

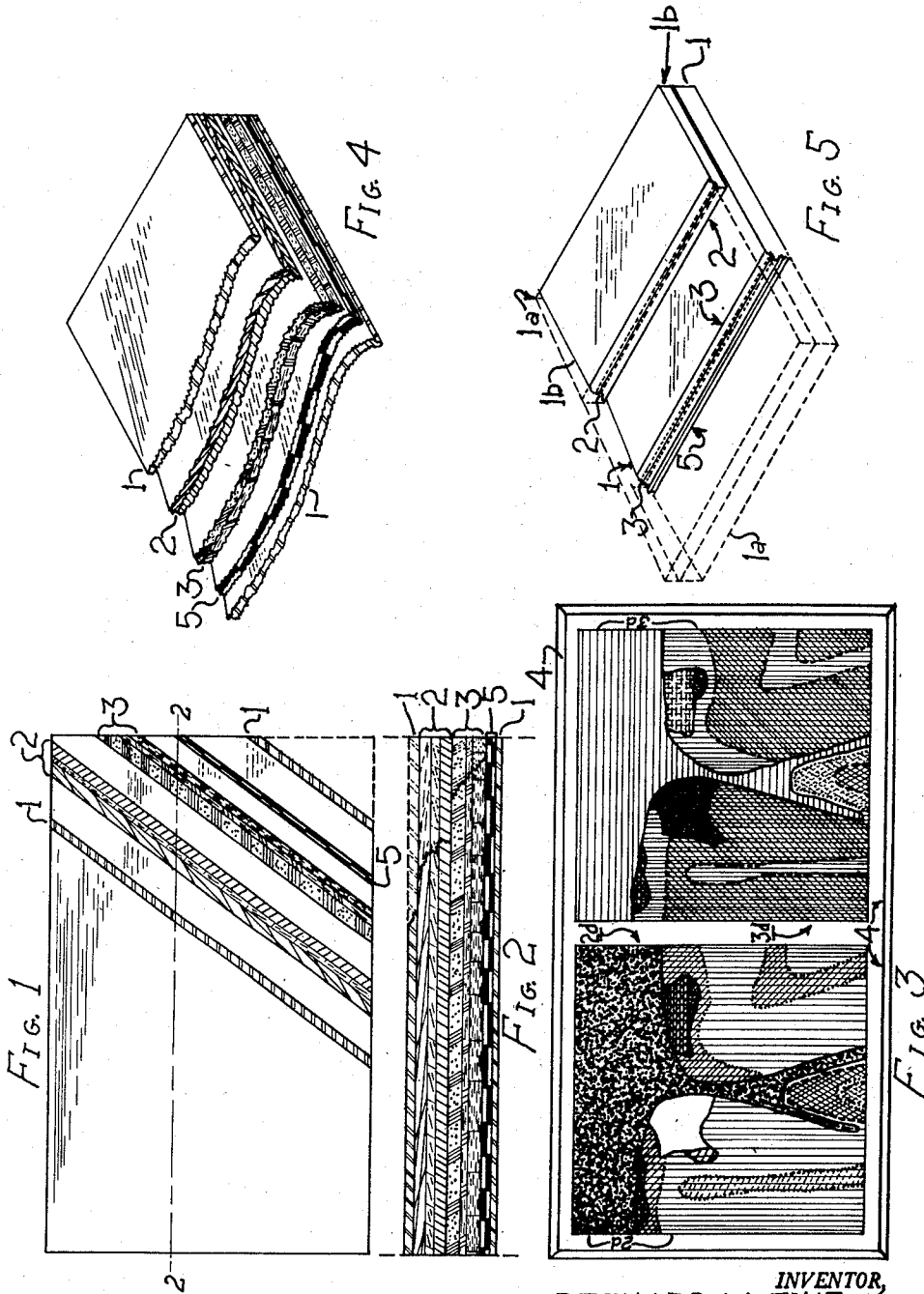
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COLOR RADIOGRAPHS, METHODS AND ARTICLES

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COLOR RADIOGRAPHS, METHODS AND ARTICLES

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This invention relates to color radiography and particularly to novel instrumentalities and methods therefor and specifically relates to the simultaneous production of multiple radiographs having superimposable images, the color values of one of the radiographs being different from that of the other whereby comparison and differentiation of structural features may be readily made.

For many years after the discovery of radiography, the radiographs have been produced in (what we shall call here) black-and-white resulting from conventional silver images. Such conventional radiographs were frequently found lacking in differentiating detail but little else was available. The Scanlan et al. U.S. Patent No. 1,973,886 improved the radiographs to a limited extent by the use of a tinted or colored film support or base. But the results thus obtained were still unsatisfactory for many purposes.

In Fine U.S. Patent No. 2,644,096 issued on June 30, 1953, the production of color radiography was set forth whereby radiographs were produced having a developed color image; the color including colors in the range from violet to red of the visible spectrum to produce color differentiation of structural features delineated by non-visible radiant energy. In this way normally invisible internal structural features of an object were delineated in color differentiation on a radiograph. Color radiography represents therefore an advance in the art in enabling structural features to be delineated that were not as sharply differentiated or not differentiated at all, in conventional radiographs.

There are situations however where it is desirable to compare structural features delineated on color radiographs with those structural features as shown on conventional radiographs. In such cases it is extremely important to have the images of the radiographs undergoing comparison in exact alignment for identical areas. Frequently it is only in this way that small areas of different image density or extent can be certainly located for comparison. While therefore it is not necessarily intended that such multiple radiographs of different color values are to be read while superimposed, it is very desirable that the images be identical in the sense of being superimposable.

Among the objects of the present invention is the production of multiple radiographs having superimposable images but in different color values.

Further objects include methods and articles for the production of such multiple radiographs.

Still further objects and advantages of the present invention will appear from the more detailed description set forth below, it being understood, however, that such more detailed description is given by way of illustration and explanation only, and not by way of limitation, since various changes therein may be made by those skilled in the art without departing from the scope and spirit of the present invention.

In connection with that more detailed disclosure there is shown in the accompanying drawing in

Figure 1, a top plan view of a cassette containing multiple radiographic elements having emulsions responsive to

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non-visible radiant energy illustrated partly in skeletonized section;

Figure 2, a cross-section on line 2—2 of Figure 1;

Figure 3, two finished radiographs having superimposed exposure images in different color values mounted for comparison;

Figure 4 is a perspective view of Fig. 1 partly in section; and in

Figure 5 is a modified form of cassette shown in perspective, partly in section.

In accordance with the present invention radiographs are produced by simultaneous exposure of any number of superimposed radiographic films, plates, or other photographic elements carrying emulsions sensitive to non-visible radiant energy, the elements being capable of giving images in different color values. In this way two or more radiographs may be produced having color differentiated images of assured alinement since the simultaneous exposure will necessarily result in a disposition of the images in superimposable relation. For convenience the elements may be placed in a single cassette of material pervious to X-rays or other non-visible radiant energy while impervious to the visible spectrum. While any number of emulsion carrying elements may be carried in such a cassette the invention can be illustrated by a cassette carrying two such elements.

Thus a cassette may be supplied having one conventional X-ray film giving the usual black-and-white or black-and-gray radiograph upon exposure and development, and one color radiography film giving a finished radiograph in which the image is delineated at least partly in color, that is one color in the visual spectrum. Any type of conventional X-ray film may be used for this purpose including film of the Scanlan type referred to above; while any type of color photographic film may be used for the color radiograph. Simultaneous exposure and subsequent development of the several films by any conventional methods yields superimposable radiographs in which the images are in different color values whereby comparison may be made to differentiate structural features of the subject. Similarly, one radiograph may carry at least one negative image, or both may carry negative or positive images. A single film capable of being separated, such as a "stripping" type film or a film with a dual or split base (emulsion carrier) may also be used.

Accordingly the term color as used herein includes black, gray and white as well as the colors of the visible spectrum which show differences in hue. And the example given above illustrates generally comparative radiographs where one is in black-and-gray or black-and-white, and the other in spectral color tones.

However, the invention is not limited to those cases where one of the radiographs is in black-and-white or black-and-gray. It is possible to produce two or more radiographs having superimposable images, where each has its own color differentiating tones, e.g. color tones in one differentiated from the color tones in the other. For example, two or more color films or other photographic elements may be included in the cassette and simultaneously exposed. The color films may be of different type so that development in the same processing baths gives different color tones for the corresponding structural areas of the object. Or the color films may be of the same kind and different color tones produced by the use of different processing baths. Or combinations of these expedients may be used. Where identical films are used for example, it is possible to vary density or actual color tone or value or hue by the manner of processing. Differences in time-temperature relationship may for example be employed to give different tonal or color values for radiograph comparison. Or differences in bath composition may be employed. A

simple expedient is to use two films of identical character such as "Ektachrome" for example, expose them simultaneously in a single cassette, and develop them separately for example one by an "Ektachrome" kit, and the other by an "Ansco" kit. Any desired procedural arrangements may thus be employed to give alignment-identical radiographs having different comparative tonal or color values for corresponding areas in the color radiographs.

In this connection it should be kept in mind that the present invention is not concerned with reproducing the color of the object X-rayed, but of producing structural detail of the object by color or color tone differentiation. Hence techniques that could not be utilized in producing color photographs, can be employed in the production of color radiographs.

While any type of color film now available on the market may be used for the ray-sensitive elements in the cassette, any other types of films or other emulsion-carrying elements may be used including those described in Patent No. 2,644,096 and in the parent application Serial No. 364,609 referred to above.

While the use of a single cassette containing two or more energy responsive elements has been given as a preferred example, simultaneous exposure of such films while carried in separate cassettes may be used.

A cassette containing two or more elements having ray-sensitive emulsions may thus be exposed by the same technique as that employed for producing conventional radiographs. However, the exposures used may be adjusted primarily from the standpoint for most of the conventional X-ray film to give the optimum effect with that film, since many color films have wide latitude when used for many of the purposes herein set forth.

While X-rays have been referred to above to illustrate the invention, any other type of non-visible radiant energy may be employed, as long as films, plates, or other photographic elements are employed with emulsions sensitive to the rays employed. For example gamma rays may be utilized and under some circumstances cathode and cosmic rays also. Various ionizing particles may be employed such as alpha particles, beta particles, protons, mesons, and neutrons, etc. The addition of boron (B^{10}) to the emulsion facilitates the utilization of the film in registering the effect of neutrons. Other analogous additions can be made for utilization of non-ionizing particles because of the ionization produced by secondary particles. Both interaction and recoil procedures can be used. The boron isotope (B^{10}) desired may be that normally present in the boron compound added to the emulsion or an enriched source of B^{10} compound can be used. The term charged particle may be used to cover certain of the effective rays employed in the present invention. However more generally the term subatomic particle may be used to cover any of the particles mentioned above and together with electromagnetic waves having a wave length outside the visual spectrum, will cover the various energy sources that can be employed as distinct from visual light.

As shown on the accompanying drawing, cassette 1 includes a conventional black-and-white X-ray film 2 and color film 3, and lead foil 5. In Figure 3 the developed films 2d and 3d are shown mounted on a viewing device or support 4 for viewing by transmitted light for comparison purposes. In Figure 5 the cassette 1a is shown as containing two emulsion carrying elements of the character described herein, in subcassettes 1 and 1b, each subcassette being made of material pervious to non-visible radiant energy but impervious to rays in the visible portion of the spectrum. The cassettes and subcassettes in all instances will completely enclose the films, plates, or other "photographic" elements. Or a dual cassette may be employed, that is a cassette of two separable subcassettes that are complete cassettes within themselves when separated. In this way each element may be con-

tained within a subcassette pervious to non-visible radiant energy but impervious to rays in the visible portion of the spectrum, the subcassettes being separable for separate treatment. The subcassettes may be detachably joined together as physically along their edges, or by a cement pervious to the non-visible radiant energy. After exposure the subcassettes may be separated for individual development and other processing, the subcassette serving to protect the exposed film until processed. Cassettes and subcassettes may be made of paper, cardboard or other conventional material. Subcassette 1b does not contain lead foil when placed in position in front of cassette or subcassette 1. An alternate method is to place film in front of subcassette 1 and within cassette 1a, thus eliminating subcassette 1b. It being also possible for cassette 1 to form part of the cassette 1a. Any of these cassettes may also be subdivided, for example, by partition so that only a portion of the cassette may be opened.

In Figure 3, radiograph 2d represents a negative image effect of the type presented by the usual black and white radiographs, while radiograph 3d represents a positive image effect that is in color. In radiograph 2d the direct effect upon the emulsion is strong and the latent image effect is weak, while in radiograph 3d the latent image effect is strong and the areas where the energy had a direct effect is weak or less intense in image contrast or effect. Thus it becomes possible to insure a more complete radiographic presentation for diagnostic analysis than has heretofore been possible. In the black and white type radiograph 2d, the alveolar bone appears dark and almost blends into the background, while in the color radiograph 3d the definition is sharp and clear. The trabecular pattern of the cancellous bone appears sharp and clear in the black and white radiograph 2d where the bone is the densest, however, where this bone is more transparent to radiation, the trabecular pattern is less distinct (in the black and white). In the color radiograph 3d the reverse is true, presenting a clearer and more distinct trabecular pattern in the areas that are more transparent to radiation, and a denser appearing trabecular pattern in the area where the cancellous bone is densest. The periodontal membrane appears dark and the lamina dura appears light in the standard black and white type roentgenogram 2d, while the color roentgenogram presents the periodontal membrane in a lighter colored area and the lamina dura in a darker colored area. The biting surfaces of certain teeth often appear dark and almost blend into the still darker background of the black and white type radiograph 2d, while in the radiochromograph 3d, the sharp clear definition of the same teeth permits the diagnosis of caries in these areas in earlier stages. To contrast this, the pulp chamber and root canal appear as a medium dark gray (comparatively speaking), in radiograph 2d, and as a lighter colored area in radiochromograph 3d. The enamel and some dentin areas show lighter achromatic images in radiograph 2d, and darker chromatic image rendition in the radiochromograph 3d. Some dentin areas which render lighter achromatic images in radiograph 2d present themselves as darker images with some chromatic or tonal contrast in the radiochromograph 3d. The contrast between the pulp chamber and the dentin sometimes appears sharper in the black and white radiograph 2d than in the radiochromograph 3d for certain teeth. Certain types of root and root tip conditions or pathology that sometimes also affect the cancellous bone are often readily identifiable in the type of radiograph represented by 2d, showing good detail in the central areas of such disturbances, but often lacking defining limits, while the type of radiograph represented by 3d will usually define the limits of such disturbances clearly and with good detail.

Thus comparative differential and color radiography presents a more complete diagnostic opportunity, permitting confirmation by comparison of suspected patho-

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logical disturbances. The methods, techniques, materials, and articles herein set forth present a greater diagnostic range with "on-the-spot" confirmation that has not been possible with or by the use of the prior art methods, techniques, materials, or articles. These applications apply similarly in medicine, science, and industry.

The following examples illustrate the invention.

I

A paper or cardboard cassette was made up containing "Ansco" color film (daylight) and conventional dental X-ray film (Du Pont "S" type), the films being in juxtaposition for simultaneous exposure. The size of the cassette and films was the conventional size for dental X-ray use and conventional dental X-ray equipment ("Ritter" or "XRM") was employed. Exposures were made in accordance with the standard exposure chart and technique for the conventional Du Pont "S" type X-ray film, using 65 kilovolts and ten milliamperes. The "Ansco" film was developed with the standard "Ansco" kit while the conventional X-ray film was given standard conventional treatment.

Different times of exposures using Ansco color films resulted in images in brown and yellow, dark tan and light tan, brown and greenish yellow, and brownish-gray with a conversely proportional yellow. Varying time in the development-temperature exposure relationship, sequence, and manipulation by changing the order of processing produced the different color effects. Further, variation in the resultant color effects may also be obtained by different modifications of the procedures in processing or by modifying the strength or constituents of the various baths, or by processing "Ansco" color film in an "Ansco" Printon Kit, etc.

One of the examples set forth above produced a brownish gray and conversely proportional yellow radiograph simultaneously with the standard black and white type radiograph. The black and white type radiograph showed a pathological disturbance at the root tip, but did not define its limits too clearly. The radiochromograph (color radiograph) presented a clearly defined line of demarcation as the limits of this pathological disturbance at the root tip. The effect of this pathological disturbance on the root canal and the pulp chamber appeared to be a little more sharply defined in the black and white type of radiograph than in the radiochromograph. A multiple type cavity in the same tooth showed clearly in the black and white radiograph, but only showed the limits of this cavity and lacked the detail within the cavity limits and almost three-dimensional effect that appeared in the radiochromograph.

The conditions of exposure, both the kilovoltage and milliamperage may be varied. It was found that change in the kilovoltage alone maintaining the milliamperes constant varied the colors slightly, while a variance in both kilovoltage and milliamperage gave further changes in color values. Voltage as high as 100 or 110 kilovolts and amperage ranging from five to ten to 500 milliamperes may be used and even higher values, but it is unlikely that normal radiology will require such high effect. In some cases in commercial and industrial work such higher ranges may be desirable. Variation in kilovoltage and especially milliamperage may also be employed in connection with substantial reduction in exposure time, and for example, it was found that the exposure time could be cut as much as half as compared with exposures employed under the conditions set forth in the examples. Variations in these factors including variation in kilovoltage, milliamperage, and exposure time will frequently result in variation in the resultant color values of the detail in the image when selected processing technique is or is not modified for the variation in exposure factors.

II

A paper or cardboard cassette was made up containing

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"Kodak Ektachrome" film and conventional dental X-ray film (Eastman Kodak "Radiatized") the films being in juxtaposition for simultaneous exposure. The size of the cassette and films was the conventional size for dental X-ray use and conventional dental X-ray equipment ("Ritter" or "XRM") was employed. Exposure was made using the standard exposure chart for the Eastman "Kodak" "Radiatized" dental films at 65 kilovolts and 10 milliamperes. The "Ektachrome" film was developed by using the standard "Ektachrome" kit available on the market. The conventional X-ray film was given standard conventional treatment.

The "Ektachrome" film under different times of exposure, produced images in dark tan and light tan, brown and greenish-tan, brown and yellow, brown and green, and brown or reddish-brown and orange-yellow. Images in brownish-gray and green or cyan were also obtained. Modification in processing times and temperatures, techniques, and/or sequence varied the color radiograph images, similar to the modifications in processing as set forth in Example I.

In this example, as in the preceding examples, results were obtained as specified in the description of Figure 3; however to further demonstrate these applications, the brownish-gray and green or cyan radiograph and black and white type radiograph which were made simultaneously compare as follows. The alveolar bone, the periodontal membrane, the lamina dura, and portions of the cancellous bone that provided generally weak detail in the black-and-white radiograph appeared in more detail and better contrast in the radiochromograph. The pulp chamber and root canal provided a sharper and clearer image rendition in the black and white type radiograph than in the radiochromograph. The outer surfaces of the teeth, especially the biting surfaces, were much more clearly defined in the radiochromograph than in the black and white type radiograph. Areas of deciduous root resorption that were not symmetrical and were associated with areas that contained a variable pattern of the bone trabeculae or partitions required both types of radiographs to present complete detail for analysis and to confirm the patterns and areas and limits of suspected pathology. Detail that was poorly defined in the black and white radiograph was well defined in the radiochromograph, while detail that was poorly defined in the radiochromograph appeared to have better definition in the black and white type radiograph.

To exemplify the differentiation of the present invention from attempts to reproduce color films or photographs of the usual type, it may be noted that it was found that the time in the development baths could be shortened in the procedures utilizing the "Ektachrome" or "Ansco" development outfit, or varied to correct for under-exposure or over-exposure however, it should be noted that changes in developing time may also vary the colors and color values and contrast, which may be desirable.

III

A paper or cardboard cassette was made up containing "Ansco" color film and "Ektachrome" color film, the films being in juxtaposition for simultaneous exposure. The size of the cassette and films was the conventional size for dental X-ray use and conventional dental X-ray equipment ("Ritter" or "XRM") was employed. Exposure in a patient's mouth was made in the conventional way using 65 kilovolts and 10 milliamperes. The "Ansco" film was developed with the standard "Ektachrome" kit and the "Ektachrome" film was developed with the "Ansco" kit.

The "Ansco" color film produced images in blue with an inversely proportional magenta or reddish-magenta. The "Ektachrome" color film produced images in various densities and tones of blue and green. Modification of

procedures, etc., as set forth above may be used to modify the color effects further.

Among the various comparative examples made by this method, results somewhat similar to the other examples were found; however, to further explain this example, it was found that the internal structure of the tooth such as the pulp chamber, root canal, and dentin, etc., appeared in better detail of low contrast in the "Ektachrome" film when processed as specified in this example. The "Ansco" color film produced much more sharply defined images in contrasting colors of the lamina dura, the periodontal membrane, and the enamel surfaces, etc. Both films together thus give complete detail of areas such as the cancellous bone, the trabecular patterns, etc., and of other portions, some of which are specified above, for the complete detail necessary for diagnosis.

IV

A paper or cardboard cassette was made up containing "Ektachrome" color film and Du Pont "D" type dental X-ray film, the films being in juxtaposition for simultaneous exposure. The size of the cassette and films was the conventional size for dental X-ray use and conventional dental X-ray equipment ("Ritter" or "XRM") was employed. Exposure in a patient's mouth was made in the conventional way using 65 kilovolts at 2 milliampere sec. The "Ektachrome" film was developed with the standard "Ektachrome" kit and the Du Pont "D" type dental film was given standard conventional treatment.

The following differences were noted upon comparison of the finished radiographs. The teeth showed a very clear sharp outline in the color radiograph, whereas in the black-and-white standard radiograph sharpness was lacking. The cellular structure of the bone showed much more clearly and in more detail in the color radiograph than in the "D" radiograph. In the color radiograph the limits of soft tissue overlying the bone were perceptible while in the "D" radiograph this detail was absent. At the root apex there was a pathological area showing a definite line of demarcation in the color X-ray whereas in the "black-and-white" X-ray, a distinct limit of this area was lacking. By comparison, normal interpretation of this "black-and-white" X-ray gave the practitioner information for certain purposes in accordance with standard practice which was then supplemented by the detail in the color radiograph to assist in diagnosis while the pathological areas disclosed by the color X-ray would give information beyond that available in black-and-white, thus greatly advancing diagnosis and facilitating surgery or treatment for which the surgeon or doctor would be forewarned and prepared.

In viewing or reading comparative radiographs, the use of light sources that can be controlled in intensity, hue, or color further modify and enhance the viewed color radiographs; likewise the use of polarized light and/or light filters produce unusual and important effects that vary in accordance with the type of film and/or exposure and/or processing techniques. Other light sources such as ultra-violet and/or infra-red also produce unusual effects in the viewing of certain films, especially when such films contain fluorescent elements that respond to any of the certain light sources that may be used in viewing the radiographs.

Thus two superimposable exposed radiographs that produce different image effects after processing may be further modified by methods or types of viewing equipment to produce or reveal diicroic or modified variable image effects on certain films or emulsions that would not be readily apparent when viewed by standard types of viewing equipment or methods in which only the intensity of light is varied. Comparative analysis by these aforementioned methods, of two radiographs with different image effects provides the opportunity for more complete diagnosis by the further or additional evaluation of

variations in image effects produced by variable viewing equipment and methods, etc.

The photographic laminations of the present invention may be used in any field where standard X-ray films and sub-atomic particle tracking plates and films have heretofore been used. The results obtained in any such fields due to the production of color radiographs as taught herein give new techniques and facilities of the greatest and most fundamental importance in said fields, results apparent from the description given above. Thus considering the fields of use of X-rays, the two main arts include industrial and medical applications. Industrially, applications of the invention include utilization in macromolecular and micromolecular fields among which may be mentioned quantitative analysis, radiography, microradiography, crystal analysis, e.g. X-ray crystallography, spectroscopy, etc. Medically, applications in radiography are particularly important. In addition, utilization as a tool or technique in research in any of the mentioned fields and in the study of sub-atomic particles and electromagnetic waves other than the visible spectrum are of great importance, as for example in tracking mesons, protons, neutrons, etc. and the effects of such particles on atoms of various elements. Applications in autoradiography, electron microscopy, stereoradiography (including analglyphic, and "Polaroid" and "Polaroid" plus color stereo-radiography, etc.), etc. offer additional utility.

Having thus set forth by invention, I claim:

1. A cassette for radiography, the cassette being pervious to non-visible radiant energy but impervious to rays in the visible portion of the spectrum, said cassette containing a plurality of separate and distinct superposed ray-responsive emulsion carrying elements for radiography, each element being complete to yield a radiograph, one element yielding a radiograph of different color values from the other on simultaneous exposure and subsequent development, whereby from a single exposure, separate and distinct radiographs for comparison are produced having superimposable images but in different color values, the color including at least one color in the visible spectrum between the infra-red and the ultra-violet.
2. A cassette as in claim 1 in which the elements are in the form of photographic film.
3. A cassette as in claim 2 in which the elements are X-ray responsive.
4. A cassette as in claim 2 in which the elements are γ -ray responsive.
5. A cassette as in claim 1 in which one of the elements yields on exposure and development a radiograph in black-and-white while another yields a radiograph in color including at least one color in the visual spectrum.
6. A cassette as in claim 5 in which the elements are in the form of photographic film.
7. A cassette as in claim 6 in which the elements are X-ray responsive.
8. A cassette as in claim 6 in which the elements are γ -ray responsive.
9. The method of producing radiographs having superimposable images which comprises simultaneously exposing to the same image at least two separate and distinct superposed photographic elements sensitive to non-visible radiant energy, said elements capable on development of giving separate and distinct complete radiographs of superimposable images but differing in color values from each other, to non-visible radiant energy and developing the simultaneously exposed elements to produce separate and distinct radiographs having superimposable images but in different color values, the color including at least one color in the visual spectrum between the infra-red and the ultra-violet.
10. The method of claim 9 in which the elements are in the form of photographic film enclosed within a single cassette.

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11. The method of claim 10 in which the non-visible radiant energy includes X-rays.

12. The method of claim 10 in which the non-visible radiant energy includes γ -rays.

13. The method of claim 9 in which one of the elements yields on exposure and development a radiograph in black-and-white while another yields a radiograph in color including at least one color in the visual spectrum.

14. The method of claim 13 in which the elements are in the form of photographic film enclosed within a single cassette.

15. The method of claim 14 in which the non-visible radiant energy includes X-rays.

16. The method of claim 14 in which the non-visible radiant energy includes γ -rays.

17. In combination, a pair of developed separate and distinct radiographs having superimposable developed images of the same image produced by non-visible radiant energy one of the radiographs having color values contrasting with the color values of the other.

18. A combination as in claim 17 in which one of the radiographs is in black-and-white and the other is in color including at least one color in the visual spectrum.

19. A cassette as set forth in claim 1 in which each element is contained within a subcassette pervious to non-

visible radiant energy but impervious to rays in the visible portion of the spectrum, the subcassettes being separable for separate treatment.

20. The method as set forth in claim 9 in which each element is contained within a subcassette pervious to non-visible radiant energy but impervious to rays in the visible portion of the spectrum, the subcassettes being separable for separate treatment.

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