

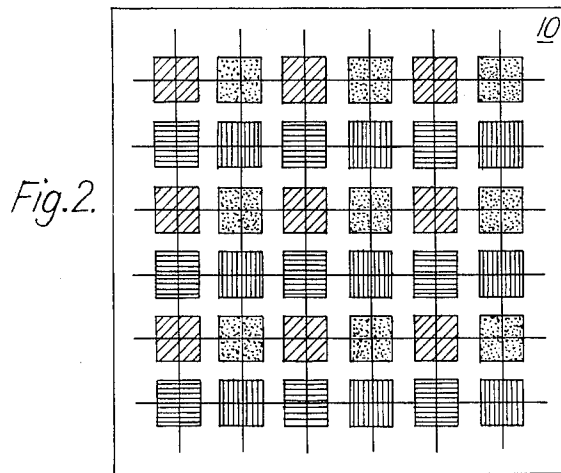
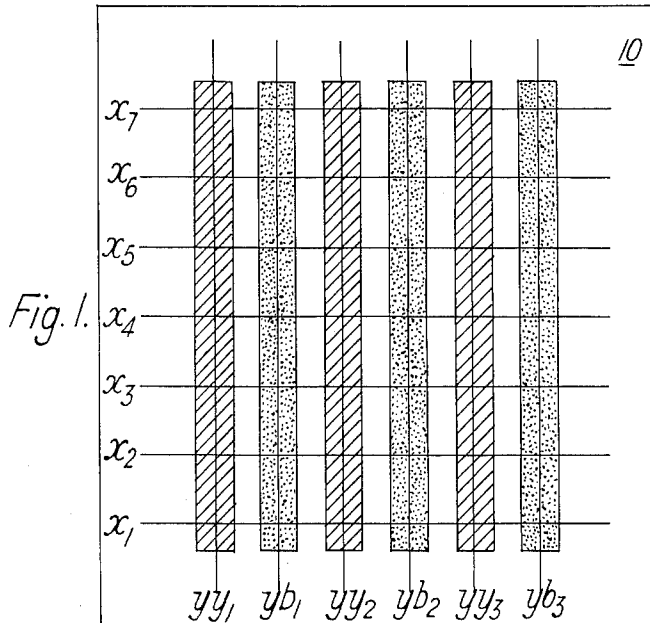
June 28, 1966

J. R. ACTON
DISPLAY PANELS WITH ELECTROLUMINESCENT AND
NONELECTROLUMINESCENT PHOSPHOR DOTS

3,258,628

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4 Sheets-Sheet 1



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Fig. 3.

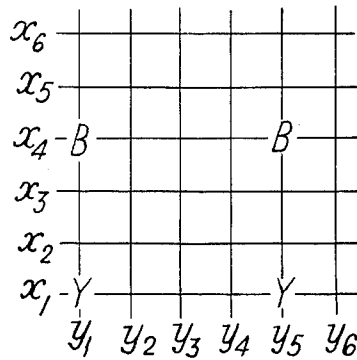
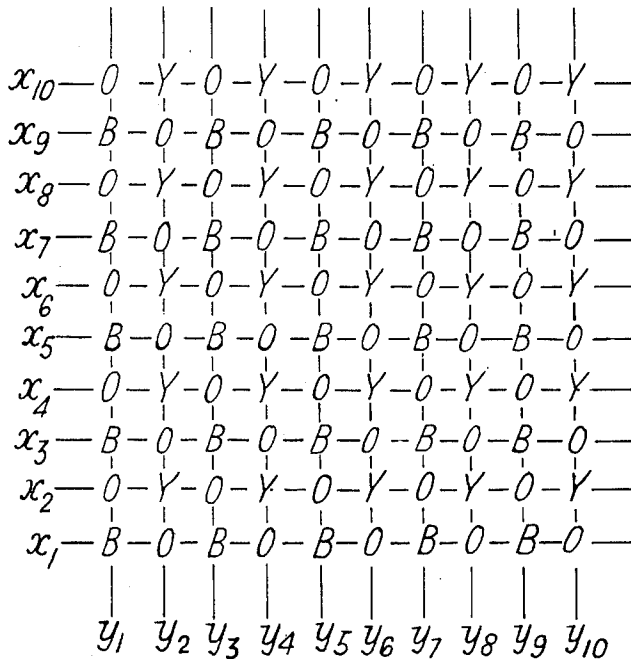


Fig. 4.



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FIG. 5.



FIG. 6.

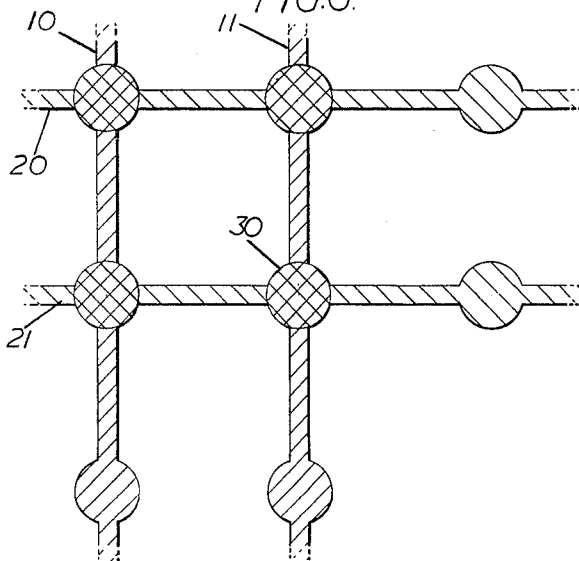
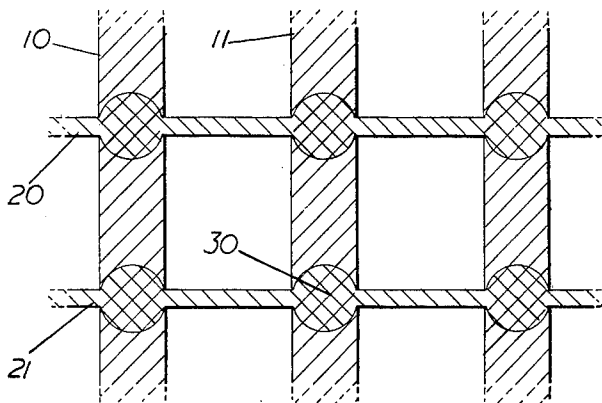


FIG. 7.



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FIG. 8.

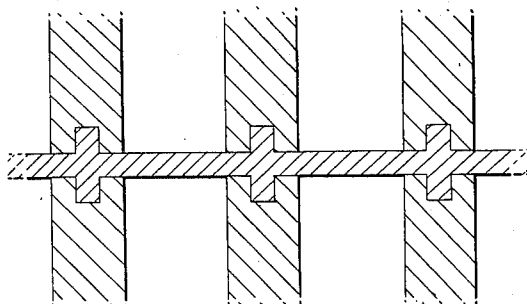
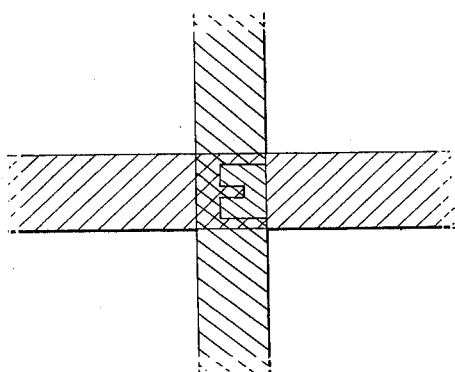


FIG. 9.



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DISPLAY PANELS WITH ELECTROLUMINESCENT AND NONELECTROLUMINESCENT PHOSPHOR DOTS

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3 Claims. (Cl. 313—108)

This invention relates to electroluminescent display panels.

An electroluminescent display panel may consist of a number of individual display elements, any one of which may be illuminated by making appropriate connections. This is accomplished by providing both front and back conductors in strip form, so that the front conductor may for instance be divided into ten long narrow strip conductors, each with a separate connection to it, and each insulated from the remainder, while the back conductor is similarly divided but the strips are made to run at an angle, usually a right angle, to those of the front conductor. Effectively, this breaks the panel up into small separated squares or elements, which may be defined by specific co-ordinates, each square corresponding uniquely to a cross-point of a selected back and front conductor. The ten back conductors and the ten front conductors have 100 points of crossover, and in general M and N front and back conductors give MN cross-points, each cross-point corresponding to the possibility of causing the intervening phosphor to emit light. It is convenient to denote the successive conductors as $x_1 \dots x_2 \dots x_m \dots x_M$, $y_1 \dots y_2 \dots y_n \dots y_N$, and to define a cross-point by its co-ordinates $x_m y_n$. It will be apparent that a crossed array of the kind which has been mentioned must have at least two front conductors and at least two back conductors, and at least one of these sets of conductors must be transparent or translucent, in order that the glowing phosphor may be perceived. On the other hand, the parallelity, straightness, and precise cartesian arrangements of the co-ordinates are not necessary, other co-ordinate arrangements, such as tri-linear, circular, and elliptical may be employed, and the co-ordinates may have any suitable shape as well as simple rectangular strips. Crossed arrays of the kind described may be used for displaying in graphical form values of y for values of x . Consider for instance the case where it is desired to indicate the temperature of and pressure in a number of reaction chambers. These physical parameters may be reduced by known means to electrical signals whose intensity corresponds to the magnitude of the original data, and these electrical signals may be fed into analogue to digital converters. These devices may be arranged so that one only of a certain number of switch contacts is closed, depending on the magnitude of the electrical signal, so that the original data is converted into a series of discrete functions. Thus a temperature of between $-1/2^\circ$ and $+1/2^\circ$ C. may close a particular contact, which we may call the 0° C. contact, and a temperature of between $+1/2^\circ$ and $+1 1/2^\circ$ may close a further contact, which we may call the 1° C. contact and so on. Using a conventional crossed array it is possible to connect the x_1 strip to a suitable array power supply, and simultaneously to connect the temperature measuring device of the first reaction chamber to the analogue to digital converter. This will close a contact which connects the appropriate y strip to the other terminal of the array power supply, so that a spot appears whose x co-ordinate indicates that the first chamber is being examined, and whose y co-ordinate is proportional to the temperature in that chamber. The next step connects the second chamber to the analogue to digital converter and connects the second x strip to the array

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power supply. By stepping rapidly, a series of dots will be produced on the array, giving a graphical picture of the temperature in the various reaction chambers. A similar array, connected to a converter which is fed with the pressure data, would record the successive pressures.

It is apparent that in many cases it would be convenient to display both parameters on a single display panel.

It is an object of the present invention to provide a display panel on which more than one parameter may be displayed simultaneously and distinctively.

According to one form of the invention, there is provided an electroluminescent display panel which includes a number of electroluminescent display elements each positioned at a cross-point of a co-ordinate array, each element being of one of a plurality of element types distributed throughout the panel in a repetitive pattern.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

FIGURE 1 shows a first embodiment of the invention;

FIGURE 2 shows a second embodiment of the invention;

FIGURE 3 is an explanatory diagram;

FIGURE 4 shows a third embodiment of the invention;

FIGURE 5 shows a single shaped conductor;

FIGURE 6 shows cross-points of two shaped conductors;

FIGURES 7, 8, 9 show alternative arrangements to that shown in FIGURE 6.

Referring now to FIGURE 1 a substratum 10 of glass is provided with a front conductor divided into long strips 1 mm. wide, each separated by 1 mm. These strips are represented diagrammatically in FIGURE 1 by lines y . In producing these strips, I deposit on one face of the glass sheet 10 a layer of cadmium oxide by reactive sputtering, in known manner. The film of oxide is then divided into separate parallel strips by the use of a photo-resist method similar to that which is used in the production of so called printed circuits. In order to effect this I cover the layer of cadmium oxide with a suitable photo-resist, expose the resist to light through a pattern reproduction of the parallel strips required, develop the photo-resist, and etch the cadmium oxide layer in a dilute acid bath.

I then position a mask, having long slits 2 mm. wide therein with each slit spaced 2 mm. apart from its neighbour, so that the centre line of each slit lies over the centre line of every alternate conducting strip. I then spray a yellow phosphor in an epoxy resin binder onto the plate through the mask, so that each alternate conducting strip yy_1 , yy_2 and yy_3 is covered with a yellow phosphor layer. I then move the mask so that the centre lines of the slits in the mask correspond to the centre lines of the remaining conducting strips, yb_1 , yb_2 and yb_3 , and a blue phosphor layer is sprayed on.

I now have part of an array in which the phosphor layer is composed of alternate bands of yellow and blue phosphor. Under the central portion of each band there lie a conductor. Finally I reactively sputter cadmium oxide onto the back surface of the phosphor layer and etch it at right angles to the front conducting strips to form the other co-ordinates shown in the figure as x_1-x_7 .

In use, I operate the device in the same manner as a simple array, except that the blue strips may be used to display one variable, and the yellow strips another. Thus, in the example which has been described the temperature analogue is fed to an analogue to digital converter whose contacts join the appropriate yellow strip conductors yy_1-yy_3 to the terminal of the array power supply, while a separate converter for pressure feeds the blue strip conductors yb_1-yb_3 . Thus, as scanning of successive x positions is carried out, two spots are illuminated, one blue and one yellow, indicating pressure and temperature for successive chambers.

It will be apparent that the device is not limited to crossed arrays capable of displaying only two y values since if every third strip is of a third colour, this will produce a three colour system with the possibility of simultaneously illuminating three colour spots, and thus displaying three variables.

Reverting to the two-colour panel just described, it is possible to use it in a number of different ways, of which the following is an example. Suppose that the reactors have an optimum value for pressure and for temperature, and that the x scales are arranged so that one x value represents the optimum value of both variables. The optimum pressure for one reactor may thus be represented by two dots in this row, one in the column yy_1 and the other in the column yy_2 . Then, when the reactor also stands at the optimum temperature a blue dot will appear between the two yellow dots in the same horizontal line. The blue dot will be in column yb_1 . With this arrangement, two yellow columns and a single intervening blue column are required for each reactor. This requirement may be met either by using a panel of the type described and leaving alternate blue columns, e.g. yb_2 , disconnected, or by providing a panel from which the unused blue columns are omitted. With the latter arrangement, the repetitive pattern will consist of two yellow columns alternating with a single blue column.

If colour-sensitive material, for instance colour photographic printing paper, is pressed against an array made in accordance with the above description, having a thin transparent back conductor, a coloured record of traces may be obtained.

It must be recognised that the coloured spots are not coincident, but are displaced by one line in one co-ordinate direction, although, in the arrangement shown in FIGURE 1, they are coincident in the other direction. Graphs plotted will therefore be of two types according to whether the colour co-ordinate of the array is designed as ordinate, or abscissa. Thus according to the manner in which the array is used there may or may not be a displacement between the two traces when the same curve is being represented. It will be further apparent that allowances may be made to provide for this phenomenon.

FIGURE 2 shows an extension of the invention, where the front and back conductors are produced in the manner described, but where the phosphor layer is sprayed through a mask which is composed of square holes instead of strips, spaced by a dimension equal to their side, this dimension being a multiple (usually twice) of the spacing between conductors. In this way it is possible to produce a dot pattern of phosphors, and FIGURE 2 shows a 4 colour dot system in which every dot has an intersection of the crossed array beneath it. It will be apparent that this may be extended to m by n colours, e.g. $3 \times 3 = 9$ colours, by suitable masks where m and n are integers. By making appropriate successive connections it will be apparent that no less than four different coloured traces can be produced to display four variables on the same array.

While I have described specific embodiments of the invention applied to a simple form of crossed array it will be apparent that the invention is applicable to more complicated devices, for example those in which the dielectric or phosphor layer is composed of several individual layers, for example an array having a phosphor layer, and a photo-conductive layer in apposition between the rear and front conductors. Again, an element may be provided with a layer of suitable material to impart a distinctive colour to light emitted by a phosphor layer of the element.

While I have also described a specific method of carrying the invention into effect, it will be apparent that the invention is not so limited, since there are many known ways of providing the front and back conductors and the phosphor layer for example, any of which might be used. Similarly I do not limit myself to phosphors in epoxy

resin binders, since although these are convenient, many other binders are possible. I have also described the invention as employing phosphors having differing colour light emitting properties, but I may use phosphors having differing intensities of one colour so that, for example, half tones may be reproduced. Instead of or as well as using different colours or different intensities of one colour to distinguish elements used for different variables, a perforated screen or screens may be used to provide one perforation for each element, the perforations being shaped to impart distinguishing cross-sectional shapes to the light beams emitted by the elements.

One difficulty arises in the use of panels as just described. Referring to FIGURE 3 which shows in diagrammatic form a crossed array having conductors x_1-x_6 , and y_1-y_6 , and on which the phosphor spots are represented by letters at the intersection of the conductors, suppose it is desired to light, simultaneously, the yellow spot at x_1y_1 and the blue spot at x_4y_5 . Now, if the first x_1 and y_1 are connected to the terminals of the supply, the yellow spot will light. Similarly if x_4 and y_5 are connected to the supply the blue spot will light. But when both x_1 and x_4 and y_1 and y_5 are connected simultaneously to the supply four spots will be lit corresponding to the co-ordinates x_1 and y_1 ; x_4y_1 ; x_1y_5 ; x_4y_5 . One way in which this can be avoided is to connect first the pair x_1y_1 , and then the pair x_4y_5 so that when the one is on the other is off. By making the connections so that every pair was connected at least once every 50 milliseconds the persistence of vision would make the display appear continuous. While perfectly satisfactory in many applications it would be an advantage if such an expedient could be avoided.

It is desirable to provide an electroluminescent display panel having a facility that connection to both the spots may be made simultaneously in time, without illuminating unwanted spots.

Accordingly I provide an electroluminescent display panel in which at least some cross-points of front and back conductors are separated by a layer which is an insulator and does not include a phosphor.

In a preferred embodiment each alternate intersection is of the kind described, with the result that the conductors are so arranged that conductors which may be used to light a phosphor of one colour do not cross phosphor patches of another colour, though they will cross patches containing no phosphor.

One embodiment of the invention will now be described by way of example and with reference to FIGURE 4 which shows in diagrammatic form an electroluminescent crossed array.

Referring now to FIGURE 4 the lines x_1-x_{10} and y_1-y_{10} represent front and back conductors, while the letters which appear at the cross-points of these lines represent phosphor patches, yellow patches being designated Y and blue patches B. Patches which are of an insulating nature and which bear no phosphor are designated by the letter O.

The figure shows a blue and a yellow phosphor sprayed on in a characteristic pattern of patches, and between every yellow and every blue patch, a patch which does not in fact bear a phosphor.

The crossed array depicted in FIGURE 4 may conveniently be made by the method described above, but with the difference that when the mask is in position for spraying the patches designated O, the spray is made up either of a plain resin, or of a resin with a non-luminescent filler, e.g. titanium dioxide.

It will be apparent that the function of these patches is simply to insulate the front and back conductors from each other.

It will be apparent that the device depicted in FIGURE 4 is a two colour crossed array having the advantage that when for instance x_1 and x_4 are connected to one terminal of the supply, and y_1 and y_6 are connected to the other terminal, only one blue patch at x_1y_1 , and one yellow

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patch at x_2y_6 light up. In the crossed array shown in FIGURE 4 the intersections $x_m y_n$ where $m+n$ is odd do not correspond to a phosphor patch, and by the method of patterning described two completely different arrays have been made on a common panel, the even co-ordinates of which control the yellow display and the odd co-ordinates of which control the blue display.

In further embodiments I may use more than two colours. Further, although spraying through a mask is a convenient way of effecting the pattern of patches, it will be apparent that many other methods of obtaining this result may be used. One example is silk screen printing.

Cadmium oxide is a convenient transparent conductor which may readily be produced in the necessary patterns, but many other transparent conducting materials may be used although it will be apparent that one or other of the conductors must be transparent or translucent in order that the display may be observed.

It is not of course essential that the phosphor patches be of different colours, and if they are made in the same colour two independent spots may be moved independently in much the same way as the two spots on a double beam cathode ray tube.

There is of course no reason why both front and back conductors should not be made transparent to allow for photographic methods of reproducing the traces displayed.

Electroluminescent crossed arrays usually comprise a transparent substratum, which is normally a glass plate, upon which is deposited a transparent conducting film, a layer of suitable phosphor material, and a further conducting film. In effect the phosphor material forms the dielectric between two electrodes which are provided by the two conducting films, and on the application of an alternating voltage across the two conducting films the phosphor emits visible light which light may be observed through the transparent front conductor.

For convenience, the conducting film which is deposited upon the glass plate will be referred to as "the front conductor" while the other conducting film will be referred to as the "back conductor."

In conventional crossed arrays, the conducting strips, as previously described, are in rectangular strip form and they cross each other at right angles, and therefore produce a rectangular spot whose dimensions are fixed by the width of the two conducting strips. For many purposes rectangular spots are suitable, but there are occasions, for example, where I require to differentiate between spots. Some spots which are not rectangular may be desired. Further examples will become apparent.

It is desired to provide a method of producing spots which are not rectangular in form.

FIGURE 5 shows a strip of one conductor, which may be either a front or back conductor etched to a special shape, to produce a circular spot. For clarity the figures do not show either the transparent substratum or the phosphor layers in between the conductors. In producing a crossed array capable of providing a display of circular spots I form for instance the front conductor from reactively sputtered cadmium oxide, which is etched using the photo-resist technique into the characteristic pattern shown in FIGURE 5. This may be accomplished by spraying photo-resist on to a uniform film of cadmium oxide carried upon a glass plate and then exposing the photo-resist to light via a photographic plate. This plate carries the desired pattern, and is clear where the pattern is to be formed. The resist material is hardened by the light in known manner and on development the unexposed resist is removed from the plate except where it is desired to form the pattern. The unprotected cadmium oxide film is etched away using dilute hydrochloric acid, leaving a glass plate covered with strips of the form shown in FIGURE 5.

A layer of electroluminescent phosphor in an epoxy resin binder is now sprayed over the pattern on the sub-

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stratum, and a film of cadmium oxide is deposited in a similar manner on the back of this layer of phosphor. This film is now etched so that a similar pattern is produced on the back of the phosphor layer as at the front, but at right angles to the front one. The spacing between the centres of the dots along a line of the back pattern is arranged to correspond to the spacing between the lines with the front pattern. FIGURE 6 shows a fragment of a crossed array which was made in the manner described, the strips 10 and 11 forming part of the front conducting layer while the strips 20 and 21 form part of the back conducting layer, each strip being patterned in the manner shown in FIGURE 5, in which the spacing between the lines of the back pattern corresponds to the spacing between the centres of dots along a line of the front pattern. It will be observed that the centres of the dots on both patterns coincide, and this was arranged by means of suitable prearranged jigs. It will now be apparent that if, say, the conductors 11 and 21 are connected to an alternating current power supply a circular patch of phosphor lying between these conductors where they cross at 30 will light up.

It will be apparent that it is not always necessary to shape both conductors in order to obtain certain patterns; thus an almost circular dot may be obtained by crossing a conductor of the form shown in FIGURE 5 with a strip conductor whose width is equal to the diameter of the circular dots, as shown in FIGURE 7, and we may obtain many other shapes in this manner. Illuminated crosses are shown for example in FIGURE 8, while the letter "E" is shown in FIGURE 9.

Thus in its widest embodiment I may produce shaped dots in a crossed array by forming one or other, or both electrodes. I may extend this by producing one or other of the array conductors modified to produce letters of the alphabet, figures or other characters, or I may produce arrays in which some or most of the intersections of front and back conductors take the form of simple rectangles, while at least one of the remaining intersections is provided with a suitably modified conductor, which may take any of the forms which have been described. Many other shapes and forms are of course possible.

Furthermore I may produce a crossed array, as described, in which one or more of the conductors, at the cross-points, has been shaped in a cyclic and repetitive manner which bears a definite relationship to the modulus of the array, i.e. to the spacing of the conductors it crosses, so as to produce a repetitive pattern.

It will be further apparent that by providing a crossed array having two or more different shaped sets of spots two or more separate concurrent displays may be provided in one array each identified by the shape of the spots illuminated.

I claim:

1. An electroluminescent display panel for displaying a plurality of values or parameters simultaneously and distinctively on a single panel which includes a set of front conductors, a set of back conductors, at least one of said conductor sets having light-transmitting properties, and the two sets together forming a co-ordinate array of cross-points, a number of different display elements each positioned at a cross-point of said co-ordinate array, each of said different display elements comprising a layer of phosphor positioned between a front and a back conductor of said sets of conductors at a cross-point of the co-ordinate array, means for determining a display feature exhibited by one display element of said number of different display elements on the application of electrical energy to the conductors forming the cross-point at which said one display element is located, and a number of dummy elements each positioned at a cross-point of said co-ordinate array at which no display element is positioned and each comprising a non-electroluminescent insulator positioned between a front and a back conductor of said sets of conductors at a cross-point of the co-

ordinate array, the said number of different display elements with different display features and the said number of dummy elements being distributed throughout the panel in a repetitive pattern.

2. A panel as claimed in claim 1 in which a dummy element is positioned at each alternate cross-point of the co-ordinate array.

3. An electroluminescent display panel for displaying a plurality of values or parameters simultaneously and distinctively on a single panel including a first set of electrical conductors and a second set of electrical conductors, at least one of said conductor sets having light-transmitting properties and the two sets together forming a co-ordinate array of cross-points, a number of electroluminescent display elements, each element being positioned at a cross-point of the co-ordinate array and being one of two types of which the first type appears only at the cross-points of alternate conductors of said first and said second sets and the second type appears only at the cross-points of the remaining conductors of said first and said second sets, and a number of insulating non-electro-

luminescent dummy elements, each dummy element being positioned between conductors of said first and second sets at a cross-point of the co-ordinate array at which no display element is positioned.

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