *San Diego*; **Chris A. Isaacson**, Poway; **Andrew H. Smith**, Escndido, all of Calif.

[73] Assignee: **Gamma-Metrics**, San Diego, Calif.

[21] Appl. No.: **492,575**

[22] Filed: **Jun. 20, 1995**

Related U.S. Application Data

[63] Continuation of Ser. No. 89,274, Jul. 9, 1993, abandoned.

[51] **Int. Cl.**[6] **G21G 1/06**

[52] **U.S. Cl.** **376/159**

[58] **Field of Search** 376/159, 157, 376/153–155; 250/393.01–390.07, 390.11, 391, 392, 336.1, 357.1, 370.09, 491.1; 209/589; 266/168

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,053,388	9/1962	Title	376/159
3,124,679	3/1964	Titman et al.	376/159
3,146,349	8/1964	Jordan	376/159
3,278,747	10/1966	Ohmart	250/83.3

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

747312	5/1970	Belgium	376/257
2066233	1/1992	Canada .	

OTHER PUBLICATIONS

Strahlenther. Onkol., vol. 165, (1989), pp. 87–90, Less et al.

Nuclear Instruments and Methods, vol. 75, (1969), pp. 13–33, Krinninger et al.

LA-6788-PR, (Jun. 1977), Sapir, pp. 1–54.

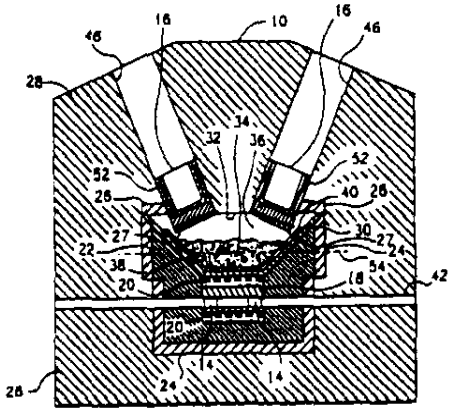
Primary Examiner—Harvey E. Behrend

Attorney, Agent, or Firm—Edward W. Callan

[57] **ABSTRACT**

In a bulk material analyzer in which bulk material is received in an activation region between a pair of neutron sources laterally disposed on one side of the activation region for emitting neutrons for bombarding the bulk material within the activation region to cause gamma-rays to be emitted from the bombarded bulk material and a pair of gamma-ray detectors laterally disposed on another side of the activation region for detecting gamma-rays emitted from the bulk material, a primary neutron moderator is disposed about the neutron sources for reducing the velocity of the emitted neutrons; and a secondary neutron moderator is disposed about the primary neutron moderator for further reducing the velocity of the neutrons and is further disposed adjacent the lateral edges of the activation region for channeling and reflecting the neutrons into the activation region. The two gamma-ray detectors are disposed toward opposite lateral edges of the activation region, with each detector being skewed so that a portion of each detector that is closer to the edge of the activation region toward which the detector is disposed than to the lateral center of the activation region is disposed closer to a plane passing laterally through the center of the activation region than is another portion of each detector that is closer to the lateral center of the activation region than to the edge of the activation region toward which the detector is disposed. Spatial compensators are disposed adjacent the same side of the activation region as the detectors for reflecting neutrons toward the activation region at a greater density toward opposite lateral edges of the activation region than toward the center of the activation region. Bladders containing a liquid primary neutron moderating material that expands and contracts with temperature variations, such as heavy water, are tightly packed within a compartment for maintaining a substantial quantity of the liquid material between the neutron sources and the activation region notwithstanding thermal contraction of the liquid material; and a resilient compressible foam is disposed about the bladders for enabling the tight packing of the liquid material to be maintained notwithstanding expansion and contraction of the liquid material.

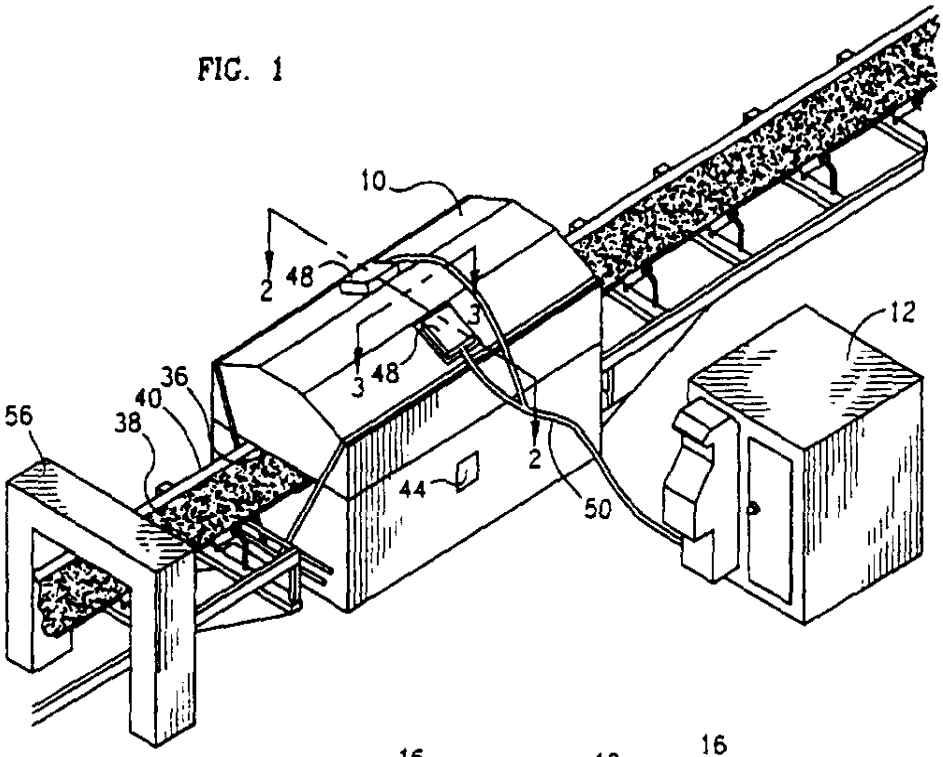
9 Claims, 2 Drawing Sheets



U.S. PATENT DOCUMENTS

3,631,247	12/1971	Barton, Jr.	250/83.3 R
3,794,843	2/1974	Chen	250/392
3,881,110	4/1975	Hounsfield et al.	250/360
3,889,112	6/1975	Holmes et al.	376/159
4,028,267	6/1977	Christell et al.	250/359
4,041,315	8/1977	Hounsfield	250/360
4,314,155	2/1982	Sowerby	250/390
4,582,992	4/1986	Atwell et al.	376/159
4,672,648	6/1987	Mattson et al.	378/4
4,682,043	7/1987	Marshall	376/159
4,809,172	2/1989	Hopkinson et al.	378/901
5,076,502	12/1991	Kitaguchi et al.	209/589
5,098,640	3/1992	Gozani et al.	376/159
5,124,554	6/1992	Fowler et al.	376/159
5,144,140	9/1992	Allyson et al.	376/159
5,153,439	10/1992	Gozani et al.	376/159
5,162,095	11/1992	Alegre et al.	376/159
5,162,096	11/1992	Gozani	376/159

FIG. 1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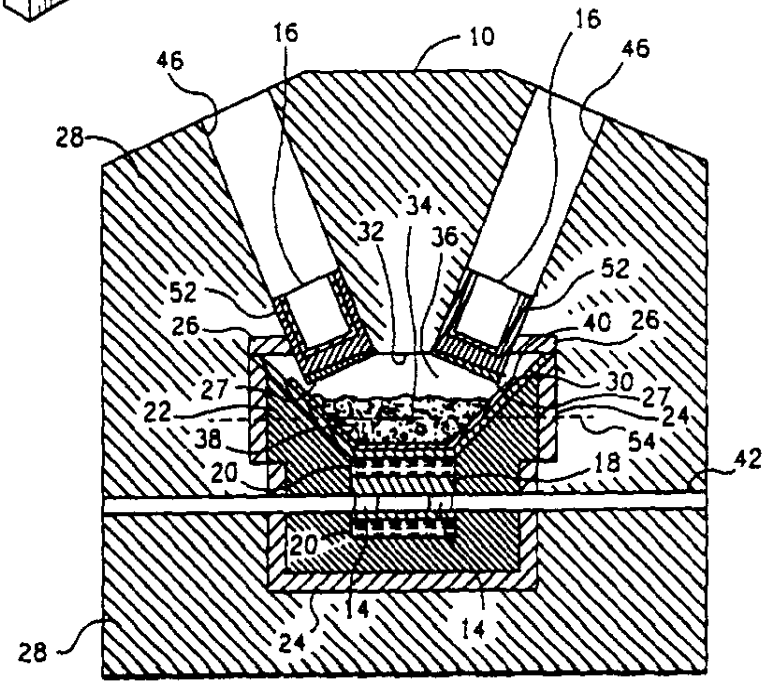
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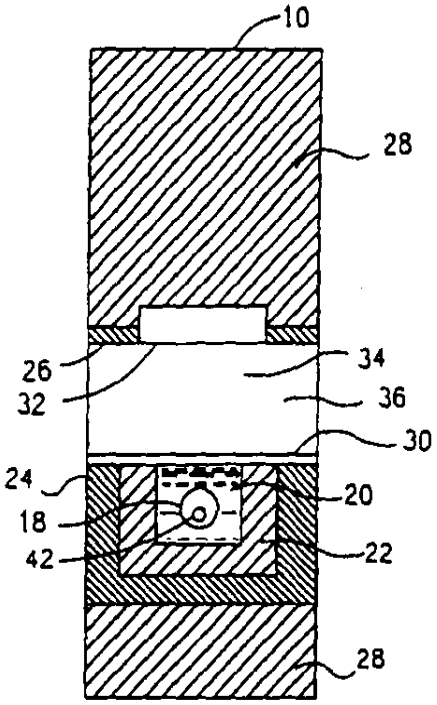
FIG. 2

FIG. 3



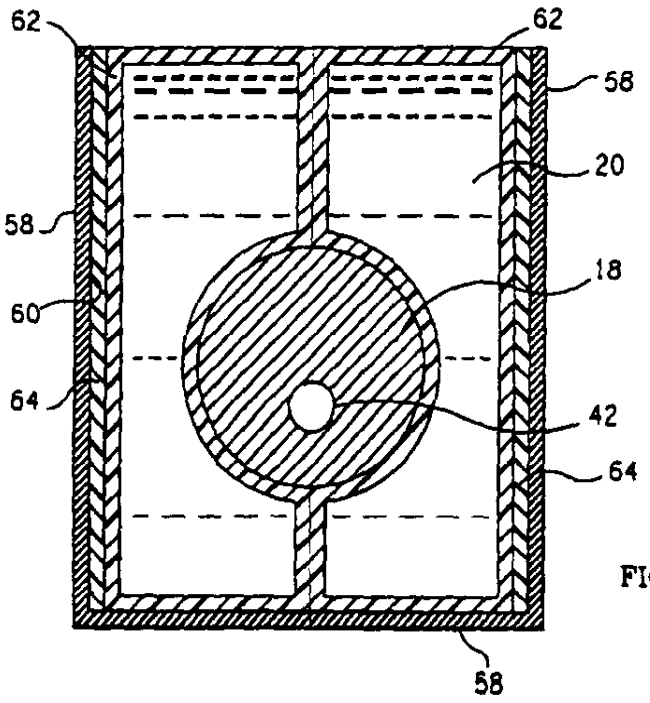


FIG. 4

ENHANCEMENT OF MEASUREMENT ACCURACY IN BULK MATERIAL ANALYZER

This is a continuation of application Ser. No. 08/089,274 filed on Jul. 9, 1993, now abandoned.

BACKGROUND OF THE INVENTION

The present invention generally pertains to bulk material analyzers and is particularly directed to improving the spatial uniformity of gamma-ray detection in bulk material analyzers of the type in which the bulk material is bombarded by neutrons within an activation region.

Bulk material analyzers are used to measure the elemental content of bulk materials. One type of bulk material analyzer includes one or more neutron sources and one or more gamma-ray detectors. When the bulk material within an activation region between at least one neutron source disposed on one side of the activation region and at least one gamma-ray detector disposed on another side of the activation region opposite from said one side is bombarded by neutrons, secondary emissions of gamma-rays are produced from the bulk material and detected by the gamma-ray detector(s). The gamma-ray detector(s) produce signals which are processed to provide an indication of the elemental content of the bulk material. Different characteristic gamma-ray energy spectra are produced from different elements in the bulk material. By processing detected signals that are indicative of the gamma-ray spectrum, a measurement is provided of the quantitative elemental content of the bulk material. This measurement process is known in the art as prompt gamma-ray neutron activation analysis (PGNAA).

In prior art bulk material analyzers, the response of the gamma-ray detectors to gamma-ray emission from different areas of a cross-sectional profile of the activation region is extremely non-uniform, with said response being less for a given quantity of a given bulk material located near the edges of the activation region than for the same given quantity of the same given bulk material located at the center of the activation region. Therefore, the measured quantity of a given element within a non-homogeneous bulk material is dependent upon the particular location of such given element in a cross-sectional profile of the activation region.

SUMMARY OF THE INVENTION

The present invention provides a bulk material analyzer in which measurement accuracy is enhanced by improving the spatial uniformity of response by the gamma-ray detector(s) to gamma-ray emission from different areas of a cross-sectional profile of the activation region.

The present invention provides a bulk material analyzer in which bulk material is received in an activation region between at least one neutron source and at least one gamma-ray detector, comprising a conveyor belt having upwardly and outwardly extended sides, a container having surfaces defining said activation region, wherein the container surfaces further define a passageway for enabling bulk material to be transported through said activation region on the conveyor belt; at least one neutron source disposed within the container beneath the passageway on one side of the activation region for emitting neutrons for bombarding bulk material being transported on the conveyor belt through said activation region to cause gamma-rays to be emitted from said bombarded bulk material; at least one gamma-ray detector disposed within the container above the passageway on another side of the activation region opposite from said one side for detecting gamma-rays emitted from said bombarded bulk material; a primary neutron moderator disposed about said neutron source(s) for reducing the velocity of said emitted neutrons; and a secondary neutron moderator disposed about the primary neutron moderator for further reducing the velocity of said neutrons and further disposed adjacent said one side of the activation region at which the neutron source(s) are disposed, for channeling and reflecting said neutrons into said activation region, wherein a lower portion of the passageway-defining surfaces define a trough having upwardly and outwardly extended sides adjacent said activation region for cradling the conveyor belt; and wherein the secondary neutron moderator is further disposed adjacent the sides of the trough for channeling and reflecting said neutrons into said activation region.

The spatial uniformity of response of the detectors to gamma-ray emission from different areas of various cross-sectional profiles of the activation region is further improved by providing at least two neutron sources and/or at least two gamma-ray detectors. Preferably, there are two neutron sources, which are separated laterally from the center of said one side of the activation region, and two said gamma-ray detectors, which are disposed toward opposite ends of said other opposite side of the activation region, with each detector being skewed so that a portion of each detector that is closer to the end of said other opposite side toward which said detector is disposed than to the center of said other opposite side is disposed closer said one side of said activation region than is another portion of each detector that is closer to said center of said other opposite side than to said end of said other opposite side toward which said detector is disposed.

The spatial uniformity of response of the detectors to gamma-ray emission from different areas of various cross-sectional profiles of the activation region is still further improved by providing spatial compensating means disposed adjacent said other opposite side of the activation region for reflecting neutrons toward said activation region at a greater density toward opposite ends of said other opposite side than toward the center of said other opposite side; and including neutron moderating material respectively disposed over the detectors for reflecting neutrons toward said activation region in accordance with proximity to the center of said other opposite side of said activation region, with said reflection increasing in a direction away from the center of said other opposite side.

The spatial uniformity of response of the detectors to gamma-ray emission from different areas of a cross-sectional profile of the activation region is also improved by providing a tertiary neutron moderator disposed about the secondary neutron moderator for further reducing the velocity of said neutrons and for reflecting said neutrons into the secondary neutron moderator, and for isolating the secondary neutron moderator from the radiation shielding material. The tertiary neutron moderator is also disposed adjacent radiation shielding material within the container for isolating the secondary neutron moderator from the radiation shielding material.

Additional features of the present invention are described in relation to the detailed description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a perspective view illustrating a preferred embodiment the bulk material analyzer of the present inven-

tion with a conveyor belt transporting bulk material through the material analyzer assembly.

FIG. 2 is a sectional elevation view taken along lines 2—2 showing the construction of the bulk material analyzer adjacent the activation region.

FIG. 3 is a sectional elevation view taken along lines 3—3 further showing the construction of the bulk material analyzer adjacent the activation region.

FIG. 4 is an enlarged sectional elevation view taken in the same plane as FIG. 3 showing the portion of the bulk material analyzer that includes the primary neutron moderator.

DETAILED DESCRIPTION

Referring to FIGS. 1, 2 and 3, a preferred embodiment of a bulk material analyzer according to the present invention includes a container 10, a data processor (not shown) within a separate housing 12, a pair of neutron sources 14, a pair of gamma-ray detectors 16, a gamma-ray shield 18, a primary neutron moderator 20, a secondary neutron moderator 22, a tertiary neutron moderator 24, spatial compensators 26, 27 and radiation shielding material 28.

The container 10 has interior surfaces 30, 32 defining an activation region 34 between the neutron sources 14 and the gamma-ray detectors 16. A lower portion 30 of the passageway-defining surfaces 30, 32 defines a trough 30 having upwardly extended sides adjacent the activation region 34. The container surfaces 30, 32 further define a passageway 36 for enabling bulk material 38 to be transported through the activation region 34 on a conveyor belt 40.

The neutron sources 14 are disposed within the container 10 beneath the passageway 36 on one side of the activation region 34 for emitting neutrons for bombarding bulk material 38 being transported on a conveyor belt 40 through the activation region 34 to cause gamma-rays to be emitted from the bombarded bulk material 38. The neutron sources 14 are inserted through a tubular neutron source cavity 42 in the container 10 into selected positions beneath the passageway 36, and are separated laterally on opposite sides of the longitudinal axis of the passageway 36. The neutron sources 16 are inserted into the neutron source cavity 42 through a door 44 in the container 10. Lateral separation of the neutron sources 14 suppresses the response of the gamma-ray detectors 16 to a given quantity of a given bulk material 38 located at the center of the activation region 34.

The gamma-ray detectors 16 are disposed within the container 10 above the passageway 36 on another side of the activation region 34 opposite from the one side for detecting gamma-rays emitted from the bombarded bulk material 38. The gamma-ray detectors 16 are inserted through detector cavities 46 in the container 10 into selected positions above the passageway 36. The gamma-ray detectors 16 are inserted into the detector cavities 46 through hatches 48 in the container 10. Signals produced by the gamma-ray detectors 16 are provided by electrical cables 50 to the data processor within the housing 12.

The gamma-ray shield 18 is a heavy metal, which is disposed within the container 10 about the neutron sources 14 for shielding the detectors 16 from gamma rays emitted from the neutron sources 14 so as to minimize detection by the detectors 16 of gamma rays from other than the bulk material 38 in the activation region 34.

A neutron shield 52 is disposed about each gamma-ray detector 16 for the detectors 16 from stray neutrons so as to prevent detection by the detectors 16 of gamma rays secondarily emitted from within the gamma-ray detectors 16 as result of bombardment by neutrons of materials within the gamma-ray detectors 16.

The primary neutron moderator 20 is disposed about the neutron sources 14 for reducing the velocity of the neutrons emitted from the neutron sources 14. Reduction of neutron velocity enhances capture of the neutrons by the bulk material 38 so as to produce gamma-ray emission from the bulk material 38.

The secondary neutron moderator 22 is disposed about the primary neutron moderator 20 for further reducing the velocity of neutrons emitted from the neutron sources 14. The secondary moderator 22 is further disposed adjacent the sides of the trough 30 for channeling and reflecting the slower neutrons into the activation region 34 to thereby enhance the response of the gamma-ray detectors 16 for a given quantity of a given bulk material 38 located near the edges of the activation region 34.

The portion of the trough 30 adjacent the primary moderator 20 and the secondary neutron moderator 22 is made of a neutron transmissive material that enables the neutrons to diffuse into the activation region 34 from the primary moderator 20 and the secondary neutron moderator 22.

The tertiary neutron moderator 24 is disposed about the secondary neutron moderator 22 and adjacent the radiation shielding material 28 for further reducing the velocity of the neutrons, for reflecting the neutrons into the secondary neutron moderator 22, and for isolating the secondary neutron moderator 22 from the radiation shielding material 28, which would absorb the neutrons, rather than reflect the neutrons.

The two gamma-ray detectors 16 are disposed toward opposite ends of the other opposite side of the activation region 34, with each detector 16 being skewed so that a portion of each detector 16 that is closer to the end of the other opposite side toward which the detector 16 is disposed than to the center of the other opposite side is disposed closer to a plane 54 parallel to the other opposite side and passing through the center of the activation region 34 than is another portion of each detector 16 that is closer to the center of the other opposite side than to the end of the other opposite side toward which said detector 16 is disposed. Such skewing of the gamma-ray detectors 16 further enhances the response of the gamma-ray detectors 16 for a given quantity of a given bulk material 38 located near the edges of the activation region 34, and also suppresses the response of the gamma-ray detectors 16 to said given quantity of said given bulk material 38 located at the center of the activation region 34.

Still additional enhancement of the response of the gamma-ray detectors 16 for a given quantity of a given bulk material 38 located near the edges of the activation region 34, and suppression of the response of the gamma-ray detectors 16 to said given quantity of said given bulk material 38 located at the center of the activation region 34 is provided by the spatial compensators 26, which are disposed near the edges of the activation region 34 and the spatial compensators 27, which are disposed over the ends of the gamma-ray detectors 16 that are adjacent the activation region 34.

In one embodiment, in which the spatial compensators 26, 27 are primarily neutron moderating material, the spatial compensators 26, 27 are disposed adjacent said other opposite side of the activation region 34 for reflecting neutrons toward the activation region 34 at a greater density toward

opposite ends of the other opposite side than toward the center of the other opposite side. The spatial compensators 27 are wedges of neutron moderating material having a thickness that increases in a direction away from the center of the other opposite side of the activation region 34, as shown in FIG. 2.

In an alternative embodiment, the spatial compensators 27 are respectively disposed over the gamma-ray detectors 16 for gradually attenuating gamma-ray detection by the detectors 16 in accordance with proximity to the center of the other opposite side of the activation region 34, with said attenuation increasing in a direction toward the center of said other opposite side. The spatial compensators 27 are wedges of gamma-ray absorbing material having a thickness that decreases in a direction away from the center of the other opposite side of the activation region 34, which is the opposite from that which is shown in FIG. 2 for the neutron-reflecting material wedges.

The number of neutron sources 14 and the number of gamma-ray detectors 16 is dependent upon the width of the activation region 34, and may be increased beyond two neutron sources 14 and two gamma-ray detectors 16 as required to optimize the spatial uniformity of response by the gamma-ray detectors 16. The equivalence of two or more neutron sources 14 and/or two or more gamma-ray detectors 16 can be provided by rapid reciprocal movement of one neutron source 14 and/or one gamma-ray detector 16, respectively, between two or more locations.

The spatial uniformity of response of the gamma-ray detectors 16 to gamma-ray emission from different areas of a cross-sectional profile of the activation region 34 is also dependent upon the cross-sectional profile of the bulk material 38 on the conveyor belt 40 within the activation region 34, as defined by the depth of the bulk material 38 at different lateral positions of a cross-section normal to the direction of movement of the conveyor belt 40, as shown in FIG. 2. Accordingly, the disposition of the neutron sources 14 within the neutron source cavity 42 and the disposition of the gamma-ray detectors 16 within detector cavities 46 may be adjusted in accordance with the cross-sectional profile of the bulk material 38 on the belt 40 within the activation region 34.

In one embodiment, a profile of the bulk material 38 within the activation region 34 is determined continuously as the bulk material 38 is being transported by the conveyor belt 40 through the activation region 34; and the disposition of the neutron sources 14 and/or the disposition of the gamma-ray detectors 16 are dynamically adjusted in accordance with said determined profile. Said profile is determined by the data processor in the housing 12 in response to signals provided by a sensing apparatus 56 disposed in advance of the activation region 34 in the direction of movement of the conveyor belt 40; and the data processor controls positioning apparatus (not shown) within the container 12 to dynamically adjust the disposition of the neutron sources 14 and/or the disposition of the gamma-ray detectors 16 in accordance with said determined profile so that when the bulk material 38 having the profile determined at the position of the sensing apparatus 56 reaches the activation region 34, the neutron sources 14 and/or the gamma-ray detectors 16 are so disposed as to optimize the spatial uniformity of the response of the gamma-ray detectors 16. The sensing apparatus 56 may include any commonly known distance and direction sensing means such as radar, sonar, or laser beam range finding equipment.

In one preferred embodiment, the primary neutron moderator 20 includes a liquid material, such as heavy water D_2O, that expands and contracts with variations in temperature. In this embodiment, the container 10 includes a set of side and bottom walls 58 of secondary neutron moderating material defining a compartment 60 for containing the liquid primary moderator material 20, as shown in FIG. 4. A pair of bladders 62 containing the liquid material 20 are disposed by being tightly packed within the compartment 60 for maintaining a substantial quantity of the liquid primary moderator material 20 between the neutron sources 14 and the activation region 34 notwithstanding thermal contraction of the liquid primary moderator material 20. The bladders 62 are contoured to fit tightly around the gamma-ray shield 18. A resilient compressible material 64, such as a closed cell foam is disposed about the bladders 62 for enabling such tight packing of the liquid primary moderator material 20 to be maintained notwithstanding expansion and contraction of the liquid material 20.

We claim:

1. A bulk material analyzer in which bulk material is received in an activation region between at least one neutron source and at least one gamma-ray detector, comprising

a conveyor belt having upwardly and outwardly extended sides;

a container having surfaces defining said activation region, wherein the container surfaces further define a passageway for enabling bulk material to be transported through said activation region on the conveyor belt;

at least one neutron source disposed within the container beneath the passageway on one side of the activation region for emitting neutrons for bombarding bulk material being transported on the conveyor belt through said activation region to cause gamma-rays to be emitted from said bombarded bulk material;

at least one gamma-ray detector disposed within the container above the passageway on another side of the activation region opposite from said one side for detecting gamma-rays emitted from said bombarded bulk material;

a primary neutron moderator disposed about said neutron source(s) for reducing the velocity of said emitted neutrons; and

a secondary neutron moderator disposed about the primary neutron moderator for further reducing the velocity of said neutrons and further disposed adjacent said one side of the activation region at which the neutron source(s) are disposed, for channeling and reflecting said neutrons into said activation region;

wherein a lower portion of the passageway-defining surfaces define a trough having upwardly and outwardly extended sides adjacent said activation region for cradling the conveyor belt; and

wherein the secondary neutron moderator is further disposed adjacent the sides of the trough for channeling and reflecting said neutrons into said activation region.

2. A bulk material analyzer according to claim 1, wherein two said gamma-ray detectors are disposed toward opposite ends of said other opposite side of the activation region, with each detector being skewed so that a portion of each detector that is closer to the end of said other opposite side toward which said detector is disposed than to the center of said other opposite side is disposed closer to said one side of said activation region than is another portion of each detector that is closer to said center of said other opposite side than to said end of said other opposite side toward which said detector is disposed.

3. A bulk material analyzer according to claim 2, further comprising

a pair of spatial compensators including neutron moderating material respectively disposed over the detectors for reflecting neutrons toward said activation region in accordance with proximity to the center of said other opposite side of said activation region, with said reflection increasing in a direction away from the center of said other opposite side.

4. A bulk material analyzer according to claim 3, wherein there are two said neutron sources, which are separated laterally on opposite sides of the longitudinal axis of the passageway.

5. A bulk material analyzer according to claim 1, further comprising

spatial compensating means disposed adjacent said other opposite side of the activation region for reflecting neutrons toward said activation region at a greater density toward opposite ends of said other opposite side than toward the center of said other opposite side.

6. A bulk material analyzer according to claim 1, wherein there are at least two said so disposed neutron sources and at least two said so disposed gamma-ray detectors.

7. A bulk material analyzer according to claim 1, further comprising

radiation shielding material disposed within the container; and

a tertiary neutron moderator disposed about the secondary neutron moderator and adjacent the radiation shielding material for further reducing the velocity of said neutrons, for reflecting said neutrons into the secondary neutron moderator, and for isolating the secondary neutron moderator from the radiation shielding material.

8. A bulk material analyzer according to claim 1, wherein there are two said neutron sources, which are separated laterally on opposite sides of the longitudinal axis of the passageway.

9. A bulk material analyzer according to claim 1, wherein a portion of the trough adjacent the primary neutron moderator and the secondary neutron moderator is made of a neutron transmissive material that enables said neutrons to diffuse into said activation region from the primary neutron moderator and the secondary neutron moderator.

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