July 16, 1963 E. F. WELLER, JR 3,097,522

IMAGE CONVERTER

Filed June 13, 1961

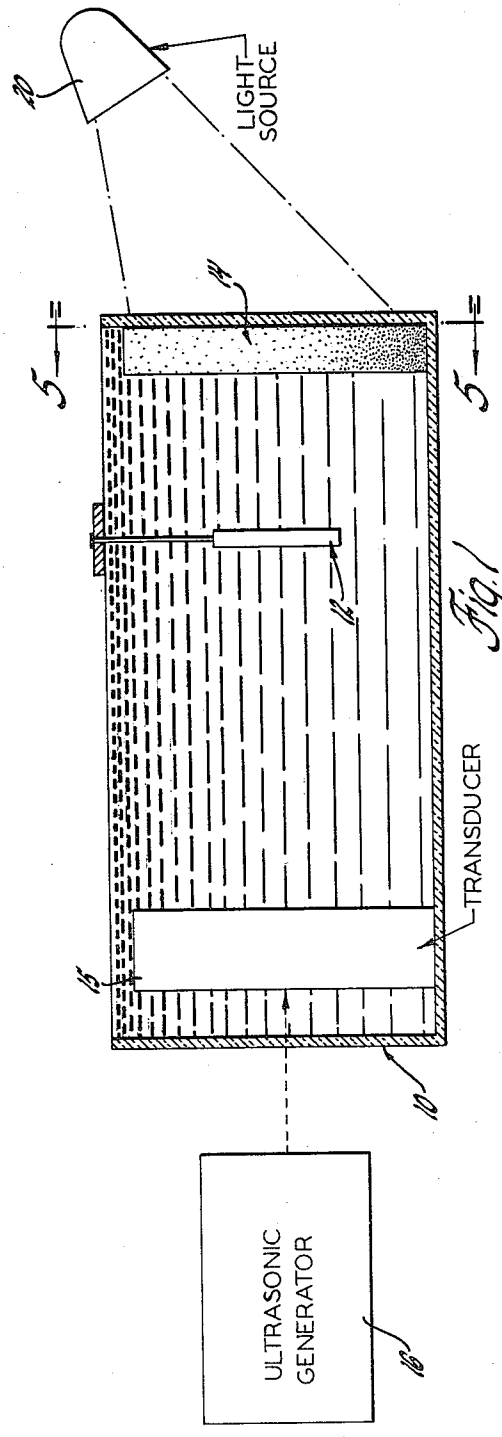


Fig. 1

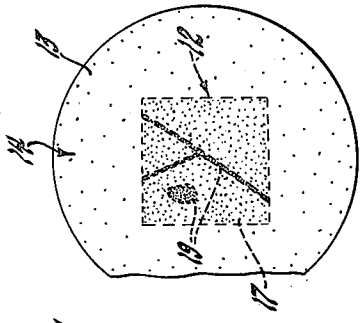


Fig. 5

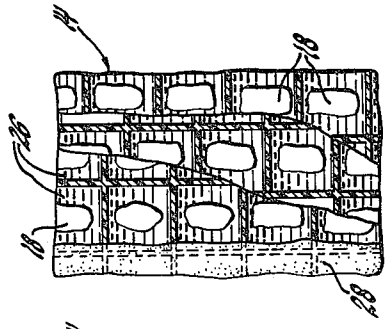


Fig. 4

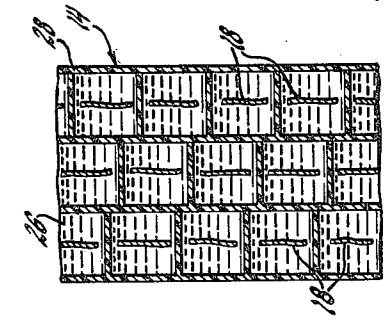


Fig. 3

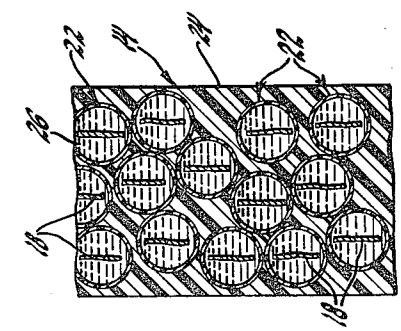


Fig. 2

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IMAGE CONVERTER

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This invention relates to image converters and more particularly to image converters of the type used in ultrasonic systems.

The ultrasonic image converter is adapted to produce an optical image corresponding to the intensity distribution within a beam of ultrasonic energy. Such converters are commonly used in flaw detection systems wherein ultrasonic energy is directed through a test piece so as to impinge upon the image converter. Heretofore, image converters have been constructed by suspending flakes of aluminum or other suitable materials in a liquid medium between two sheets of glass. The difficulty with this type of converter is that over a period of time the flakes will settle to the bottom of the converter thus requiring some means of agitation to re-suspend the flakes before the converter can be used.

With the present invention, the flakes will remain suspended in the liquid medium indefinitely without the application of an agitating means. This is accomplished by providing a transparent rigid member having a large number of compartments each of which contains a small number of flakes preferably a single flake, suspended in a low viscosity liquid.

The operation of this invention will be more easily understood from the following explanation and the drawings of which:

FIGURE 1 illustrates a particular application of the invention to a material inspection system;

FIGURE 2 is a cross-sectional side view of one form of the inventive image converter showing a capsular compartment arrangement;

FIGURE 3 is a cross-sectional side view of an alternate form of the inventive image converter;

FIGURE 4 is a front view in cross section of the alternative form of the inventive image converter shown in FIGURE 3, and

FIGURE 5 is an example of the image which may be observed on the faces of the image converter.

An ultrasonic image converter works on the principle that only longitudinal waves can exist in a liquid. Hence, microscopic flakes suspended in a liquid medium under the influence of an ultrasonic field tend to align perpendicular to the field; that is, the flakes will be aligned normal to the direction of propagation of the ultrasonic wave front. Applying this principle to the system of FIGURE 1, a tank 10 containing water has submerged therein a test piece 12 and the novel image converter 14. A transducer 15 is energized by an ultrasonic generator 16 such that ultrasonic energy vibrations induced in the transducer 15 are transmitted in a plane wave through the test piece 12 and the image converter 14, this energy wave tending to align the flakes 18 in the image converter 14 in a direction normal to the direction of propagation of the wave. If an object, such as the test piece 12 is placed between the transducer 15 and the image converter 14, the plane wave of ultrasonic energy will be reduced by the solid portions of the test piece 12. Thus the flakes in the portions of the image converter 14 under the projected area of the test piece 12 will be aligned to a lesser degree than those flakes which are located outside of the

projected area of the test piece 12. Since a crack or void within the test piece 12 will reflect or absorb ultrasonic energy, the presence of these defects will result in areas within the image converter in which the flakes experience no aligning force whatsoever. Light from a source 20 will, under the proper orientation, be reflected from the flakes 18 in the image converter 14 in varied degrees according to the degree of alignment of the flakes 18 resulting in a variable intensity pattern on the face of the image converter 14 which is an actual representation of the test piece 12 and the irregularities therein. If the light from the source 20 is directed substantially normal to the face of the image converter 14, the area 13 of the image converter face not affected by the test piece 12 appears as a light background against the projected area 17 of the test piece 12 which appears as a gray area, while the area 19 under the flaws appears as a dark spot as indicated in FIGURE 5. In this matter, the presence of a flaw or irregularity in the test piece 12 will be easily detected in a non-destructive type of test.

Referring to FIGURE 2, there is shown a first converter structure for preventing the undesirable settling of the flakes in an image converter which can be incorporated into the system of FIGURE 1, thus eliminating the need for the aforementioned agitation means. In this embodiment of the improved image converter, a plurality of compartments are formed by the microscopic substantially transparent gelatinous capsules 22 which are embedded in or otherwise bonded to a sheet of transparent plastic defining a positioning member 24. The positioning member 24 may be constructed from an acrylic resin material such as methyl methacrylate, which exhibits good optical properties, but the particular composition is not critical to the invention as its function is to rigidly position the capsules 22. Each of the capsules 22 is filled with a substantially transparent, water insoluble medium 26 of low viscosity such as kerosene or mineral oil and has suspended therein a flake 18 which is free to move within the capsule. The flake 18 must necessarily be in the form of a thin lamina of light reflecting material of which aluminum has been found to be satisfactory. The face area of the flake 18 need be of no particular shape although nearly equal dimensions of height and width provide the best operational results. The largest dimension of the flake should be on the order of 40 microns. This largest dimension must necessarily be somewhat smaller than the wave-length of the applied ultrasonic energy in order that the flake-aligning forces can be exerted by the ultrasonic energy wave. Since the capsule 22 must be large enough to allow complete rotational freedom of the flake 18, a suitable size would be on the order of 50 to 100 microns. While capsule sizes which would contain perhaps three or four flakes would be satisfactory, interference between the flakes indicates that a capsule containing only one flake will provide the best operational results. The capsules 22 are manufactured by a process of microencapsulation and may be obtained from the National Cash Register Company. Since the sharpness of the image observable on the face of the image converter is directly related to the capsule density within the converter as well as the optical qualities of the materials from which the converter is made, the capsules are placed in the plastic positioning member 24 as close together as possible and in a fairly uniform fashion. The image converter need not be more than four or five capsule diameters thick.

It will be apparent that the capsules 22 could merely be placed between two layers of glass or plastic with a

clear oil filling the spaces between the capsules to provide adequate transmission of the ultrasonic wave. However, the arrangement of FIGURE 2 provides certain advantages in handling the image converter with a minimum danger of breakage and spilling of the encapsulated oil.

A second converter structure which prevents the settling of the flakes in the image converter is shown in FIGURES 3 and 4. This embodiment of the inventive image converter includes a transparent member **28** which may be a rigid plastic material. This member **28** is constructed in cellular or honeycomb fashion to form layers of compartments within the member **28**. Each layer of compartments may be individually formed and sealed and then fastened to the other layers. Each of the compartments is filled with the previously mentioned low viscosity oil **26** and has suspended in the oil a flake **18** which is free to rotate within the compartment. The size requirements of the flakes with respect to the ultrasonic energy wave length and of the compartment dimensions with respect to the flake size are the same as for the capsules and flakes shown in FIGURE 2 and described previously. While the converter of FIGURE 4 is shown as being three compartment layers thick, this is not intended as a limiting figure as more or less layers may be used as desired. However, a maximum number of layers will depend on the strength of the ultrasonic wave. The compartments of each layer are offset from the compartment of the adjacent layer by a degree such that the face of the converter will provide maximum reflectivity to light when the flakes, under the influence of the ultrasonic energy beam, are fully aligned.

It is to be understood that the embodiments shown and described herein are illustrative and that further modifications of this invention may be contemplated by those skilled in the art without departing from the scope and spirit of the invention.

I claim:

1. Means for detecting the presence of an ultrasonic energy field comprising transparent support means defining a viewing screen and having a plurality of compartments therein, each compartment being filled with a substantially transparent liquid of low viscosity and having an opaque flake suspended in the liquid, the largest dimension of the flake being smaller than the wave length of the ultrasonic energy in the liquid, the compartments being large enough to permit rotational freedom of the flakes contained therein, whereby an ultrasonic field impinging upon the compartments exerts a force on the suspended flakes tending to align each flake perpendicular to the ultrasonic field.

2. Means for detecting the presence of an ultrasonic energy field comprising support means including a transparent portion defining a viewing screen, a plurality of substantially transparent capsules disposed over said portion, each capsule being filled with liquid and having an opaque flake suspended therein, the largest dimension of said flakes being smaller than the wave length of said ultrasonic energy in said liquid, said capsules being large enough to permit rotational freedom of said flakes whereby an ultrasonic field impinging upon said capsules exerts a force on the suspended flakes tending to align each flake perpendicular to the ultrasonic field.

3. Apparatus responsive to ultrasonic wave energy comprising a plurality of substantially transparent capsules, each capsule having a quantity of liquid therein, an opaque flake suspended in the liquid, the largest dimension of the flake being smaller than the wave length of the ultrasonic energy in said liquid, said capsules being large enough to permit rotational freedom of said flake, and means positioning the capsules relative to the ultrasonic wave so that a force is exerted on the suspended flakes tending to align the flakes in a direction normal to the direction of propagation of the energy wave, the aligning force corresponding to the intensity of the ultrasonic energy waves.

4. Apparatus responsive to ultrasonic wave energy comprising a plurality of substantially transparent capsules, each capsule being filled with liquid and having a metallic flake suspended therein, the largest dimension of the flakes being smaller than the wave length of the ultrasonic energy in the liquid, the capsules being large enough to permit rotational freedom of the flakes, a member made of transparent material defining a viewing screen, the capsules being embedded in the transparent memebr such that ultrasonic energy waves directed through the transparent member exert forces on the suspended flakes tending to align the flakes in a direction normal to the direction of propagation of the energy wave, the aligning force corresponding to the intensity of the ultrasonic energy waves.

5. Means for detecting the presence of an ultrasonic field including transparent support means one of whose surfaces defines a viewing screen, a light source oriented to direct a light beam upon and substantially normal to the viewing screen, said support means comprising a plurality of layers, each layer having a plurality of adjacent compartments each of which is filled with a substantially transparent liquid of low viscosity and has suspended therein a flake of light reflecting material, the largest dimension of the flake being smaller than the wave length of the ultrasonic energy in the liquid, the compartments being large enough to permit rotational freedom of the suspended flakes, said layers being assembled such that the compartments in one layer are offset from the compartments of the adjacent layers such that an ultrasonic field impinging upon the compartments exerts a force tending to align the flakes perpendicular to the ultrasonic field thereby to reflect the light beam impinging upon the viewing screen.

6. Apparatus for the ultrasonic inspection of objects including a source of ultrasonic energy, transducing means for generating ultrasonic vibrational waves from the energy received from the source, means responsive to ultrasonic wave energy comprising support means one of whose surfaces defines a viewing screen, said means having a plurality of compartments therein, each compartment being filled with a substantially transparent liquid of low viscosity and having an opaque flake suspended in the liquid, the largest dimension of the flake being smaller than the wave length of the ultrasonic energy in the liquid, the compartments being large enough to permit rotational freedom of the flake, the support means being positioned such that the ultrasonic energy from the transducing means is transmitted first through an object and then through the support means such that the flakes tend to align in a manner which is indicative of irregularities in the object.

7. Apparatus for the ultrasonic inspection of objects including a source of ultrasonic energy, a transducer for generating ultrasonic vibrational waves from energy received from the source, an ultrasonic energy detector including a plurality of substantially transparent capsules each having a quantity of substantially transparent liquid therein, and an opaque flake suspended in the liquid, the largest dimension of the flake being smaller than the wave length of the ultrasonic energy, the capsules being large enough to permit rotational freedom of the flakes, and support means positioning the capsules relative to the ultrasonic energy wave so that a force is exerted on the suspended flakes tending to align the flakes in a direction normal to the direction of propagation of the energy wave, the aligning force corresponding to the intensity of the ultrasonic energy waves.

8. Apparatus for the ultrasonic inspection of objects including a source of ultrasonic energy, transducing means for generating ultrasonic vibrational waves from energy received from the source, an image converter responsive to ultrasonic wave energy comprising a plurality of substantially transparent capsules, a member of transparent material, the capsules being embedded in the transparent member, each capsule being filled with a substantially

transparent liquid and having a metallic flake suspended therein, the largest dimension of the flake being smaller than the wave length of the ultrasonic energy in the liquid, the capsules being large enough to permit rotational freedom of the flake, the image converter being positioned such that ultrasonic energy from the transducing means is transmitted first through an object and then through the image converter whereby irregularities in the project produce a visible image on the face of the image converter.

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