Aug. 23, 1949. C. W. WALLHAUSEN ET AL 2,479,882
RADIOACTIVE METAL PRODUCTS AND
METHOD FOR MANUFACTURING
Filed March 14, 1946

FIG. 1

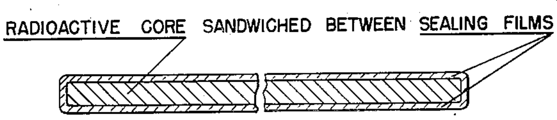


FIG. 2

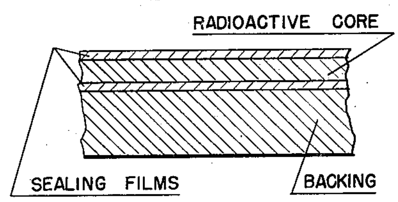


FIG. 3

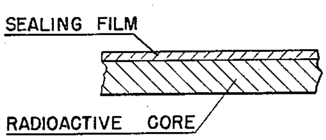


FIG. 4

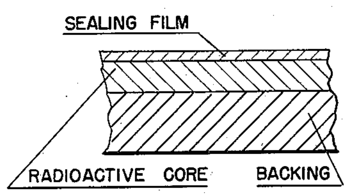


FIG. 5

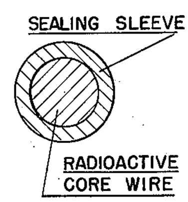


FIG. 6

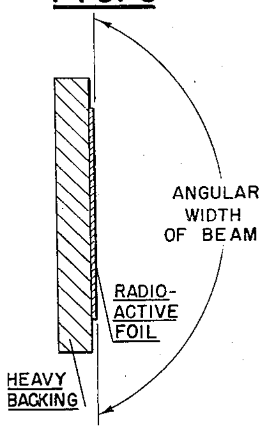


FIG. 7

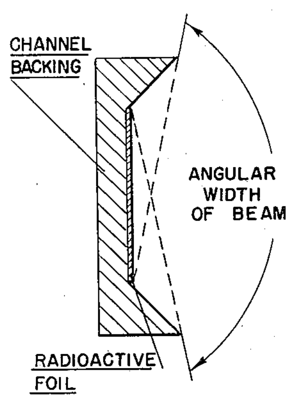


FIG. 8

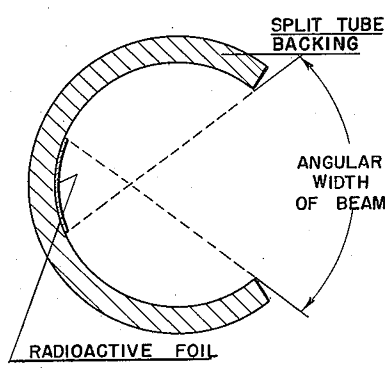


FIG. 9

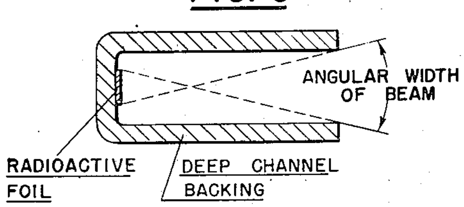
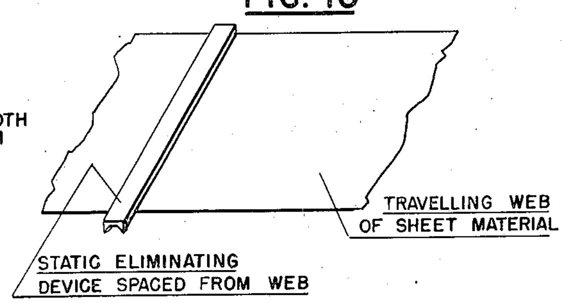


FIG. 10



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RADIOACTIVE METAL PRODUCTS AND METHOD FOR MANUFACTURING

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15 Claims. (Cl. 250—106)

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This invention relates to radioactive metal products, and is concerned especially (but not solely) with an improved radioactive metal product that emits alpha particles. Basically this product comprises a metallic core in which a radioactive substance is incorporated, and a sealing film over the core which prevents escape of gaseous products of the radioactive disintegration process but which advantageously is thin enough to be penetrable by alpha particles emitted in this process. The invention further provides a new method for making radioactive metal products of this character, and a device based on the new radioactive metal product for eliminating static charges.

Various proposals have been made heretofore for incorporating radioactive substances in metal products. In particular the patent to Alois Fischer No. 2,326,631 describes a metal foil in which a radioactive substance is incorporated, and specifically a metal foil capable of emitting alpha particles and efficient in its use of the radioactive substance employed. Foils and extremely fine wires are especially advantageous forms of metal products which are intended to emit alpha particles, because the depth of penetration in metals of alpha particles having the average energy with which they are emitted by ordinary radioactive elements is very small. When the radioactive substance is uniformly distributed through the body of the metal product, the thickness of the product should be no greater than can be penetrated by an alpha particle as emitted by the substance; otherwise alpha particles originating deep in the metal will not be able to reach the surface and be emitted from the metal. In consequence efficient use will not be made of that portion of the radioactive substance distributed deep in the metal.

While thin foils and very fine wires are known to possess the above-indicated advantage of being efficient in the use of the radioactive substance when the foil or wire is primarily intended to emit alpha particles, the very thinness of the foil or wire which leads to this advantage contributes also to a substantial disadvantage. This disadvantage arises from the fact that in each of the well-known natural radioactive disintegration series, one of the early disintegration products is a radioactive gas. For example, radon, a gas, is the first disintegration product after radium in the uranium-radium series; thoron (an isotope of radon) is the fifth disintegration product after thorium in the thorium series; and actinon (another isotope of radon)

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is the third disintegration product after actinium in the uranium-actinium series. These radioactive gases all have short half-lives, but when they are produced by disintegration of their parent substance in very thin foils or extremely fine wire, at least a small percentage of some of them can and does escape beyond the surface of the foil or wire before disintegrating to the next product in the series. Escape of the radioactive gas is disadvantageous on two accounts. First, the escaped gas is highly poisonous and even very dilute concentrations are dangerous to human and animal life. Second, the escaped gas is no longer able to contribute, by its own disintegration and the disintegration of its products, to the radioactivity of the foil or wire—the escaped gas thus represents a waste of radioactive energy which would not occur if the gas did not escape.

The present invention contemplates the provision of an improved radioactive metal product which retains the efficient alpha-particle-emitting characteristics of thin foils but avoids the foregoing disadvantages of thin radioactive foils as heretofore used or proposed. The new radioactive metal product comprises a thin metallic core or base structure (for example, a metallic film, ribbon, or fine wire) having a radioactive alpha-particle-emitting substance intimately dispersed therein. A thin, substantially continuous sealing film substantially free of radioactive material is bonded to a surface of the core metal. The combined thickness of the core and the sealing film is no greater (for a product that emits alpha particles) than can be penetrated by viz., is permeable to alpha particles having the maximum energy with which they are emitted by the radioactive substance dispersed in the core. If desired, this thin metal product may be bonded to a backing sheet or strip, advantageously of metal, to provide it with mechanical support, and which may also act as an emanation shield, and to limit the angular width of the emitted beam of alpha particles. (The term "emanation" is used throughout this specification to denote all the products emitted in the course of the radioactive process, and not, as is often the case, to denote merely the gaseous disintegration products.)

The core of the new product most advantageously is a metal film and preferably a film of noble metal such as gold or platinum. A film of gold or other metal composed of pressed metal powder is especially satisfactory because such films are conveniently fabricated to incorporate, intimately dispersed, the radioactive substance.

The radioactive substance may be a radioactive element, but most conveniently is a salt of such element, for example, a salt of radium such as radium sulphate or radium bromide.

The sealing film serves primarily to prevent the escape of gaseous disintegration products of the radioactive substance incorporated in the base structure. It may be composed of any material capable of forming a sufficiently thin film which yet is sufficiently continuous to perform this sealing function, viz., to be impermeable to the radioactive gas. Organic film-forming compounds, such as various plastic compositions, will serve as the sealing film material, but it is usually better to employ a material which is more resistant than organic compounds to emanations from radioactive substances. Non-metallic inorganic films, such as a thin film of fused silver chloride, perform satisfactorily and may be used. Generally, however, a metallic sealing film, and preferably a noble metal sealing film of the same metal as that comprising the core, will be found most satisfactory.

When, as is generally the case, the core is in the form of a thin ribbon or film, it is desirable to apply the sealing film to both surfaces of the base structure film. This is not always necessary however. For example, if the film is to be mounted on a relatively heavy backing strip, it is not necessary, in order to prevent radon loss through the back, that a sealing film be applied to that surface of the core which is to be bonded to the backing. Nevertheless, if the backing strip is of metal (such as silver) different from that of the core (such as gold), it is preferable that a sealing layer of suitable non-radioactive metal (such as gold) be interposed between the radioactive core and the backing to prevent migration of radium or its products into the backing when the material is employed at high temperatures.

The combined thickness of the base structure and the sealing film is made no greater than can be penetrated by alpha particles having the maximum energy with which the radioactive substance emits them, so as to attain efficient emission of alpha particles from the metal product. For optimum alpha particle emission, the core and sealing film combined should be thin enough to be penetrable by alpha particles possessing the average energy with which they are emitted by the radioactive substance employed. The metal product will emit alpha particles, however, so long as the sealing film alone is permeable to alpha particles, viz., is of a thickness less than that which can be penetrated by alpha particles having the maximum energy with which the radioactive substance emits them.

In the case of the metals that are most satisfactory for use in making the new metal product, such as gold and other noble metals, the maximum thickness of the base structure and sealing film combined generally should not exceed about 5 microns, and advantageously does not exceed about 4 microns, with the core contributing about ½ to 2½ microns to the total thickness and the sealing film contributing about ½ to 1½ microns.

By making the sealing film of a material which is substantially continuous and free of any radioactive substance, it is effective in preventing the escape outside the metal of any appreciable amount of gaseous disintegration products of the radioactive process, even though it be of the thickness necessary to permit the passage of alpha particles emitted in this process. Sealing films thicker than specified above also are effective for preventing escape of radioactive gas, and may be employed if alpha-particle emission from the metal product is not required. For example, if a foil product that emits only beta particles and gamma radiation is desired, the sealing film, or the core, or both, may be substantially thicker than above indicated, and the sealing film will still perform the useful function, with the above-stated advantages, of preventing escape of radioactive gas.

If a backing sheet or strip is employed to support the thin product, it is usually so heavy as to effectively prevent emission of alpha particles from the surface to which it is bonded. In such case therefore, if a sealing film is applied to both surfaces of the core film before bonding the resulting composite film to the backing, the thickness of the sealing film between the base structure and the backing is of no great consequence, and it may appreciably exceed the thickness indicated above. In such case only the thickness of the core film and the sealing film on its exposed side need be as thin as indicated for efficient alpha-particle emission.

Any material capable of providing the degree of support desired for the thin metal foil product described above may be used as a backing. Silver is especially satisfactory for this purpose. Corrosion-resistant metals such as copper, nickel and stainless steel are also well suited for backing purposes, but other backing materials, metallic or non-metallic, may be used if desired. The thin composite radioactive foil may be secured to the backing by any conventional method, such, for example, as by soldering, brazing or welding, or by the use of an adhesive.

The invention provides a method for making thin radioactive metal products, as described above, preferably using metal powders. In accordance with this method, a metal powder such as gold powder and a finely-divided, radioactive alpha-particle-emitting substance such as a radium salt are intimately mixed together. The radioactive substance advantageously constitutes about 1% to about 12% by weight of the mixture. The powder mixture is pressed and sintered into a compact mass, and if desired, it may then be compacted somewhat more by a rolling operation. A layer of metal substantially free of radioactive material is applied to a surface of the compacted mass, or advantageously the compact is sandwiched between layers of such metal. The resulting composite structure or sandwich then is reduced by rolling or other metal-working operation to a thickness no greater than can be penetrated by alpha particles having the maximum energy with which they are emitted by the radioactive substance. The layer of sealing metal may be bonded to the core compact by welding or otherwise before the composite is reduced in thickness, or the metal-working operation may be carried out at an elevated temperature high enough so that at the pressure applied the several layers of metal are firmly and permanently bonded together.

In an advantageous embodiment of this method, a backing metal is applied and bonded to the composite of radioactive and sealing metals, preferably after the composite has been reduced substantially in thickness but before it has been reduced to its final thickness. The composite and backing metals then may be rolled together sufficiently so as to reduce the composite component and other layers to the thicknesses specified.

The radioactive metal product herein described serves admirably as the fundamental element of a device for eliminating static charges wherever their accumulation interferes with normal or desired operation. Such charges, for instance, accumulate on webs or sheets of paper in paper-making, -fabricating and -printing operations; on travelling webs of cloth in the textile industry; and on plastic materials in operations involving their manufacture and use. The accumulation of static charges may constitute a fire hazard, because the potential of the charge may become sufficient to cause a spark capable of igniting the inflammable material on which the charge accumulates, or of igniting other inflammable material nearby. Such static charges also often cause sheets of material to adhere to each other or to other objects.

A device for eliminating such static charges based on the radioactive metal product described herein may comprise a narrow strip of the radioactive metal product, advantageously supported by a backing strip and of a length about equal to the width of the web from which static charges are to be eliminated. The strip is mounted fairly close to the web, but is spaced therefrom by a short distance of the order of an inch or so, and it extends transversely across the web. Since the radioactive metal product emits alpha particles efficiently, it is highly effective for ionizing the atmosphere between it and the web with safety, and static charges tending to accumulate on the web are neutralized and discharged in consequence of this ionization.

If desired, the radioactive strip may be mounted in the hollow of a channel, semi-cylinder, or other shape which is thick enough to prevent the passage of alpha particles. In this manner the effective beam of emitted alpha particles may be confined to a particular direction (determined by the direction in which the open side of the channel faces). The angular width of the effective beam may be controlled by suitable choice of the depth of the channel flanges relative to the width of the radioactive strip, and other factors affecting the geometry of assembled structure.

The following description of the manufacture of a radioactive foil will afford a better understanding of the invention, although it is understood that the invention is not specifically limited to the embodiments described below.

In the following description reference is made to the accompanying drawings, in which

Figs. 1 to 5 show schematic cross-sections through various forms of the new radioactive metal product;

Figs. 6 to 9 show various forms of backing for limiting the angular width of the alpha particle beam emitted from the radioactive metal product; and

Fig. 10 shows diagrammatically the relation in which a static eliminating device according to the invention may be mounted relative to a travelling web of sheet material.

Generally, the first step in the manufacture of the radioactive metal product is the preparation of the material for the radioactive core or base structure. Various procedures may be employed for this purpose. For example, a metal sheet or strip may have a very thin layer of a radioactive element or compound deposited on it by electrodeposition, by sputtering or evacuation in vacuum, or by other means, and the deposit then may be caused to diffuse into the underlying metal by heating to an elevated temperature for a sufficiently long period of time. A more satisfactory method is to mix the radioactive substance, in finely divided form, intimately with a metal powder of the composition desired. Numerous metal powders are available and may be used, such as copper powder, nickel powder, tungsten powder, or alloy powder such as brass powder. Ordinarily, however, a noble metal powder such as gold or platinum powder or a gold-platinum alloy powder is preferred. Noble metals are virtually unaffected by the emanations of radioactive substances, they are highly resistant to corrosion and chemical attack, and they are very easily worked. While noble metal powders are costly, the amount used per unit area of the thin radioactive metal foil is very small, and the cost of the metal therefore is not a very large factor in the cost of the product.

For a metal product that emits alpha particles, the radioactive substance employed is of course one which emits alpha particles in the course of its radioactive disintegration. A radioactive element of this character may be employed as such, but production of the radioactive elements in elemental form is difficult and accordingly it is most convenient to employ a salt or other compound of a radioactive element. Salts of radium, such as radium chloride, radium bromide, or radium sulphate, are readily prepared in finely divided form and are especially advantageous substances to use. Salts of other radioactive elements may, however, also be used. For example, salts of thorium and especially salts of thorium disintegration products may be employed, as may salts of actinium. All of these elements undergo radioactive disintegration with the emission of alpha particles, and yield disintegration products which undergo further disintegration involving alpha-particle emission. It is also possible to employ salts or other compounds of radioactive elements above uranium in the periodic table, such, for example, as salts of neptunium (atomic number 93) of atomic weight 237, an alpha-particle-emitting element having a half-life of 2.25×10^6 years; salts of plutonium (atomic number 94) of atomic weight 238, an alpha-particle-emitting element having a half-life of 50 years; and salts of plutonium of atomic weight 239, an alpha-particle-emitting element having a half-life of 24,000 years.

Besides the foregoing elements, which are normally radioactive, it is possible to employ elements and compounds which are not normally radioactive but in which radioactivity has been artificially induced. For example, radioactive forms of carbon have been prepared and may be used as the radioactive substance, especially those forms that emit alpha particles. Also compounds such as common salt (sodium chloride) have been rendered radioactive, and such compounds (as well as compounds prepared from elements in which radioactivity has been artificially induced) may be employed as the radioactive substance.

The proportions of radioactive substance and metal powder used in preparing the mixture may be varied over wide limits, and in general will depend upon how intense a degree of radioactivity is desired. Ordinarily, however, the radioactive substance should constitute at least 1% by weight of the mixture. Where intense radioactivity is desired, as much as 12% by weight of the mixture may be made up of radioactive salt, and even higher percentages may sometimes be used within the limit of forming a cohesive and workable compact with the metal powder.

The mixture of metal powder and radioactive salt or other substance are subjected to high mechanical pressure of the order of 30 tons per square inch, to compact the powders and form a cohesive mass. The compressed mass, while cohesive, is very fragile, and it therefore is next subjected to a sintering operation involving heating it at about 950° C. for about one-half hour. When well-purified gold powder is used, no harm is done to the pressed mass by introducing it directly into an oven at the sintering temperature of 950° C. If, however, impure powder is used, occluded gases may be driven off during sintering and raise blisters on the pressed mass unless the sintering operation is conducted carefully. In such case, it is best to heat the pressed mass very slowly (over a period of several hours) to the final sintering temperature, and then to hold it at this temperature for ½ to 2 hours. The compacted mass after sintering is quite strong and may be handled without fear of breakage.

The sintered compact is next rolled to reduce its thickness and increase its density. After some reduction in thickness has been affected, it is wrapped in a sheet of suitable metal containing no radioactive substance, and the resulting sandwich is further rolled to reduce the thickness of both the sintered compact and the metal wrapping, which, in the finished product, forms the sealing film. Alternatively the sintered compact, before being rolled at all, may be wrapped in the metal and may be subjected to its first rolling operation only when thus enclosed.

Various metals may be used for the wrapping. Noble metals, especially gold and platinum, are particularly suitable for this purpose, for the same reasons that make them advantageous for the core metal. Other metals, however, such as copper, nickel, tin or chromium, or alloys such as brass, bronze or platinum-gold may be employed successfully.

Advantageously the thickness of the gold or other metal wrapping sheet is substantially less than the thickness of the sintered compact, but it must not be so thin that in the finished product it does not form a continuous sealing film impervious to the radioactive gas. A wrapping about $\frac{1}{10}$ the thickness of the compact generally is satisfactory.

In lieu of mechanically applying the sealing metal as a separate sheet, by wrapping about the core or otherwise, it may be electrodeposited on the radioactive core metal, either immediately after sintering or after preliminary rolling of the core following sintering. There is no particular difficulty in applying the sealing metal by electrodeposition, and any electroplating bath and technique suitable for the sealing metal to be applied (gold, platinum, nickel, copper or chromium, for example), using soluble or insoluble anodes, may be employed. After a layer of sealing metal of desired thickness has been electrodeposited on the core, it is sometimes advantageous to heat the resulting metal product to an elevated temperature (say 950° C.) for a sufficient period of time (say ½ hour) to eliminate hydrogen which often accumulates in undesirably large amounts in electrodeposited metal and, if not eliminated may make it difficult to roll the product.

The rolling operation may be carried out at room temperature, or at a higher temperature if desired. The radioactive substance incorporated in the sintered compact constitutes an impurity which reduces the ductility of the gold, and it is therefore usually necessary to anneal the product periodically during rolling (generally after each three or four passes through the rolls when the rolling operation is conducted at room temperature). Annealing is effected by heating the product to about 800 to 900° C. The combination of rolling and annealing steps contributes to firmly and permanently bonding the outer layers of metal to the core metal, especially when the outer layers have been applied by simply wrapping them about the core metal.

Rolling, with intermediate anneals, may be continued until the total thickness of the product has been reduced to about .002 inch. This is a convenient thickness at which to apply the backing sheet or strip. Owing to the extreme thinness of the product in its finished form, a fairly heavy backing strip almost always is necessary to provide support for handling. Silver is a particularly advantageous metal to employ for backing purposes although other metals such as copper, nickel, etc., may be employed, if desired.

The rolled product advantageously is initially bonded to the backing metal by welding under pressure. For this purpose the foil and backing metal, suitably cleaned, are pressed together with a force of about 5 tons per square inch while heated electrically or otherwise to a welding temperature. After welding the rolled product to the backing metal, the assembly is further rolled to reduce the radioactive component to the required thinness. As above indicated, rolling should be continued until the total thickness of the radioactive metal core and the exposed sealing film is no greater than can be penetrated by alpha particles having the maximum energy with which they are emitted by the radioactive substance employed, and preferably to a thickness slight enough to be penetrable by alpha particles having the average energy with which such substance emits them. The thickness of the backing metal, at the time the rolled radioactive product is welded to it, should be such that in the final rolled product the backing metal is still sufficiently thick (say about 0.010 inch) to provide effective support. If the rolling operation reduces the backing metal to a thickness less than this, a further layer of backing metal of adequate thickness may be applied by welding or otherwise.

The radioactive metal product made as described above is illustrated (without a backing) in Fig. 1, which shows the core of pressed metal powder and radioactive substance sandwiched between the sealing films which completely surround the core. A fragmentary cross-section through a structure of this type bonded to a backing is shown in Fig. 2. Fig. 3 shows a modified structure in which the sealing film is bonded to only one surface of the radioactive core, and Fig. 4 shows a foil of this structure bonded to a backing. Fig. 5 shows a fragmentary cross-section through a wire structure in which the radioactive core wire is enclosed in a sealing sleeve substantially free of radioactive material.

Figs. 6 to 9 illustrate how the backing layer (or a second separate backing or supporting element) may be configured to limit the angular width of a beam of alpha particles emitted from a strip of radioactive foil (or from a radioactive wire) made as herein described. Fig. 6, for example, illustrates how a flat backing at least as wide as the foil limits the angular width of the effective beam to 180°. Figs. 7 and 8 show channel shaped backing elements (of conventional channel cross-section as in Fig. 7 or in the form of a longitudinally sectioned tube as in Fig. 8) which limit the angular width of the alpha particle beam to something less than 180°. A deep channel backing element as shown in Fig. 9 may be employed if a beam of narrow angular width is required. The backing elements in all of the structures shown in Figs. 6 to 9 are, of course, thick enough to be impenetrable by alpha particles of even the maximum energy with which they are emitted from the radioactive foil, so as to confine the effective emitted beam of these particles to the desired angular width.

Fig. 10 illustrates diagrammatically a static-eliminating device according to the invention (which advantageously consists essentially of a long narrow strip of the new radioactive metal product mounted on a backing and supporting element of the character shown in Figs. 6 to 9) mounted for eliminating static charges that accumulate on a web of travelling sheet material. The static-eliminating device extends transversely of the web, and preferably completely across its width. It is spaced an inch or so from the web, with the beam of emitted alpha particles directed toward the web. The alpha particles ionize the atmosphere between the radioactive foil and the web, and static charges accumulated on the web are neutralized or discharged as the web passes over or under this region of ionized atmosphere. The spacing between the web and the static-eliminating device should not exceed about three inches, as this is the maximum distance in air at ordinary atmospheric pressure at which the alpha particles emitted from a radium-metal foil of the character herein described are effective for ionizing the air. Optimum ionization of the air for static elimination purposes occurs within an inch or less of the foil, and accordingly it is desirable to mount the static eliminator with the exposed surface of the foil no farther than this from the web.

It is evident that instead of the web of sheet material travelling over a stationary static eliminator, the static eliminator may be moved over a stationary sheet. It may be set up to be moved mechanically, or it may be hand operated as a wand. It also may be of other physical form than a thin ribbon—for example, it may be in the form of a broad sheet, and may be flat or curved. The radioactive element may cover a continuous surface expanse of the backing structure, or it may be arranged thereon as a series of spaced strips, triangles, squares, circles, or other shapes. The alpha particles emitted from the foil diverge unless confined by a shield of some sort, so even when the foil is discontinuous on the backing, the separate foil pieces may be arranged so that the alpha particle density in the atmosphere a short distance from the plane of the foil is substantially uniform.

It is also evident that the web itself may be thin and continuous, as is usually the case with paper or sheet plastic material, or it may be relatively thick and discontinuous, as are the rovings and bats encountered in textile mills.

Another advantageous use of the new product is to eliminate static charges on the parts of analytical and other balances, the accurate operation of which is affected by such charges. A foil or wire prepared in accordance with the invention, with or without a backing, may be mounted near the pans, or beam, or both, wherever objectionable static charges might accumulate, to eliminate such charges. Numerous other similar uses of the new product are apparent.

Radioactive metal products prepared as above described with a thin, continuous sealing film substantially free of any radioactive substance over the radioactive core give off virtually no radioactive gas. Their use therefore will not result in contaminating the surrounding atmosphere with these highly poisonous gases. Moreover, by retention of the radioactive gas within the core, the radioactive effects of its own disintegration, and of the disintegration of its products, are preserved for use in the environment in which the metal product is employed.

The effect of the sealing film in retaining the gaseous disintegration products in the core makes the use of such film advantageous even in those instances where the thickness of the sealing film alone, or of the sealing film and metal core combined, is greater than can be penetrated by any alpha particles emitted by the radioactive substance. Such thick metal products, of course, will not emit alpha particles, but for uses where beta-particle emission and gamma radiation are all that are required of the foil, the sealing film, even though thicker than above specified, still is advantageous and performs the highly useful functions of preventing contamination of the surrounding atmosphere with a radioactive gas and preserving within the metal the radioactive energy of the gas and its disintegration products.

We claim:

1. The method of making a radioactive metal product which is substantially proof against leakage of radioactive gas which comprises, intimately admixing a finely divided metal and a finely divided radioactive alpha-particle-emitting substance, pressing and sintering the resulting mixture into a compact, applying a sealing layer of metal substantially free of radioactive material to one surface of said compact, bonding a relatively thick metal backing to the other surface of said compact, and rolling the resulting product until the thickness of said sealing layer is no greater than can be penetrated by alpha particles having the maximum energy with which they are emitted by said radioactive substance.

2. The method of making a radioactive metal product which is substantially proof against leakage of radioactive gas, which comprises, intimately admixing a metal powder and a finely divided radioactive alpha-particle-emitting substance, pressing and sintering the resulting mixture into a compact, sandwiching the compact between layers of a metal substantially free of radioactive material, rolling the sandwich to reduce the thickness thereof and to bond the several layers together, applying a relatively thick layer of backing metal to the resulting bonded sandwich, and rolling the sandwich and backing metal together until the compact and at least one of the layers of the sandwich component of a thickness no greater than can be penetrated by alpha particles having the maximum energy with which they are emitted by said radioactive substance.

3. The method of making a radioactive metal product which is substantially proof against leakage of radioactive gas, which comprises, intimately admixing a finely divided metal and a finely divided radioactive alpha-particle-emitting substance, pressing, sintering and forming the resulting mixture into a compact, wrapping said compact in a sheet of non-radioactive malleable metal of a thickness about one-tenth that of the compact to form a sandwich, rolling said sand-

wich successively until the thickness thereof is of the order of two-thousandths of an inch, annealing said sandwich periodically between said rollings by heating to about 800 to 900 degrees C., welding said rolled sandwich to a metal backing strip considerably thicker than said sandwich, and rolling said sandwich and backing metal together until the thickness of the sandwich component does not exceed about five microns.

4. The method of making a radioactive metal product which is substantially proof against leakage of radioactive gas, which comprises, intimately admixing a finely divided metal and a finely divided radioactive alpha-particle-emitting substance, pressing, sintering and forming the resulting mixture into a compact, electrodepositing on said compact a layer of non-radioactive malleable metal of a thickness less than that of the compact to form a sandwich, heating said sandwich at an elevated temperature for a period sufficient to drive off hydrogen accumulated during said electrodeposition, rolling said sandwich successively until the thickness thereof is of the order of two-thousandths of an inch, annealing said sandwich periodically between said rollings by heating, bonding said rolled sandwich to a metal backing strip considerably thicker than said sandwich, and rolling said sandwich and backing metal together until the thickness of the sandwich component is no greater than can be penetrated by alpha particles having the maximum energy with which they are emitted by said radioactive substance.

5. A radioactive product, comprising a core containing a radioactive substance which emits alpha particles and amanates a radioactive gas as a disintegration product, and a continuous thin sealing film substantially free of radioactive material bonded to a surface of said core, said sealing film being sufficiently thin to be permeable to said alpha particles and sufficiently thick to be substantially impermeable to said radioactive gas.

6. A radioactive metal product that emits alpha particles comprising a thin metallic core having a radioactive alpha-particle-emitting substance intimately dispersed therein, and a substantially continuous radioactive-gas-sealing film substantially free of radioactive material bonded to a surface of said core, the combined thickness of said core and film being no greater than can be penetrated by alpha particles having the maximum energy with which they are emitted by said radioactive substance.

7. A radioactive metal product that emits alpha particles comprising a thin metallic film having a radioactive alpha-particle-emitting substance intimately dispersed therein, a substantially continuous radioactive-gas-sealing film substantially free of radioactive material bonded to a surface of said metallic film, the combined thickness of said two films being no greater than can be penetrated by alpha particles having the maximum energy with which they are emitted by said radioactive substance, and a relatively thick backing element bonded to and providing support for said films.

8. A radioactive metal product that emits alpha particles comprising a metallic core having a radioactive alpha-particle-emitting substance intimately dispersed therein, and a substantially continuous gas sealing film substantially free of radioactive material completely surrounding and bonded to said core, the thickness of said sealing film being less than the depth of penetration therein of alpha particles having the maximum energy with which they are emitted by said radioactive substance.

9. A radioactive metal product that emits alpha particles comprising a thin film composed of pressed metal powder intimately mixed with a finely divided radioactive alpha-particle-emitting substance, sandwiched between thin substantially continuous metallic gas sealing films substantially free of radioactive material, the combined thickness of said first-mentioned film and at least one of said sealing films being no greater than can be penetrated by alpha particles having the maximum energy with which they are emitted by said radioactive substance, and a relatively thick metallic backing element bonded to and providing support for said films.

10. A radioactive metal product comprising a gold film having a radioactive alpha-particle-emitting substance intimately incorporated therein, a substantially continuous gold sealing film bonded to a surface thereof, the combined thickness of said two films being no greater than can be penetrated by alpha particles having the maximum energy with which they are emitted by said radioactive substance, and a relatively thick metallic backing element bonded to and providing support for said films.

11. A radioactive metal product comprising a thin film about ½ to 2½ microns in thickness composed of gold having a radioactive substance intimately incorporated therein, and a sealing film of non-radioactive gold approximately ½ to 1½ microns in thickness bonded to at least one surface of said first-mentioned film.

12. A radioactive metal product comprising a thin film about ½ to 2½ microns in thickness composed of pressed gold powder intimately admixed with about 1% to 12% by weight of a finely divided radioactive substance, sandwiched between thin gold films substantially free of radioactive material and each about ½ to 1½ microns in thickness, and a metallic backing element bonded to and providing support for said films.

13. A radioactive metal product which emits alpha particles, comprising a thin core film of noble metal having an alpha-particle-emitting radium compound intimately dispersed therein, a substantially continuous radioactive-gas-sealing film of noble metal substantially free of radioactive material bonded to a surface of said core film and constituting the alpha-particle-emitting front of said product, the combined thickness of said two films being no greater than can be penetrated by alpha particles having the maximum energy with which they are emitted by said radium compound, a backing and supporting member positioned at the back of said core film, said member being greatly thicker than said core and sealing films together and being of a metal different from that of said core film such that radium may tend to migrate from said core film into said member, and a layer of radium impervious metal substantially free of radioactive material interposed between and bonded to said core film and said backing member so as to constitute a radium-sealing layer and a bonding agent between said core film and said backing member.

14. A radioactive metal product which emits alpha particles, comprising a thin gold core film having an alpha-particle-emitting radium compound intimately and substantially uniformly dispersed therein, a substantially continuous radioactive-gas-sealing film of gold substantially free of radioactive material bonded to a surface of

said core film and constituting the alpha-particle-emitting front of said product, the combined thickness of said two films being no greater than can be penetrated by alpha particles having the maximum energy with which they are emitted by said radium compound, a backing and supporting member positioned at the back of said core film, said member being greatly thicker than said core and sealing films together and being of silver whereby radium may tend to migrate from said core film into said member, and a sealing layer of gold substantially free of radioactive material interposed between and bonded to said core film and to said backing member so as to constitute a radium-sealing layer and a bonding agent between said gold core film and said silver backing member.

15. As an article of manufacture, a device serving as a source of alpha-particle emission within a restricted field and substantially proof against leakage of dangerous radioactive gas, which comprises, a narrow strip of thin metallic core film having a radioactive alpha-particle-emitting substance intimately dispersed therein, an effectively continuous radioactive-gas-sealing film of noble metal free of radioactive material and bonded to a first surface of said core film whereby radioactive gas is substantially prevented from escaping from said first surface of said core film, said sealing film being thin enough to be penetrable by alpha particles having the maximum energy with which they are emitted by said radioactive substance whereby alpha particles are free to escape from said core film through said sealing film, and a metallic backing element affixed to the second surface of said core film, said element being sufficiently thick to support said core and sealing films and to be impenetrable by said emitted alpha particles and radioactive gas and having side flanges so deep as to limit the angular width of the beam of alpha particles emitted from said first surface to substantially less than 180 degrees.

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Certificate of Correction

Patent No. 2,479,882

August 23, 1949

CLARENCE W. WALLHAUSEN ET AL.

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 2, line 35, before "viz." insert an opening parenthesis; line 36, after "to" insert a closing parenthesis; column 10, line 62, after "component" insert *are*; column 11, line 2, for "oft he" read *of the*; line 36, for "amanates" read *emanates*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 10th day of January, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.

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