United States Patent [19]

Barbin

[11] **3,766,419**

[45] **Oct. 16, 1973**

[54] **CATHODE-RAY TUBE WITH SHADOW MASK HAVING RANDOM WEB DISTRIBUTION**

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[73] Assignee: **RCA Corporation**, New York, N.Y.

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[21] Appl. No.: **305,244**

[52] **U.S. Cl.** .... **313/92 B,** 313/348

[51] **Int. Cl.** **H01j 29/06,** H01j 1/52

[58] **Field of Search** .... 313/85 S, 92 B, 348, 313/349, 295

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Assistant Examiner—Wm. H. Punter
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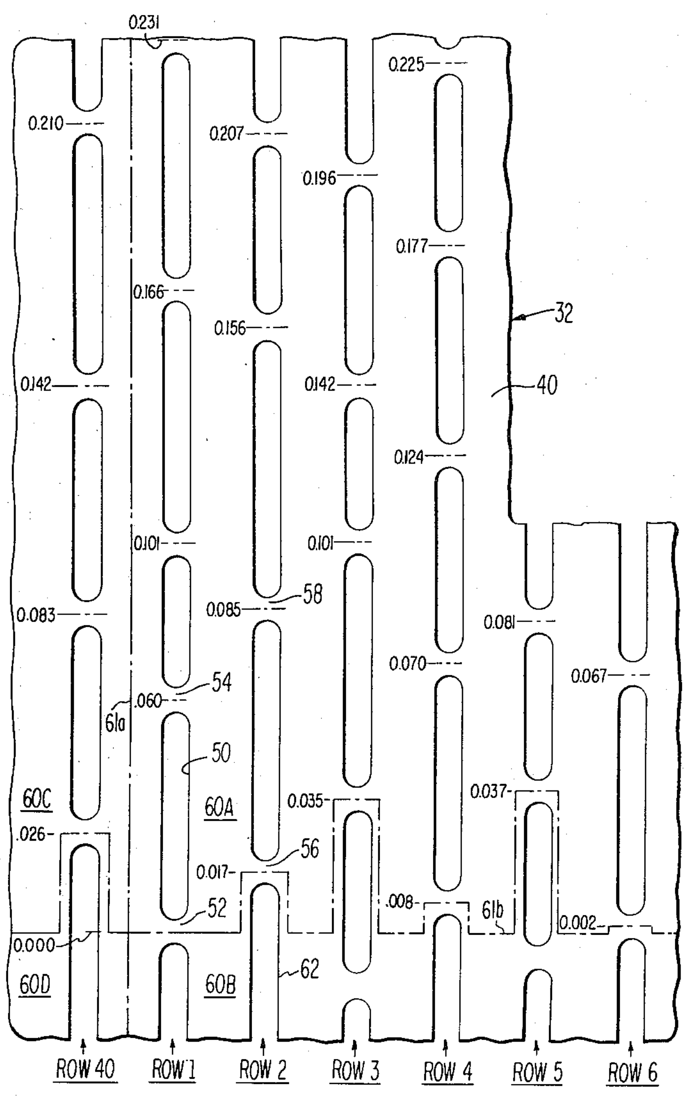
[57] **ABSTRACT**

The problem of moire is eliminated by randomizing the vertical and horizontal pattern of webs between apertures of a shadow mask. A cathode ray tube is provided having a color phosphor screen structure comprising a plurality of arrays of substantially parallel lines. The lines in each array are adapted to emit light of a particular color. A shadow mask, having a plurality of substantially parallel rows of apertures that are elongated in the direction of the rows and separated from adjacent apertures in each row by webs, is spaced from the screen. The webs are randomly spaced along each row and the webs in adjacent rows are randomly displaced from one another in the direction of the rows. Alternatively, the web spacing in each row can be uniform and the rows randomly displaced from one another in the direction of the rows.

15 Claims, 6 Drawing Figures



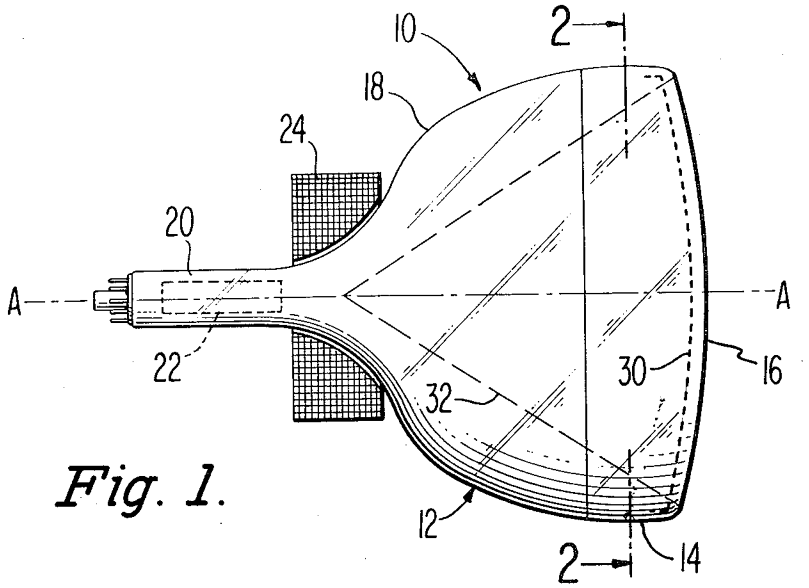

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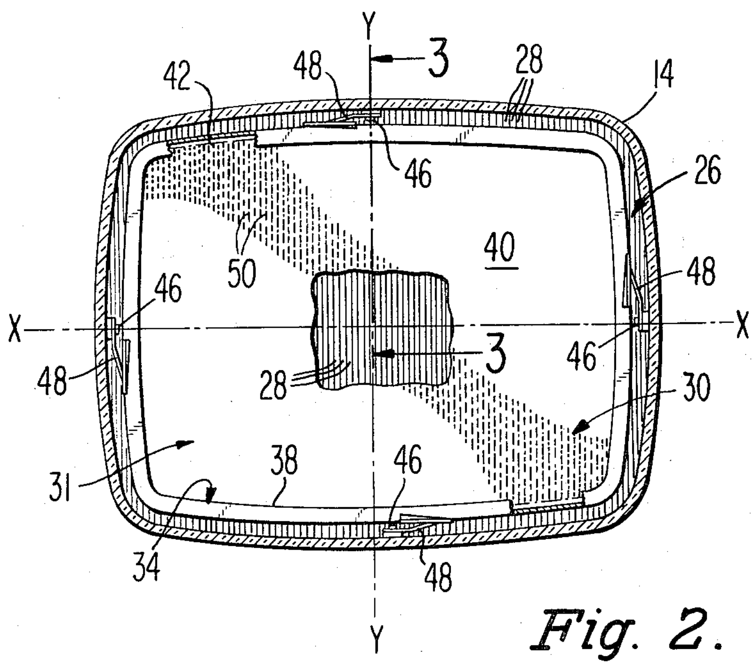
Fig. 1.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X
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3
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38
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34
48
Y

Fig. 2.

PATENTED OCT 16 1973 3,766,419

SHEET 2 OF 4

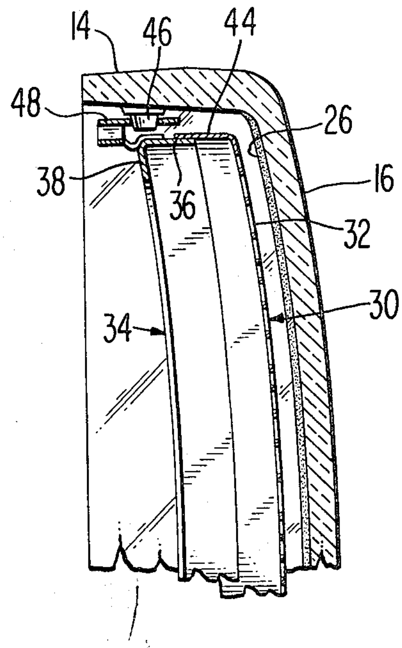


Fig. 3.

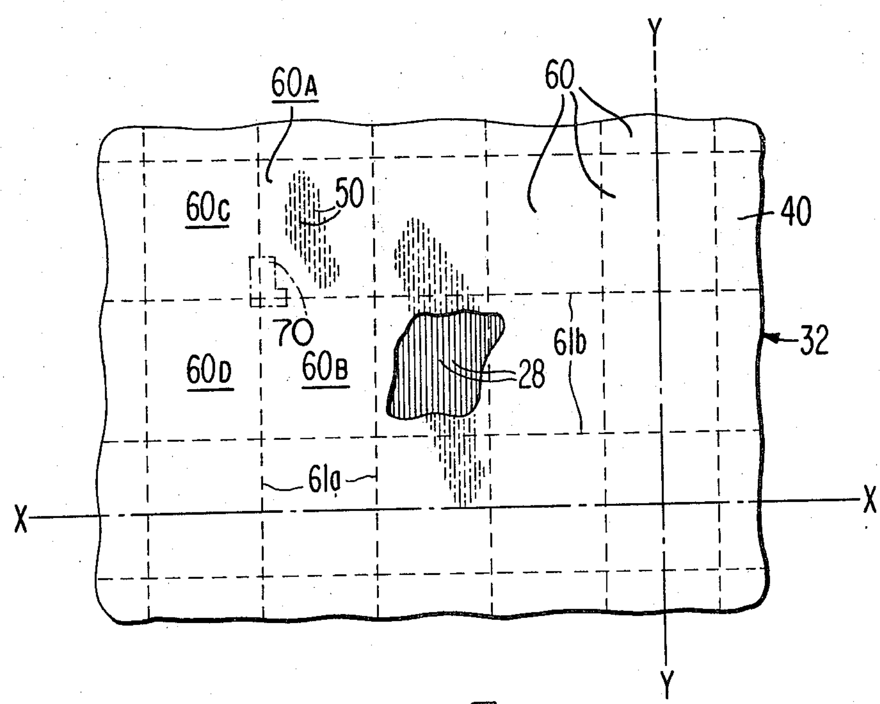
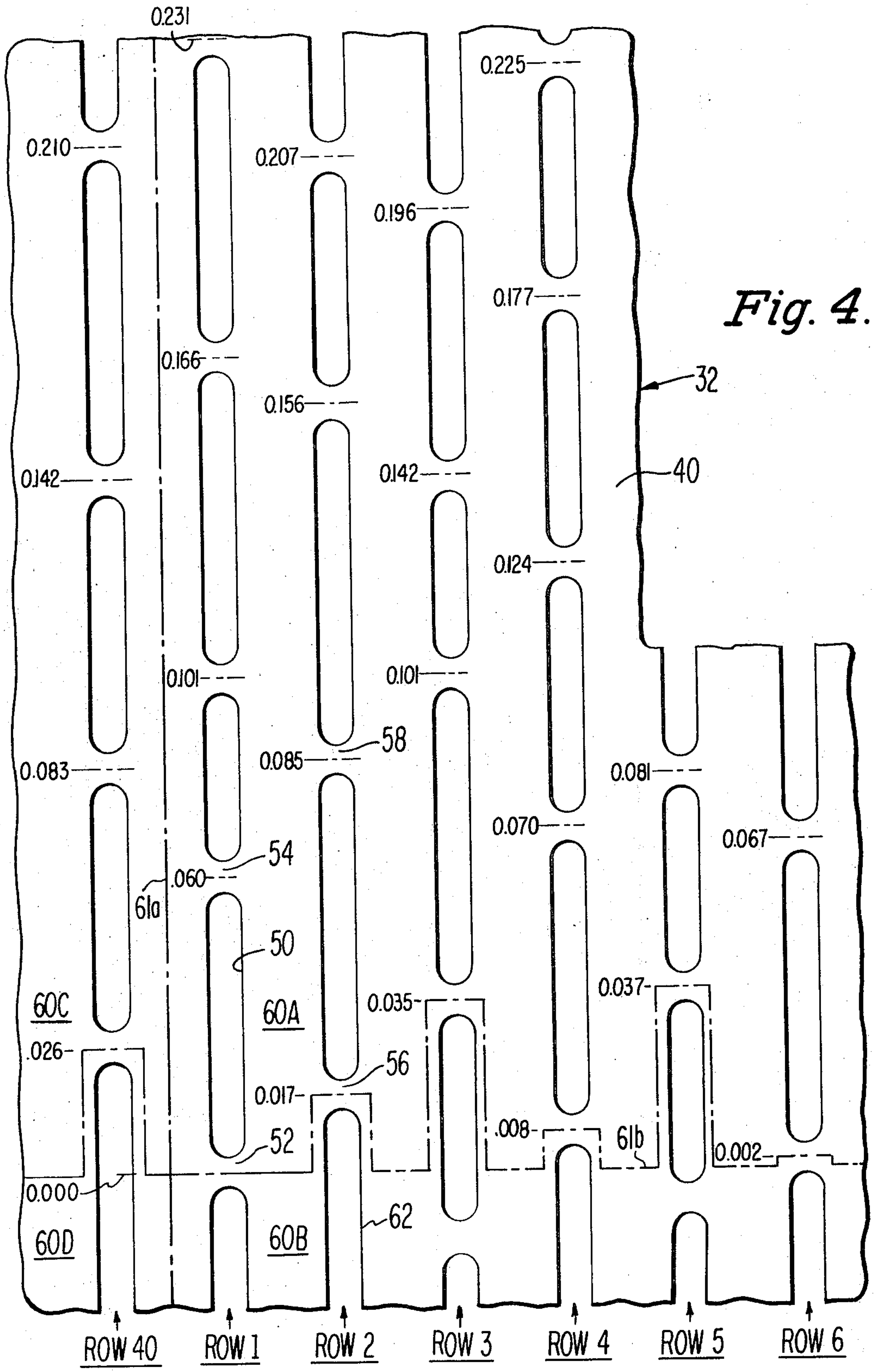


Fig. 5.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.060
54
61a
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60C
60A
0.035
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61b
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ROW 3
ROW 4
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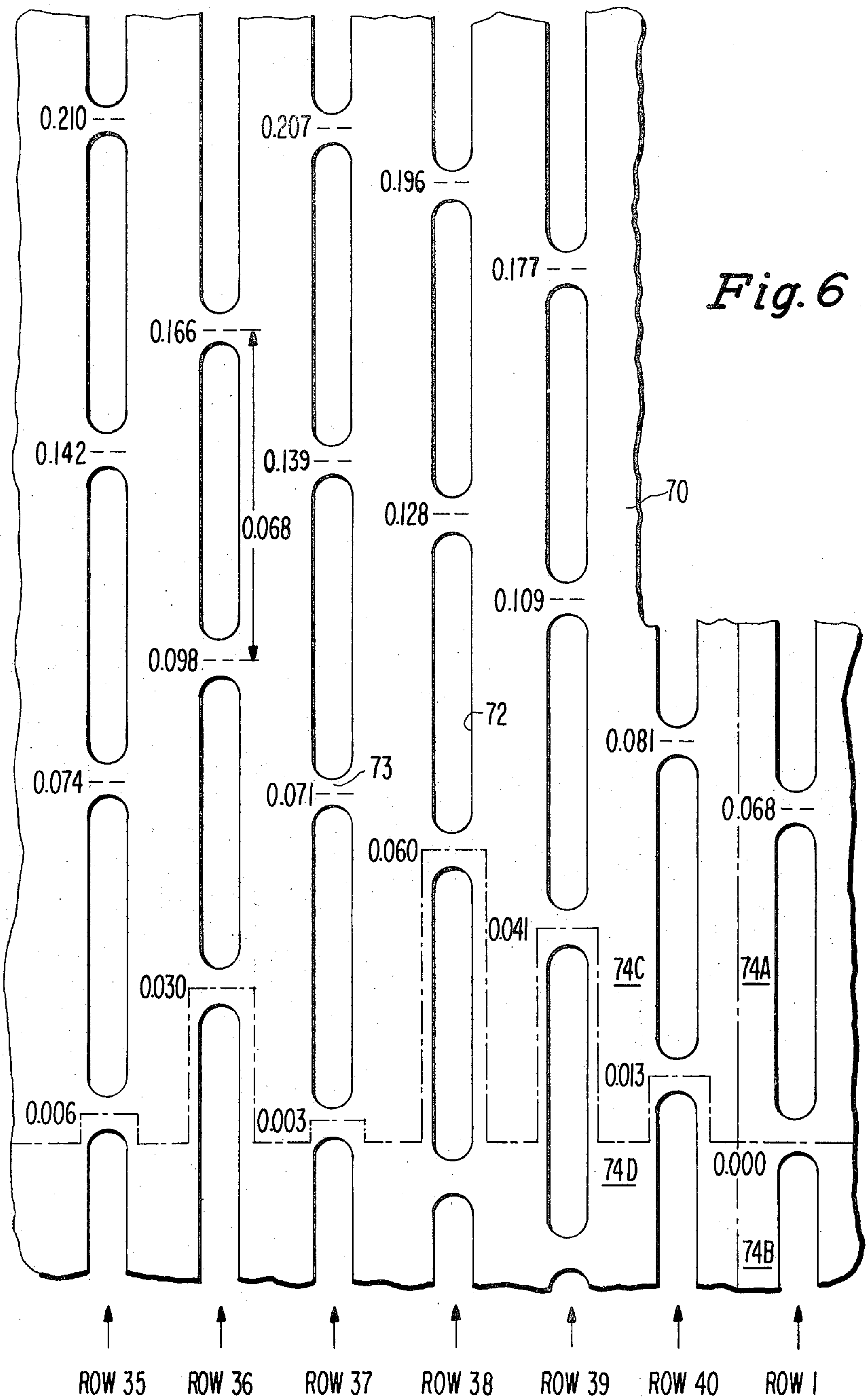
ROW 6

Fig. 4.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0.003
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0.000
74B
ROW 35
ROW 36
ROW 37
ROW 38
ROW 39
ROW 40
ROW 1

Fig. 6

CATHODE-RAY TUBE WITH SHADOW MASK HAVING RANDOM WEB DISTRIBUTION

BACKGROUND OF THE INVENTION

This invention relates to shadow mask type cathode-ray tubes. More particularly, it relates to a color television picture tube having an elongated or slit-type aperture shadow mask.

One of the problems encountered in the use of prior art shadow mask type picture tubes is the phenomenon of moire. Moire appears on a viewing screen as alternating light and dark bands, often resembling a wood grain, that move with changes in scan line spacing and phase. When moire occurs, certain mathematical relationships exist between the vertical pitch of the webs that separate the shadow mask apertures and the vertical pitch of the horizontal scan lines of a raster. The shadow mask apertures, or alternatively the shadow mask webs, in all prior art shadow masks form a regular pattern in the vertical direction and in most prior art masks form a regular pattern horizontally. Scan line pitch is determined by the height of a tube and by the number of scan lines in a raster. When the center of the scan line exactly coincides with the center of the shadow mask apertures, maximum screen illumination is obtained. However, a slight shift in scan line pitch or phase will cause the scan line to impinge partly on the mask webs. As this shift increases, more of the scan line electron beam impinges on the mask webs interposed between the apertures, until finally, screen illumination for a particular line may be completely cut off.

One method that has been found to be effective in reducing moire is to choose the spacing between apertures such that if a first scan line coincides with the center of a row of apertures, the second line will lay halfway between rows of apertures. In this case, a vertical shift in the location of the line causes the first line to get dimmer and the second line brighter so that when the eyes of an observer integrate the light from both lines, the observer does not discern the light and dark pattern. This approach has several drawbacks. For example, it reduces moire only for one scan line spacing and therefore, moire still occurs when there are variations in vertical scan line height and spacing. Furthermore, with this approach different, scan line spacings must be used for different tube sizes and for different scanning frequencies, (e.g., U.S. 525 lines vs. European 625 lines).

The practice of tailoring the web array of a shadow mask for every tube size and raster, considerably increases tube manufacturing costs and difficulties by requiring separate special designs, production, handling and installation procedures for each different picture tube. Moreover, with prior regular mask web arrays, even if no change is made in tube size or raster, pincushion distortion and other television malfunctions that cause imperfect linearity can still produce moire by changing the scan line pitch enough to bring the web pitch to scan line pitch relationship close to a critical value.

SUMMARY OF THE INVENTION

The novel cathode-ray tube comprises a color phosphor screen structure comprising a plurality of arrays of substantially parallel lines. The lines in each array are adapted to emit light of a particular color. A shadow mask, having a plurality of substantially parallel rows of apertures that are elongated in the direction of the rows and separated from adjacent apertures in each row by webs, is spaced from the screen. The rows are randomly displaced from one another in the direction of said rows.

The present invention avoids the problem of moire by randomizing the horizontal pattern of webs between apertures of the shadow mask. Therefore, there is no appreciable variation in electron transmission caused by any degree of shift in scan line pitch or phase since there is no regular or repeatable web pattern.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of a novel shadow mask color television picture tube embodying the present invention.

FIG. 2 is a cross-sectional view taken on line **2—2** of FIG. **1.**

FIG. **3** is a cross-sectional view on line **3—3** of FIG. **2.**

FIG. **4** is an enlarged view of FIG. **5** outlined portion **70** illustrating web and slit details of the shadow mask tube of FIG. **1.**

FIG. **5** is an enlarged view of mask and screen details of the tube of FIG. 1.

FIG. **6** is an enlarged view illustrating web and slit details of an alternate shadow mask for the tube of FIG. **1.**

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1** depicts a novel cathode-ray tube in the form of a rectangular color television picture tube **10** having a longitudinal axis A—A. The tube **10** comprises an evacuated glass envelope **12** including a faceplate panel **14** having a spherically curved, viewing window **16.** The envelope **12** also includes a funnel portion **18** and a neck portion **20.** An electron gun **22** within the neck **20** is adapted to project at least one, and preferably three, electron beams through a magnetic deflection yoke **24** which upon being suitable energized, causes the beams to scan in a rectangular raster over a color viewing screen **26** (see also FIGS. **2** and **3**) on the inner surface of the window **16.** The screen **26** is composed of a plurality of arrays of parallel strips or lines **28** of phosphor fluorescing in different colors. The color strips **28** may, for example, comprise cyclically successive strips of red-emitting, green-emitting and blue-emitting phosphors.

To produce color selection, an apertured, shadow mask **30** which is part of a shadow mask-frame assembly **31,** is mounted adjacent to the screen **26** in the path of the electron beams so that electrons from each pass through the apertures in the mask to impinge selectively upon strips of one emission color on the screen. Dashed lines **32,** outline the average maximum vertical deflection angle for three beams in a 90° rectangular tube.

The shadow mask **30** has a horizontal major axis X—X and a vertical minor axis Y—Y as shown in FIG. **2.** The electron beams scan the mask and screen in a direction transverse to the minor axis. Stated more specifically, the electron beams traverse a multiplicity of substantially horizontally extending, vertically spaced scan lines to produce a raster on the screen.

The shadow mask-frame assembly **32** comprises a somewhat spherically curved, sheet metal shadow mask

30, secured to a frame 34 as shown in FIGS. 2 and 3. The frame 34 may be a continuously formed metal strip of generally L-shaped cross-section. Included in the frame 34 is a first or axial flange 36, which extends in the same direction as the tube axis A—A, and a second or transverse flange 38. The second or transverse flange 38 extends inwardly from the axial flange 38 toward the tube axis and may serve as an electron shield for preventing appreciable impingement of electrons upon the periphery of the shadow mask 30 and upon the axial flange 36 during overscan of the beams at maximum deflection angles.

The shadow mask 30 includes a central apertured portion 40 surrounded by an imperforate border portion 42. The border portion includes a peripheral skirt 44 which extends axially relative to the tube axis A—A and is attached to mask frame 34. The skirt 44 telscopically engages, and is welded to the axial flange 36 of the frame 34.

The mask frame 34 is detachably mounted on the faceplate panel 14 by four studs 46 which are attached to the panel 14 at or near the midpoints of the four sides of the panel. Mask support structures 48 engage the studs and support the mask-frame assembly 31 in the manner disclosed in Sohn U.S. Pat. No. 3,588,568. Of course, other mask support methods also may be utilized without departing from the scope of the present invention.

The apertured portion of the shadow mask 30 includes a multiplicity of apertures 50 in the form of slits for electron transmission through the mask. In FIGS. 1, 2, 3 and 5 of the drawings, the sizes of the slits, as well as of the phosphor lines 28, have been exaggerated for purposes of illustration.

Slits 50 are arrayed in generally equally horizontally spaced parallel rows extending in the direction of the vertical minor axis Y—Y of the shadow mask. The slits are oriented with their major axes aligned with the direction of the rows and extend in the direction of the minor axis Y—Y of the shadow mask. Each row of slits is thereby aligned with a set of phosphor lines that also extend in the direction of the minor axis Y—Y.

Apertured portion 70, outlined in FIG. 5, of the shadow mask 30 also includes a multiplicity of web portions identified as 52, 54, 56 and 58 in FIG. 4. The webs separate the apertures 50 in the direction of the vertical minor axis of the shadow mask.

In contradistinction to the prior art, the distribution of the webs of the apertured portion of the shadow mask 30 is random in the direction of the minor axis Y—Y of the mask and all webs in adjacent rows are randomly displaced from one another in the direction of the rows. That is to say, in contrast to the regular or patterned spacing of the web arrays of the prior art, the vertical spacing of the webs of the apertured portion 40 is random in nature. As used herein, the term "random" refers to chance selection from population which may be restricted in one or more ways.

Another way to characterize the web distribution is that the distribution of the webs is such that the mask does not exhibit any substantial line structure in the direction of the major axis of the shadow mask (i.e., perpendicular to the rows of slits). In prior regular-array masks, the regularity or patterned spacing of the web array established a recognizable line structure in the shadow mask defined by webs aligned along each of a multiplicity of horizontal lines. With a random web array spacing, such as embodied in shadow mask 30, there is no such line structure.

The random nature of the web array spacing of the preferred embodiment is illustrated in FIG. 4 considered in conjunction with the accompanying TABLE of random values for web centerline ordinates, wherein each ordinate corresponds to a distance from a datum to the center of a particular web.

TABLE

WEB ORDINATES (INCHES)

ROW NUMBER

1	2	3	4	5	6	7	8	9	10
0.000	0.017	0.035	0.008	0.037	0.002	0.031	0.006	0.034	0.003
0.060	0.085	0.101	0.070	0.081	0.067	0.097	0.064	0.088	0.064
0.101	0.156	0.142	0.124	0.157	0.112	0.162	0.140	0.161	0.142
0.166	0.207	0.196	0.177	0.193	0.174	0.245	0.198	0.218	0.201
0.231	0.274	0.251	0.225	0.257	0.229	0.317	0.260	0.297	0.244
0.308	0.342	0.299	0.309	0.323	0.292	0.360	0.336	0.348	0.311
0.355	0.386	0.376	0.361	0.381	0.340	0.414	0.374	0.407	0.363
0.417	0.443	0.432	0.415	0.455	0.402	0.464	0.441	0.458	0.421
0.492	0.504	0.490	0.466	0.506	0.479	0.506	0.496	0.528	0.472
0.541	0.560	0.548	0.537	0.583	0.530	0.584	0.548	0.568	0.510

ROW NUMBER

1	2	3	4	5	6	7	8	9	10
0.604	0.625	0.611	0.596	0.637	0.600	0.656	0.613	0.627	0.593
0.657	0.673	0.651	0.675	0.702	0.676	0.696	0.685	0.667	0.650
0.730	0.740	0.726	0.738	0.759	0.723	0.771	0.726	0.742	0.712
0.805	0.792	0.805	0.783	0.814	0.783	0.815	0.799	0.784	0.771
0.849	0.867	0.881	0.833	0.877	0.825	0.864	0.837	0.855	0.834
0.914	0.903	0.926	0.892	0.928	0.889	0.937	0.881	0.914	9.880
0.986	0.957	0.998	0.966	1.001	0.947	1.003	0.959	0.971	0.944
1.035	1.024	1.070	1.013	1.047	1.014	1.045	1.028	1.050	0.996
1.078	1.102	1.144	1.093	1.117	1.079	1.097	1.077	1.125	1.081
1.139	1.160	1.187	1.168	1.194	1.132	1.154	1.143	1.187	1.158
1.200	1.217	1.235	1.208	1.237	1.202	1.231	1.206	1.234	1.203

ROW NUMBER

11	12	13	14	15	16	17	18	19	20
0.030	0.059	0.038	0.057	0.024	0.004	0.024	0.002	0.027	0.001
0.096	0.124	0.080	0.108	0.079	0.050	0.075	0.064	0.085	0.055
0.162	0.190	0.150	0.173	0.126	0.102	0.132	0.108	0.149	0.122
0.216	0.248	0.225	0.238	0.200	0.179	0.203	0.192	0.225	0.164
0.276	0.291	0.269	0.294	0.277	0.236	0.275	0.247	0.263	0.215
0.333	0.354	0.338	0.350	0.324	0.297	0.316	0.293	0.307	0.284
0.403	0.417	0.381	0.395	0.368	0.337	0.389	0.353	0.370	0.323
0.447	0.474	0.442	0.469	0.422	0.408	0.450	0.423	0.434	0.394
0.523	0.539	0.508	0.521	0.482	0.462	0.501	0.471	0.490	0.470
0.573	0.584	0.552	0.570	0.531	0.512	0.549	0.534	0.550	0.530
0.629	0.656	0.621	0.644	0.613	0.593	0.629	0.603	0.624	0.607
0.692	0.721	0.681	0.726	0.664	0.646	0.679	0.655	0.699	0.647
0.753	0.776	0.738	0.799	0.739	0.694	0.754	0.715	0.741	0.724
0.810	0.847	0.814	0.848	0.819	0.767	0.817	0.768	0.803	0.780
0.868	0.891	0.878	0.905	0.871	0.839	0.863	0.828	0.845	0.822
0.921	0.965	0.931	0.970	0.930	0.906	0.926	0.882	0.912	0.895
0.981	1.012	1.002	1.020	0.986	0.958	0.972	0.949	0.977	0.956
1.052	1.063	1.051	1.077	1.038	1.003	1.033	1.007	1.038	1.027

ROW NUMBER

11	12	13	14	15	16	17	18	19	20
1.124	1.113	1.130	1.149	1.102	1.086	1.110	1.089	1.104	1.088
1.172	1.185	1.172	1.210	1.179	1.136	1.180	1.145	1.168	1.153
1.230	1.259	1.238	1.257	1.224	1.204	1.224	1.202	1.227	1.201

ROW NUMBER

21	22	23	24	25	26	27	28	29	30
0.023	0.001	0.018	0.043	0.005	0.042	0.021	0.041	0.020	0.041
0.075	0.048	0.077	0.092	0.062	0.089	0.078	0.103	0.063	0.098
0.150	0.096	0.130	0.146	0.131	0.165	0.149	0.169	0.127	0.157
0.203	0.172	0.211	0.190	0.204	0.243	0.199	0.211	0.198	0.231
0.253	0.237	0.288	0.243	0.256	0.286	0.261	0.283	0.248	0.283
0.308	0.318	0.356	0.313	0.303	0.343	0.313	0.333	0.304	0.331
0.358	0.389	0.406	0.387	0.366	0.393	0.371	0.396	0.346	0.387
0.430	0.462	0.444	0.464	0.427	0.462	0.432	0.468	0.417	0.433
0.491	0.512	0.498	0.522	0.480	0.505	0.489	0.526	0.481	0.519
0.565	0.576	0.559	0.606	0.543	0.576	0.537	0.581	0.542	0.579
0.630	0.655	0.641	0.657	0.592	0.616	0.592	0.666	0.595	0.629
0.699	0.713	0.687	0.711	0.668	0.689	0.641	0.718	0.653	0.681
0.754	0.766	0.752	0.776	0.742	0.767	0.702	0.790	0.700	0.763
0.800	0.822	0.809	0.832	0.816	0.835	0.754	0.828	0.778	0.811
0.845	0.889	0.872	0.891	0.861	0.885	0.816	0.875	0.838	0.869
0.919	0.934	0.949	0.970	0.902	0.934	0.903	0.945	0.886	0.921
1.003	0.979	1.010	1.023	0.948	0.991	0.963	1.004	0.961	0.989
1.054	1.027	1.062	1.075	1.013	1.058	1.020	1.071	1.028	1.071
1.132	1.106	1.117	1.139	1.087	1.103	1.082	1.127	1.097	1.128
1.177	1.149	1.168	1.187	1.152	1.163	1.145	1.174	1.141	1.192
1.223	1.201	1.218	1.243	1.205	1.242	1.221	1.241	1.220	1.241

ROW NUMBER

31	32	33	34	35	36	37	38	39	40
0.024	0.057	0.020	0.038	0.010	0.047	0.001	0.023	0.052	0.026
0.076	0.137	0.075	0.105	0.063	0.092	0.063	0.088	0.105	0.083
0.121	0.184	0.121	0.146	0.124	0.171	0.116	0.141	0.182	0.142

ROW NUMBER

31	32	33	34	35	36	37	38	39	40
0.171	0.263	0.167	0.214	0.185	0.220	0.183	0.209	0.254	0.210
0.247	0.328	0.235	0.279	0.245	0.285	0.250	0.268	0.332	0.281
0.294	0.375	0.294	0.320	0.300	0.331	0.295	0.309	0.398	0.353
0.364	0.432	0.356	0.373	0.347	0.402	0.348	0.379	0.475	0.415
0.416	0.511	0.407	0.441	0.425	0.456	0.425	0.447	0.517	0.467
0.492	0.579	0.491	0.501	0.472	0.536	0.487	0.503	0.557	0.524
0.559	0.624	0.534	0.569	0.556	0.592	0.549	0.579	0.621	0.581
0.607	0.702	0.610	0.630	0.602	0.658	0.611	0.648	0.681	0.642
0.670	0.768	0.684	0.703	0.670	0.732	0.671	0.697	0.738	0.697
0.737	0.831	0.753	0.768	0.745	0.773	0.713	0.753	0.791	0.760
0.797	0.881	0.809	0.821	0.802	0.831	0.792	0.808	0.837	0.821
0.858	0.950	0.853	0.866	0.851	0.881	0.856	0.870	0.915	0.882
0.937	0.986	0.932	0.922	0.908	0.945	0.904	0.930	0.960	0.937
1.010	1.036	0.973	1.001	0.967	1.000	0.961	0.977	1.038	1.012
1.054	1.102	1.021	1.045	1.028	1.066	1.041	1.027	1.096	1.065
1.116	1.158	1.092	1.106	1.091	1.110	1.095	1.085	1.155	1.116
1.170	1.207	1.168	1.181	1.141	1.179	1.156	1.145	1.198	1.168
1.224	1.257	1.220	1.238	1.210	1.247	1.201	1.223	1.252	1.226

Correlation of the TABLE with FIG. **4** can be made as follows. The first ordinate in Row 1 of the TABLE is 0.000 which corresponds to the centerline of the web **52** in FIG. **4.** The centerline ordinate of the second web **54** in Row 1 is 0.060. Similarly, the ordinate of the first web **56** in Row 2 is 0.017 and the ordinate of the second web **58** in Row 2 is 0.085. Further correlation between the TABLE and FIG. **4** can be made by continuing to measure each web ordinate in the TABLE vertically from the zero ordinate established for the web **52,** and as developed hereinbelow, the TABLE as a whole prescribes a web array for an elemental area of the apertured portion of the shadow mask.

It can be seen from the values in the TABLE and from FIG. **4** that the spacings between adjacent webs in a row (as measured between centerlines) vary randomly along each row, i.e., the webs are distributed at random distances along each row. This web distribution has the effect of making the slit lengths random , since the webs are of uniform height.

It has been stated hereinabove, that certain restrictions may be established upon web placement without preventing the effect of the web array from being random in overcoming moire problems. One such restriction is the placement of maximum and minimum values upon the slit length or web spacings of each row. A maximum web spacing limitation is desired for strength considerations. When a slit is unduly long, i.e., when adjacent webs are too far apart along a row, the thin sheet metal of the shadow mask **30** does not have enough strength to hold its desired form particularly when the mask member is curved as is the usual case. Accordingly, the maximum slit length desirable is of magnitude sufficient to provide the apertured portion of the mask with adequate strength to hold its form. A maximum of about 90 mils, measured between web centerlines, is used in the preferred embodiment which employs a cold rolled steel mask 6 mils in thickness.

A minimum web spacing is also desirable for reasons primarily having to do with electron transmission through the mask **30.** When the webs are too close together, not enough electrons are permitted to pass through the mask **30** and the picture is too dark to be of acceptable viewing quality. Accordingly, the minimum web spacing is of sufficient magnitude to provide the apertured portion of the shadow mask with electron transmission of at least 15 percent at the mask center to produce a bright picture on the screen. A minimum web spacing of about 30 mils (measured between web centerlines) is employed in the preferred embodiment.

Another of the restrictions which may be established upon web placement is the vertical displacement of webs in adjacent rows from one another in the direction of the minor axis of the shadow mask. This restriction is also desirable for strength considerations so as to provide a self-supporting mask. A minimum displacement between webs in adjacent rows of 10 mils, measured between web centerlines, is employed in the preferred embodiment.

Ideally, the entire apertured portion of the mask could be formed with nonrepeated random lines throughout. However, to facilitate manufacture, the apertured portion of the mask may be made up of a plurality of interleaved, adjoining, duplicate, elemental areas. Utilization of such elemental areas does not destroy the random effect of the mask web array as a whole. The interfitted duplicate construction is used in the preferred embodiment as illustrated in FIG. 5. FIG. 5 depicts an enlarged area of the apertured portion of the shadow mask **30**, and illustrates how a plurality of elemental areas **60**, each having a random web array as prescribed in the TABLE above, are repeated in building-block fashion. These elemental areas **60** are repeated to cover the entire apertured portion of the shadow mask **30.**

In the preferred embodiment, each elemental area **60** is about 1.2 inches in height and about 0.96 inches in width. The TABLE sets forth the complete web array for one such elemental area. The dimensions of the elemental area are determined by several considerations. One consideration is that the area should be sufficiently large so that area repetition will not destroy the random effect of the web array as a whole in preventing moire. About a 1-inch square area meets this requirement.

Within the foregoing broad guidelines, desired orders of vertical web spacing and horizontal slit spacing make the last fine increments of adjustment in determining the dimensions of the incremental area. For example, it has been stated that the maximum and minimum limits on web spacing measured between centerlines of consecutive webs, in the preferred embodiment are 90 mils and 30 mils, respectively. This range has an average of 60 mils, which multiplied 20 times equals 1.2 inches. Twenty is a convenient number of webs with which to work, and 1.2 inches is quite close to the 1-inch height limitation determined from the broad guidelines. Accordingly, each elemental area of the preferred embodiment is 1.2 inch in height, measured from the centerline of the lowermost web to the centerline of the topmost web. Since the zero ordinate is at the center of the lowermost web in a row, there are 21 ordinates in the preceding TABLE in order to provide 20 full webs. Use of the average web spacing to determine the size of the elemental area may be viewed as another form of restriction on web placement.

As to the width of the elemental area, a horizontal slit spacing of 24 mils (measured between slit centerlines) is employed in the preferred embodiment. Forty rows of slits is a convenient number with which to work, and 40 times 24 mils equals 0.960 inches, which is very close to the 1-inch squire prescription. Accordingly, the elemental area is determined to be 0.96 inch in width, measured from the midpoint between Row 1 and the last row in the left adjacent elemental area to the midpoint between Row 40 and the first row of the right adjacent elemental area. Use of the horizontal slit spacing to determine the width of the elemental area may also be viewed as a restriction on web placement. In the preferred embodiment, the slit width is 7 mils, which is desirable for tubes having a light absorbing matrix material (not shown) between phosphor areas. A narrower slit width, e.g., 4.3 mils, may be used for non-matrix tubes.

In order to avoid establishing horizontal lines of webs at the horizontal jointures of vertically adjacent elemental areas, the rows of slits of each elemental area interleave with the rows of the vertically adjacent elemental areas. This interleaving of rows is illustrated in FIG. 4 which embraces fragments of four elemental areas 60A, 60B, 60C and 60D of FIG. 5, as defined by the vertical and horizontal dashed lines *61a* and *61b*, respectively. The interleaving is by randomly varying distances, as appears hereinafter.

As previously stated, the average web spacing is used to determine the exact height dimensions of the elemental area. To maintain that height dimension across the width of the area, i.e., for each row, the average web spacing of each row in the elemental area is the same as the average web spacing of the other rows. At the same time, to provide for interleaving and avoid impairment of the random nature of the web array, rows of adjacent elemental areas have their lowermost web ordinate displaced from the zero ordinate of Row 1 a random distance up to the average web spacing of the rows. Since each row is still 1.2 inches in height, the top web ordinate of each row will also be displaced the same distance from the top web ordinate of Row 1. One way to characterize the arrangement is to say that each 1.2 inch row is displaced vertically a distance corresponding to the displacement of its lowermost web ordinate. The lowermost web ordinate in each row is randomly selected with the restriction that it be a value which is not greater than the average adjacent web spacing, but is at least equal to the minimum required displacement for webs in adjacent rows from the lowermost web in the preceding (next-left) row. In FIG. 4, the tops of the rows of elemental area **60B** interleave with the bottoms of the rows of elemental area **60A**. The bottom of Row 2 of area **60A** is displaced 0.017 inch. The centerline ordinate of the web **56** is coincident with the uppermost ordinate for Row 2 of the elemental area **60B**, and similarly the same is true for all top ordinates of the elemental area **60B** and all bottom ordinates of the elemental area **60A**.

Because of the vertical displacement of the 1.2 inches high rows in an elemental area, the general outline of the area is slightly higher than 1.2 inches. That is to say, the outline of the area will have a height which is equal to the sum of 1.2 inches plus the maximum displacement of any row from the zero ordinate. As previously indicated, such maximum displacement in the preferred embodiment is not greater than the average web spacing of a row.

With respect to repetition of the elemental areas, the webs of the last row (Row 40) of each elemental area are displaced at least the minimum required distance from the webs of the first row (Row 1), since each Row 40 is placed horizontally adjacent a Row 1 when the elemental areas are repeated.

Preferably, random web arrays are generated on a suitably programmed digital computer, such as an RCA Spectra 70/45 computer manufactured by RCA Corporation, New York, N.Y. This computer can be equipped with a random number generator and programmed in a conventional way to produce random web ordinates from a population with the following restrictions: the average web spacing in each row is 60 mils, each row of the array s 1.2 inches in height (20 average web spacings) the array is 0.960 inch in width and no two webs in adjacent rows are less than 10 mils apart. The population is also limited to a maximum and minimum web spacing in each row of 80 and 40, respectively, since it is necessary to program narrower maximum and minimum limits than the approximately 90 and 30 desired to assure that the computer can remain within the maximum and minimum guidelines when normalizing each row to 1.2 inches in height. The computer then generates the web ordinates reproduced in the TABLE.

The ordinates generated by the computer are used in a program to control a plotter (such as a Gerber Model No. 632 plotter manufactured by Gerber Scientific Co., Hartford, Conn.) in a conventional manner to obtain a photographic plate of an elemental area. This plate has clear areas corresponding to the slit locations surrounded by opaque unexposed areas. The plate of the elemental area next is used as a negative and moved through a plurality of steps to expose a larger first master plate which will contain the entire shadow mask pattern. This first master may then be reduced in size by a technique employing a series of photographic reproductions until eventually two final masters are obtained that are to be used in exposing both sides of the shadow mask sheet material. Usually, one of these final masters has larger slit areas than the other so that each slit will have slanted sides opening toward the screen. Also by using various known photographic techniques it is possible to grade the size of the slit areas over each final master to provide for various misregistration errors of the electron beam.

The final masters are placed in accurate alignment on opposite sides of a flat metal sheet that is to become a shadow mask. The sheet is coated with a photoresist that is exposed by passing light through each final master. Thereafter the photoresist is developed and the unexposed areas (corresponding to slit areas) are washed away. Next, the uncoated slit areas are etched in a conventional manner until the final slits are formed. The apertured portion of such a mask in a 15-inch viewable diagonal rectangular cathode ray tube has a major axis length of 11.820 inches and a minor axis height of 8.858 inches.

The flat mask is then formed into a spherically curved shape and it should be noted that all dimensions given hereinabove including the web spacings defined in the TABLE are for a flat mask and that the forming operation may produce small variations from the flat mask dimensions in various regions of the mask, as a result of metal flow in the forming operation.

Another embodiment of a shadow mask **70** is illustrated in the enlarged partial view of FIG. **6.** In shadow mask **70,** all apertures **72** are of equal length and aligned in vertical rows. The spacing between each aperture in each row is identical to the spacing between apertures in each other row. The vertical positions of each row, however, are varied randomly so that webs **73** in adjacent rows are randomly displaced from one another in the direction of the rows.

The web ordinates given in FIG. **6** were selected from the accompanying TABLE of random ordinates for illustration purposes. Various constraints can be put on the generated random numbers to ensure that visible patterns are not formed as might be the case if the constraints were not applied. Of course, constraints to ensure sufficient mask strength and electron transmission may also be imposed.

To facilitate manufacture, the apertured portion of the mask **70** can be made up of a plurality of interleaved, adjoining, duplicate elemental areas as previously described. In FIG. **6,** these areas designated as **74A–74D**, are interleaved as previously discussed.

Shadow masks embodying the present invention are highly advantageous. A random web array can be used for any tube height, or for any raster irrespective of the number of scan lines, without appearance of moire. With a random web array, there can never be a troublesome moire-producing web pitch-scan line pitch relationship for the reason that a random web array has no definite vertical or horizontal web pattern to enter into such a relationship. Similarly, television set malfunctions causing imperfect linearity can never produce moire, for the same reason.

Many modifications of the preferred embodiment illustrated can be made without departing from the scope of the present invention. Other random web arrays having ordinates differing from those in the TABLE can be used. Instead of randomly generating web ordinates for an elemental area and repeating the elemental area to cover the apertured portion of the mask, random ordinates for the entire apertured portion can be generated. Instead of repeating the elemental area to cover the mask by means of a computer-driven plotter, the repetition may be effected by photolithographic or other means.

A single random row may be generated and that row randomly repeated, staggered or displaced vertically relative to each adjacent row, in order to produce a random web array. Or, each web may be prescribed to have a particular percentage ratio to its random spacing from a vertically adjacent web, so that the web heights vary as well as the ordinates.

I claim:

1. In a cathode-ray tube having a color phosphor line screen structure comprising a plurality of arrays of substantially parallel phosphor lines, the phosphor lines in each array being adapted to emit light of a particular color, and a shadow mask spaced from said screen, said shadow mask having a plurality of substantially parallel rows of apertures being elongated in the direction of said rows and the apertures in each row being separated by webs, the improvement comprising:

said rows being randomly displaced from one another in the direction of said rows.

2. The cathode-ray tube as defined in claim **1** including said webs being randomly spaced along each row.

3. The cathode-ray tube as defined in claim **1** including said webs being uniformly spaced along each row.

4. In a cathode-ray tube having a color phosphor line screen structure comprising a plurality of arrays of substantially parallel phosphor lines, the phosphor lines in each array being adapted to emit light of a particular color, and a shadow mask spaced from said screen, said shadow mask having a plurality of substantially parallel rows of apertures aligned with said phosphor lines, said apertures being elongated in the direction of said rows and the apertures in each row being separated by webs, the improvement comprising:

said webs being randomly spaced along each row and all webs in adjacent rows being randomly displaced from one another in the direction of said rows.

5. The cathode-ray tube as defined in claim **4,**

wherein the random spacing along each row is such as to provide a self-supporting mask with at least 15 percent transmission at the mask center.

6. The cathode-ray tube as defined in claim **5**, wherein the random spacing between centerlines of consecutive webs is within the range of 30 mils to 90 mils.

7. The cathode-ray tube as defined in claim **6**, wherein an average spacing between centerlines of consecutive webs is 60 mils.

8. The cathode-ray tube as defined in claim **4**, wherein the random displacement between all webs in adjacent rows in the direction of said rows is such as to provide a self-supporting mask.

9. The cathode-ray tube as defined in claim **8**, wherein the random displacement between all webs in adjacent rows is at least 10 mils.

10. The cathode-ray tube as defined in claim **4**, wherein said webs have uniform length in the direction of said rows.

11. The cathode-ray tube as defined in claim **4**, wherein said shadow mask is divided into a plurality of randomly interleaved areas, each area having a similar pattern of apertures.

12. The cathode-ray tube as defined in claim **11**, wherein said areas are sufficiently large to maintain the random effect of web spacing.

13. The cathode-ray tube as defined in claim **12**, wherein said areas are about 1 inch square.

14. The cathode-ray tube as defined in claim **11**, wherein said areas interleave in the direction of said rows a distance not exceeding an average spacing between centerlines of consecutive webs.

15. In a cathode-ray tube having a color phosphor line screen structure comprising a plurality of arrays of substantially parallel phosphor lines, the phosphor lines in each array being adapted to emit light of a particular color, and a shadow mask spaced from said screen, said shadow mask having a plurality of substantially parallel rows of apertures aligned with said phosphor lines, said apertures being elongated in the direction of said rows and the apertures in each row being separated by webs, the improvement comprising:

said webs being randomly spaced along each row a distance to provide a self-supporting mask with at least 15% transmission at the mask center and all webs in adjacent rows being randomly displaced from one another in the direction of said rows a distance to provide a self-supporting mask.

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