United States Patent

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[54] **CONVERGENCE MEANS FOR PLURAL IN-LINE BEAM CATHODE RAY TUBE**
24 Claims, 9 Drawing Figs.

[52] U.S. Cl. 315/13, 313/77
[51] Int. Cl. H01j 29/50
[50] Field of Search 315/13C, 13CG; 313/77

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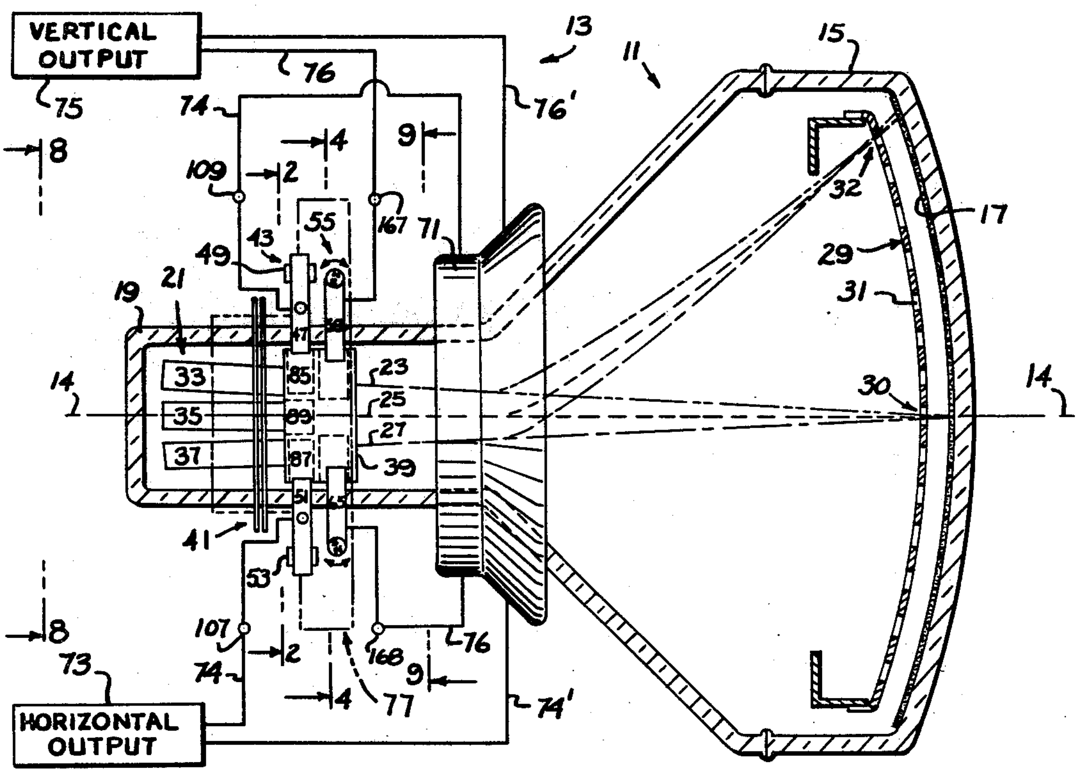
ABSTRACT: Horizontal convergence means for a plural in-line beam cathode ray tube wherein the horizontal static and dynamic convergences are accomplished by independently adjustable flux densities in two sets of common stationary core elements on either side of the gun assembly, and wherein vertical static convergence is effected by adjustable substantially symmetrical magnetic fields developed within the region of beam influence on each side of the gun assembly to move the side and center beams in a converging vertical manner. A combined convergence device is provided in a common support medium wherein the adjustments of all magnetic fields are accomplished at fixed and easily accessible locations.



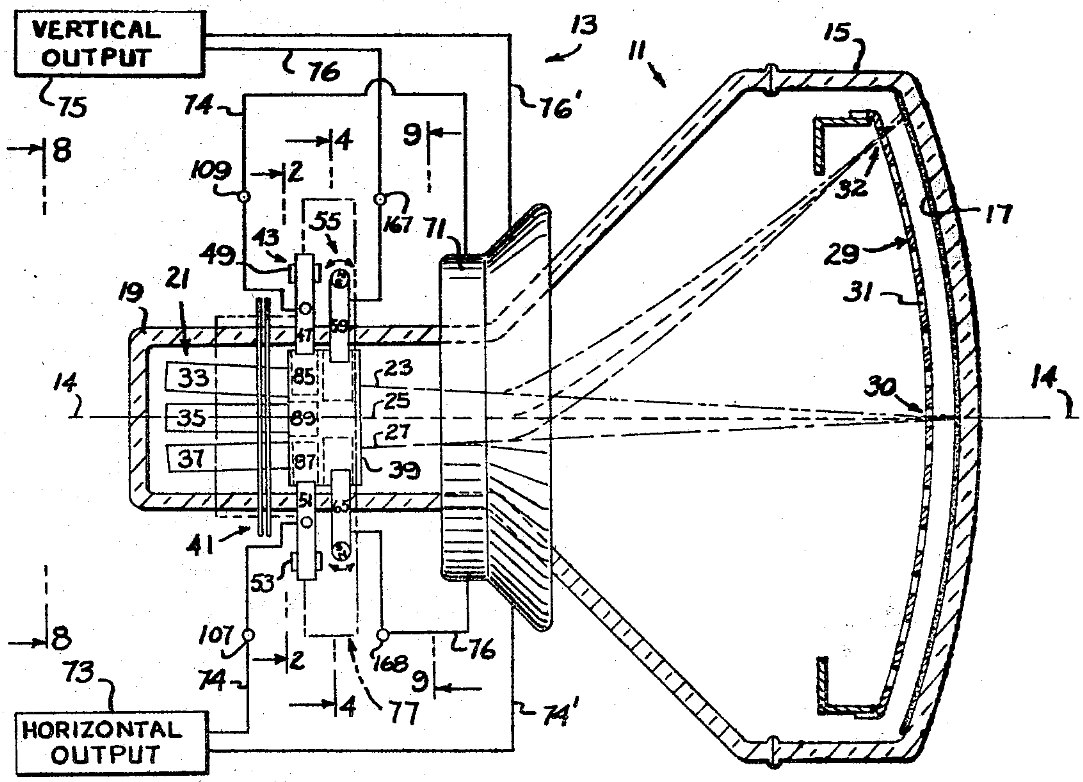


Fig. 1

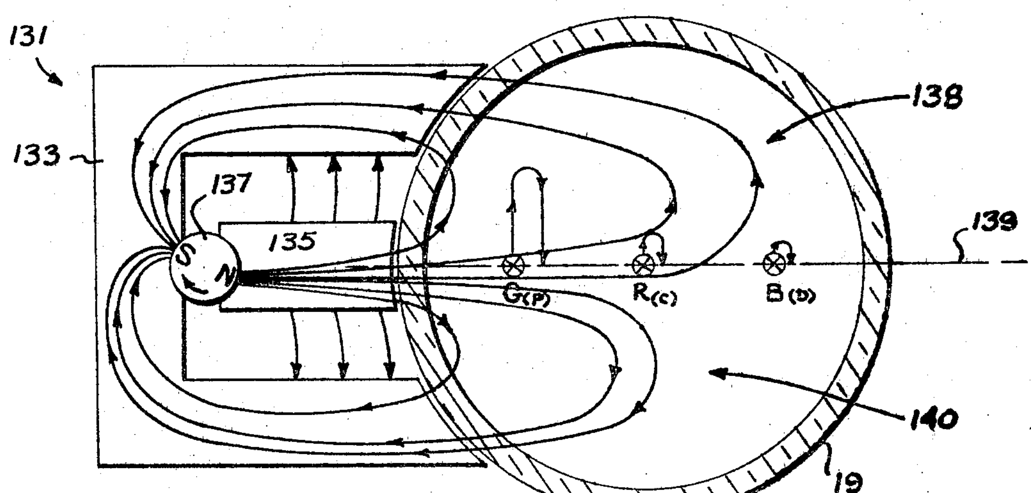


Fig. 3
PRIOR ART

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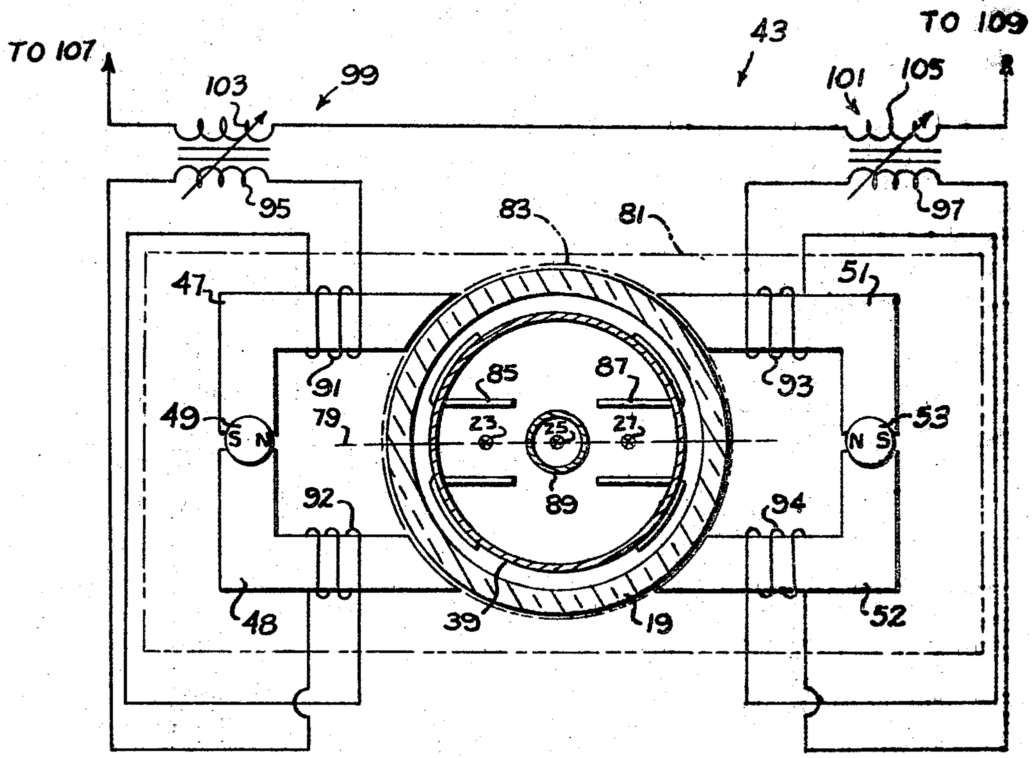

Fig. 2

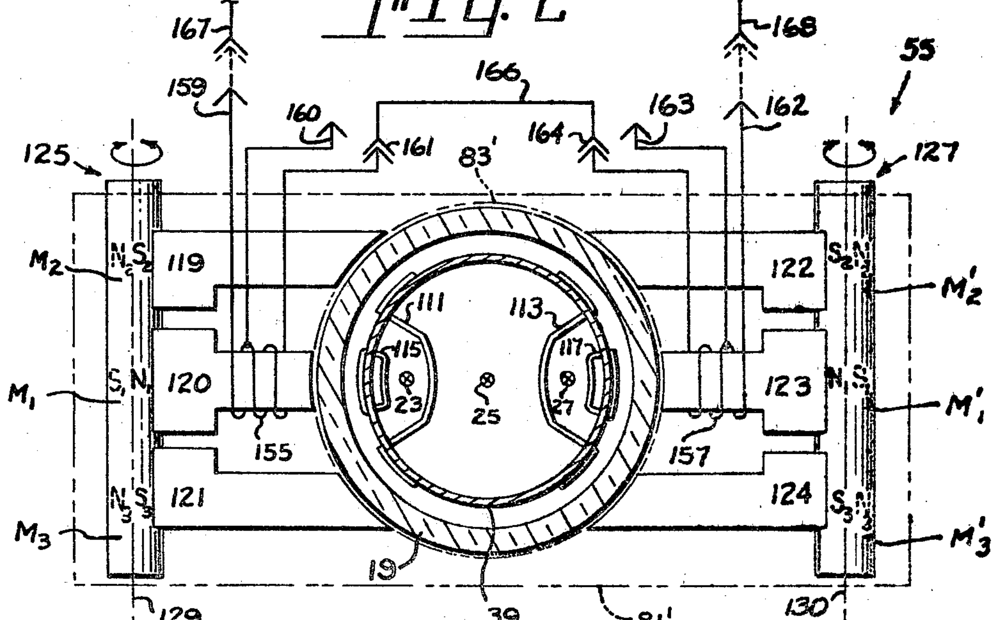

Fig. 4

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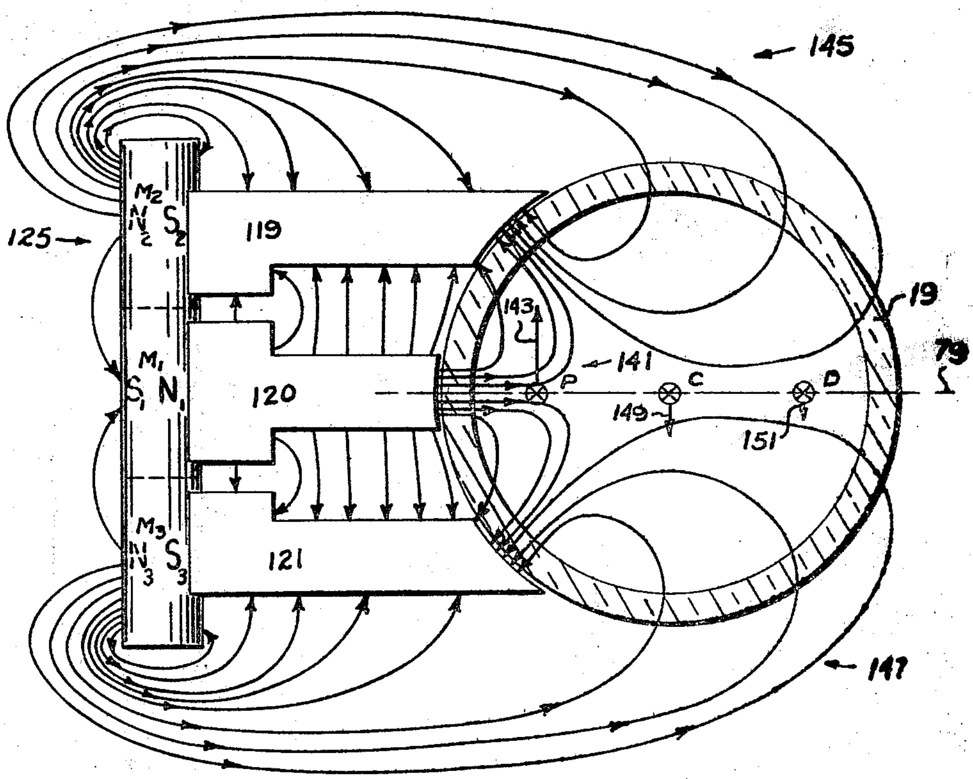

Fig. 5

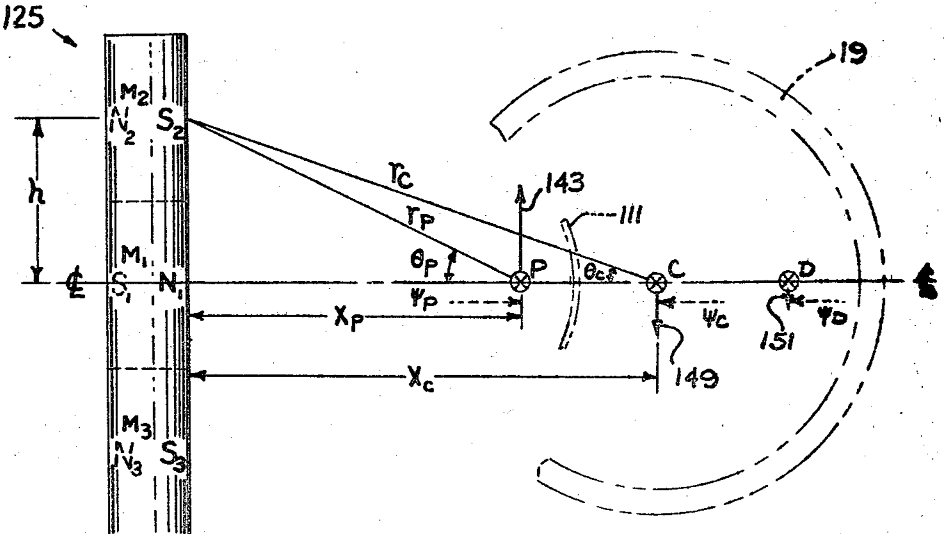

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Fig. 6

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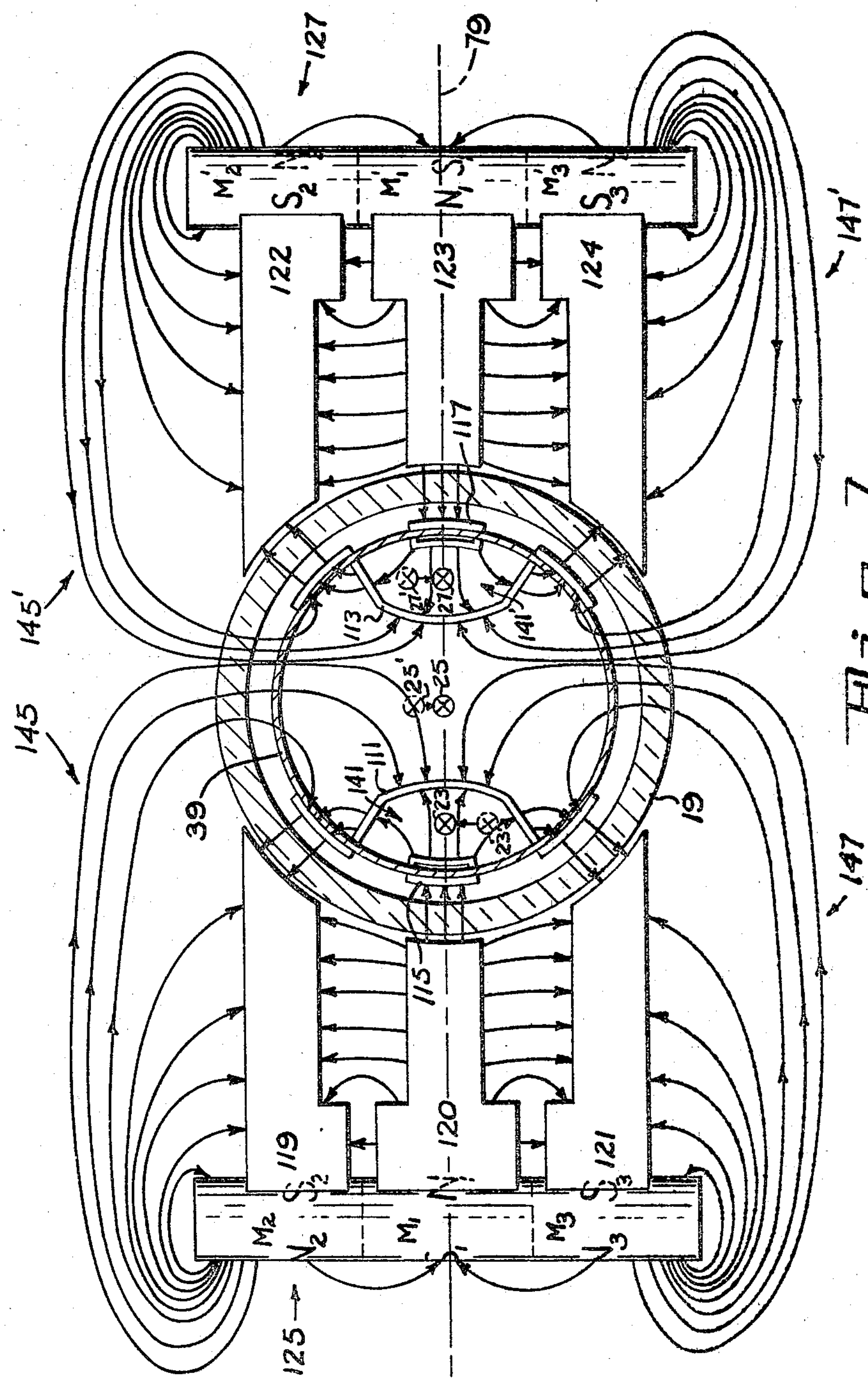

Fig. 7

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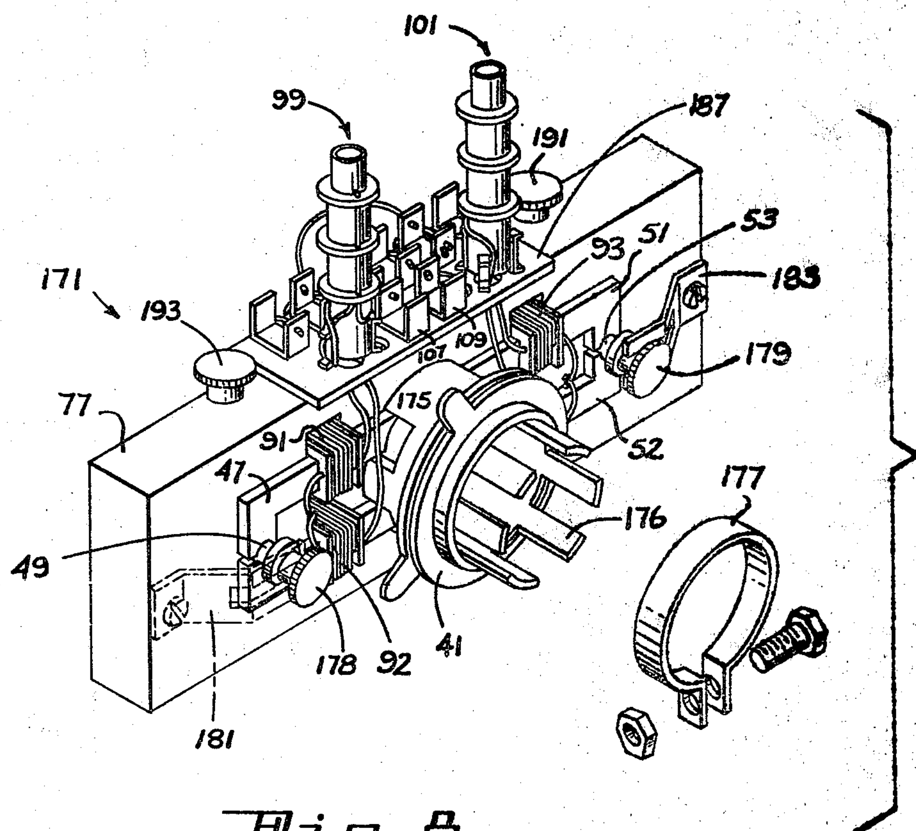

Fig. 8

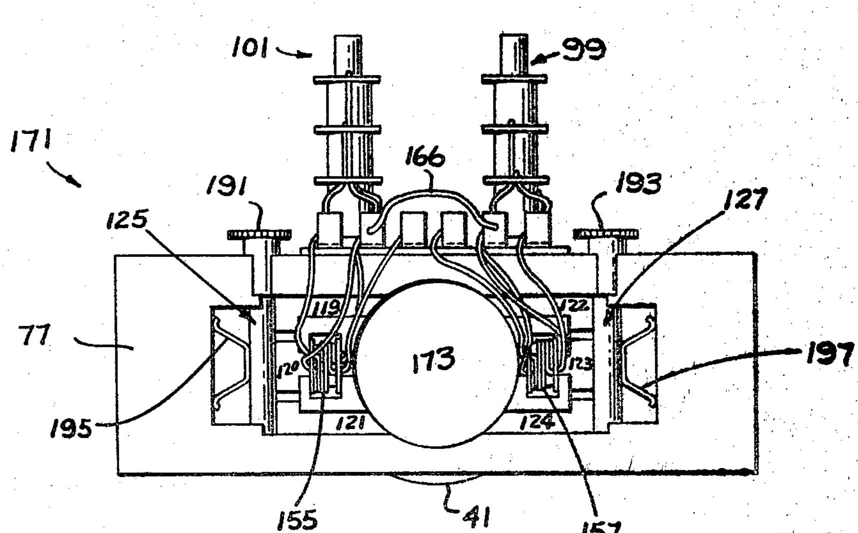

Fig. 9

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CONVERGENCE MEANS FOR PLURAL IN-LINE BEAM CATHODE RAY TUBE

BACKGROUND OF THE INVENTION

This invention relates to plural in-line beam cathode ray tubes and more particularly to means for effecting convergence of the plural electron beams in an in-line beam color cathode ray tube.

Cathode ray tubes, of the in-line beam type conventionally used in color television apparatus, generally have a patterned cathodoluminescent display screen disposed relative to a face or receiving panel. The pattern of such a screen is usually comprised of several electron responsive phosphors configurated as stripes or dots. In plural beam type tubes, the screen pattern is arranged so that the configurations will be excited individually when impinged by electrons emanating from a related electron gun assembly during tube operation. An apertured grid or mask structure is positioned between the screen and the electron gun assembly so that the respective electron beams will land on the proper pattern configuration. It is important for the several electron beams to converge at the mask aperture for all deflection angles to assure color fidelity and resolution of the display. Even though the guns of the in-line assembly are substantially positioned in a common plane with the side guns angled to promote beam convergence, the plural beams emanating therefrom are seldom in the common plane of the gun assembly because of manufacturing and component tolerances. Therefore, an adjustable purity magnet and auxiliary convergence means are positioned on the exterior of the tube relative to the forward end of the gun assembly to provide corrective magnetic convergence influences on the several beams.

One method for achieving desired beam convergence utilizes horizontal and vertical convergence means which effect both static and dynamic convergence. These means are positioned on the neck of the tube envelope exterior to the gun assembly and provide compensating adjustments for brining the beams into proper relationship for convergence at the mask. In effecting static convergence, the several beams are directed to converge at the center of the mask. As the beams are scanned across the nonspherical contour of the mask in areas other than center area, it is necessary to modify the angles of the beams by dynamic convergence means to maintain continued convergence at the plane of the mask. Static convergence is usually effected by the fields of permanent magnets, while dynamic convergence is provided by varying dynamic magnetic fields.

One known means for achieving horizontal convergence of plural in-line beams utilizes, on each side of the beam arrangement, a pair of magnetic core elements combined in a substantially U-shaped configuration slidably oriented in suitable track means supported on either side of the appropriate portion of the tube neck. Horizontal static convergence is promoted by positioning each U-shaped core arrangement relative to the neck of the tube and adjusting a rotatable permanent magnet associated with each pair of core elements to provide the magnetic flux densities required for the static convergence of the beams. To achieve horizontal dynamic convergence, the horizontal output signal of the television apparatus, or other dynamic display device, is applied to windings disposed on the legs of each pair of the U-shaped core elements to provide varying dynamic magnetic fields. In an attempt to achieve the proper dynamic magnetic flux densities for positioning the moving beams, each slidable core arrangement is moved in the track means relative to the tube neck. Unfortunately, the mechanical slide adjustment of the core elements cannot be accurately set to converge the beams, but must be set so that the dynamic convergence errors appear to be substantially equalized across the screen. This proves to be an annoying maneuver as the preset static convergence flux is no longer of the required level. This undesired change in static flux density is aggravating as the static flux density must be readjusted, and any change in static flux density may require readjustment of the purity magnet.

A conventional means for effecting vertical convergence of plural in-line beams is in the form of two substantially E-shaped magnetic cores; one being appropriately placed on either side of the tube neck in a suitable support. To provide vertical static convergence, a rotatable magnet is associated with the intermediate segment of each E-shaped core. Adjustment of each magnet provides a magnetic field which influences movement of the several in-line beams in a common substantially vertical direction. The degree of movement of the respective beams, either up or down, is dependent upon the position of the poles of the influencing magnet, the effective flux density and the position of the beams in the magnetic field. Since each magnet moves all beams in varying amounts in a like direction, it is difficult to achieve the desired vertical static beam positioning at or near the common plane of the gun assembly.

Furthermore, since the static and dynamic convergence means are usually located in close proximity to the deflection yoke and other high voltage circuitry components, it is often a tedious procedure to efficiently consummate precise movements of the slidable cores and make the necessary compensating adjustments of the several permanent magnets in the device.

OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the invention to reduce the aforementioned disadvantages and to provide a convergence device for a plural in-line beam cathode ray tube that has horizontal static and dynamic convergence means whereof each is independent to the functional setup of the other.

Another object is to provide a vertical static convergence means for a plural in-line beam tube that effects the convergence movements of at least two of the beams to move toward one another in a substantially vertical converging manner toward a plane intermediate of the two.

A further object is to provide a convergence device wherein the horizontal and vertical static and dynamic convergence means are integrated into a common support medium having all adjustments at fixed and easily accessible locations.

The foregoing objects are achieved in one aspect of the invention by the provision of horizontal convergence means wherein a pair of magnet core elements oriented on the tube neck on either side of the electron gun assembly are stationary for both static and dynamic convergence. Separate adjustment of the magnetic fields are incorporated with the core elements for independently regulating the respective magnetic flux densities in the core elements to provide the desired horizontal static and dynamic convergence influences on the beams. In accomplishing vertical static convergence, separate adjustable plural magnetic means are utilized with each set of core elements oriented on the tube neck on either side of the gun assembly. These magnetic means develop magnetic fields that are substantially symmetrically formed within the region of beam influence on each side of the beam plane of the in-line gun assembly to effect converging vertical movements to the side and center beams with each side beam moving the greater distance. By such movement, the beams are substantially oriented on or near the plane of the gun assembly which advantageously positions them in the center region of the yoke. There is also provided a combined convergence device wherein the horizontal and vertical convergence means are associated in a common support member positioned on the neck of the tube. The several adjustments for regulating the flux densities required for horizontal and vertical static and dynamic convergences are advantageously located at the back and at the top or bottom of the assembly away from the proximity of high voltage areas.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of the plural in-line beam cathode ray tube showing the beam convergence means oriented therein;

FIG. 2 is a view taken along the line 2–2 of FIG. 1 illustrating the horizontal convergence means of the invention;

FIG. 3 is a view depicting the magnetic principle utilized in a known means of effecting vertical static convergence;

FIG. 4 is a view taken along the line 4—4 of FIG. 1 showing the vertical convergence means of the invention;

FIG. 5 is a simplified partial view of the vertical static convergence means illustrating the action of the magnet fields emanating from one set of core elements;

FIG. 6 is a diagrammatic view showing the relationship of vectors influencing vertical static convergence;

FIG. 7 is a view of the vertical convergence means shown in FIG. 4 illustrating the representative magnetic fields utilized in effecting vertical static convergence;

FIG. 8 is a prospective view of the convergence device taken substantially along the line 8—8 of FIG. 1 stressing constructional features of the horizontal convergence means with details of the tube neck omitted for purposes of clarity; and

FIG. 9 is a view of the convergence device taken along the line 9—9 of FIG. 1 stressing constructional features of the vertical convergence means with details of the tube neck omitted for purposes of clarity.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

For a better understanding of the present invention, together with other and further objects, advantages and capabilities thereof, reference is made to the following specification and appended claims in connection with the aforedescribed drawings.

With reference to the drawings, there is shown in FIG. 1 a plan view of a plural, in-line beam color cathode ray tube 11 with the deflection system 13 oriented thereon. The tube envelope has an axis 14 and a viewing panel 15 with a patterned cathodoluminescent screen 17 disposed on the interior surface thereof. The envelope neck portion 19 has an in-line gun assembly 21 positioned therein in a manner to direct a plurality of three in-line electron beams 23, 25 and 27 toward the patterned screen 17. Adjacent the screen, and spaced therefrom, there is positioned a foraminous grid or mask 29, whereat the plural beams are converged. The in-line gun assembly 21 is partially detailed to delineate three related electron guns 33, 35 and 37 which are aligned in a common plane with the axes of the side guns 33 and 37 angled slightly toward the forward end of the center gun 35. A common convergence electrode assembly 39, comprising a metallic shell of nonmagnetic material, having discretely formed pole pieces of magnetic permeable material oriented therein, is terminally integrated on the forward portions of the three guns in a manner that the emitted electron beams 23, 25 and 27 are directed therethrough toward the patterned screen 17. While any gun may be denoted to excite a particular color-emitting phosphor component of the patterned screen, for purposes of illustration, gun 33 is designated as the green gun which emits and directs G beam 23 to excite the green component of the screen. The center gun 35 is the red gun from which R beam 25 is directed to impinge the red screen component, and the remaining gun 37 is denoted as the blue gun producing B beam 27 for exciting the blue color-emitting phosphor pattern.

Shown mounted on the exterior of the tube neck portion 19, adjacent to the gun assembly 21 therein, is a purity ring device 41 comprising two magnetized rings formed to be rotatable about the neck of the tube. Selective rotation of the purity rings orients a magnetic field to exert a force in any desired transverse direction to move all three beams transversely of the tube axis 14 and align them with the mask or grid apertures 31 and the respective phosphor patterns therebeneath.

Forward of the purity ring device 41 are horizontal convergence means 43, of which stationary core elements 47 and 51, of a magnetic permeable material such as ferrite, are shown positioned relative to a specific portion of the convergence means 43, are vertical convergence means 55, having core elements 59 and 65 located relative to a forward portion of the convergence electrode assembly. The horizontal and vertical convergence means 43 and 55 effect static convergence of the beams at the center portion 30 of the mask, and dynamic convergence maintains proper convergence as the scanning beams sweep over the hole of the used mask area, such as at 32.

The deflection system 13 comprises the purity ring magnets 41, the horizontal and vertical convergence means 43, 55 and an associated deflection yoke 71 which is positioned ahead of the convergence means. To effect horizontal dynamic convergence and deflection, the output signal from the horizontal output section 73 of the circuitry of the dynamic display apparatus is applied to the horizontal convergence means 43 and the horizontal deflection winding in the yoke 71 in a manner described later in this specification. Vertical dynamic convergence and deflection are accomplished by applying the signal from the vertical output section 75 to the vertical convergence means 55 and the vertical deflection winding in the yoke 71. In FIG. 1, the horizontal and vertical convergence circuits are designated as 74, 74′ and 76, 76′ respectively.

The horizontal and vertical convergence means 43 and 55 can be separately oriented in a related manner on the tube neck portion by individual support mediums or they can be combined in an integrated assembly having a common support bodymember as shown in FIGS. 8 and 9 and by phantom outline 77 in FIG. 1.

In considering the' horizontal convergence means 43 in greater detail, reference is made to FIGS. 1 and 2 whereof FIG. 2 is taken along the line 2—2 of FIG. 1. The horizontal convergence means are affixed in an insulative horizontal convergence support medium 81 oriented substantially normal to the substantially common beam plane 79. Such positioning is achieved by forming a cylindrical opening 83 in the support medium of a size to permit encirclement of the tube neck portion 19. Within the convergence assembly electrode 39 are two pair of pole pieces 85 and 87 positioned relative to the side beams 23 and 27 respectively. The center beam 25 is surrounded by a shielding element 89.

Positioned on the support medium continuous to the tube neck, are end portions of two pair of stationary L-shaped core elements 47, 48 and 51, 52, of which each pair is combined to form two substantially U-shaped stationary core arrangements, each having provisions therebetween to accommodate a cylindrical ferrite permanent magnet 49, 53. Adjustable rotation of these permanent magnets regulates the magnetic flux density required for horizontal static convergence. The core elements of each pair, 47, 48 and 51, 52 individual windings 91, 92 and 93, 94 disposed thereon which are utilized in achieving horizontal dynamic convergence. Each pair of windings 91, 92 and 93, 94 is series connected to a respective secondary winding 95 and 97 of separate inductive coupling means or transformers 99 and 101 having adjustable cores. The primary windings 103 and 105 of transformers 99 and 101 respectively, are series connected having circuit terminals 107 and 109 respectively which are connected in series relationship between the horizontal output signal source 73 and the horizontal deflection winding in the yoke 71 as shown in FIG. 1. Individual tuning of the transformer cores provides, in the secondary windings of the respective transformer, a modification of the amplitude of the sawtooth current output signal applied across the primary windings. The induced signal in the secondary windings is applied through the associated windings 91, 92, 93, 94 on the core elements 47, 48, 51, 52 to produce the magnetic flux densities required for effecting horizontal dynamic convergence. Any change in sweep current, such as would be caused by a change in supply line voltage would also change the convergence current induced in the transformer secondaries and assure tracking as the beam scans the raster.

Since the yoke 71 is the primary load in the deflection system, the inductance of the transformers should be small with reference thereto as it is desired that only a minimum of power be absorbed in the convergence transformers 99 and 101. It has been discovered that the inductance of the yoke 71 should be at least forty times greater than that of the transformers. A stepdown type of transformer is utilized wherein the primary winding has more turns than the secondary. It has been found that the impedance of the load across the secondary winding should be less than the secondary impedance to achieve a high current gain, therefore, the total number of turns comprising the windings on each pair of core elements is less than the number of turns in the secondary winding. It is important that the phase of the current induced in the secondary winding of each transformer be in phase with the current in the primary winding. In order to assure that not phase shift will occur between the primary and secondary currents, the resistive component of the secondary winding should not exceed 10 percent of the inductive component of that winding, and the resistive component of the load should not exceed substantially 10 percent of the inductive component of the load. The impedances of the load and the inductances of the transformers are determined from known values such as, the current amplitude of the horizontal output signal which is the input signal to the transformers, and the value of flux density needed to influence beam movement to effect the desired dynamic convergence. From these known values, the various winding ratios can be calculated. For example, in a typical tube wherein horizontal dynamic convergence of three in-line beams is effected, the two outside beams **23** and **27** are each separated from the center beam **25** by equal distances of substantially 0.375 inch. The convergence electrode, traversed by these beams, has a diameter of substantially 1.125 inches, and being part of the gun assembly is positioned in a tube neck having a diameter of approximately 1.44 inches O.D. At operating anode voltages of substantially 20 KV, the required maximum flux density at the pole pieces, to achieve the desired horizontal dynamic convergence, is furnished by core windings of substantially 9.25 ampere-turns r.m.s. per pair. The signal impressed across the primaries of transformers **99** and **101** has a substantially 12 microsecond voltage pulse with a current value of substantially 3.6 amperes p–p at a frequency of substantially 15,750 kc.

As examples, suitable transformers may comprise a primary winding of substantially 38 to 40 turns of 024 GA copper wire disposed in 1.5 layers with an inductance ranging substantially from 29 to 30 uh. The secondary winding is in the form of substantially 27 to 29 turns of like wire disposed in a 1.0 layer with an inductance ranging substantially from 12.5 to 13.5 uh. The primary and secondary windings of each transformer 99,101 are disposed one upon the other which results in tight coupling therebetween. An adjustable ferrite core in each transformer facilitates individual tuning. The induced current in the secondary is found to be substantially .463 amperes r.m.s. at maximum coupling from the above-noted input signal of substantially 3.6 amperes p–p. When this current is applied to the load across the transformer secondary, which comprises a winding of 10 turns per core element, or a series load of 20 turns per pair, the resultant of 9.26 ampere-turns r.m.s. is achieved to effect the magnetic flux density for beam convergence. The specific values of flux densities required for corrective beam positioning are determined by tuning the transformers accordingly.

Thus, there is provided an improved horizontal convergence device wherein the static and dynamic convergence adjustments are independent of one another. Only four permanently located adjustments are required. Reference to FIG. **8** indicates the convenient locations of these adjustments: the two rotatable permanent magnets **49** and **53** associated with static convergence, and the two tunable transformers **99** and **101** related to dynamic convergence.

Included in the deflection system for use with a plural in-line beam color cathode ray tube as shown in FIG. **1**, is a vertical convergence device **55** which is used in conjunction with the vertical deflection winding in the yoke **71** to utilize the vertical output signal in the display apparatus to achieve convergence of the moving electron beams. Reference is made to FIG. **4**, which is taken along the line **4–4** in FIG. **1**, wherein the essentials of the vertical convergence device are delineated. This device **55** is oriented relative to the aforedescribed horizontal convergence device, and as shown in FIGS. **1** and **4**, is positioned on the neck of the tube in a manner to exert magnetic influences on the in-line beams **23**, **25** and **27** as they traverse the forward position of the convergence electrode **39**.

The componental elements comprising the vertical convergence means are affixed in an insulative vertical convergence support medium **81'** positioned substantially normal to the substantially common in-line beam plane. Such orientation is realized by forming a cylindrical opening **83'** in the support medium of a size to permit encirclement of the tube neck portion **19**. Within the portion of the convergence electrode **39**, encompassed by the vertical convergence means, are two sets of pole pieces comprising inner pole pieces **111**, **113** and related outer pole pieces **115**, **117**.

Positioned in a common plane on the support medium contiguous to the neck are end portions of two sets of three stationary parallelly spaced apart core elements **119**, **120**, **121** and **122**, **123**, **124** being formed of magnetic permeable material such as soft iron or ferrite. These respective sets of core elements, which are designated as two end core elements with an intermediate core element therebetween, are located in a manner to impart magnetic lines of force to the related pole pieces within the convergence electrode.

Vertical static convergence is achieved by positioning an adjustable magnetic member **125**, **127** to seat in a contiguous manner against the outer ends of each set of core elements **119—121** and **122—124**. These magnetic members **125** and **127** are in the form of rotatable rods of magnetizable material having longitudinal axes **129**, **130** and are similarly magnetized in a permanent manner to develop a plurality of adjustable magnetic fields that are arranged in a substantially symmetrical manner within the region of beam influence on each side of the beam plane. Each rod has three diametrical portions magnetized in a radial manner to provide a plurality of three separate diametrically defined magnets each having a pair of circumferentially oriented north and south poles aligned in a common plane containing the respective axis. The end magnets are referenced in the two magnetic rods **125** and **127** as M_2, M_2' and M_3, M_3' and the intermediate magnetic portions as M_1 and M_1' respectively. In considering rod **125** as an example, the intermediate magnet M_1 has a polarity opposite that of the end magnets M_2, M_3 on either side thereof. The end magnets M_2, M_3 in each rod are magnetized to have substantially equal pole flux densities a_2, m_3, while the intermediate magnet M_1 has a pole flux density m_1, that is greater than the pole flux densities of either of the related end magnets:

$$m_2 = m_3, m_1 > m_2, m_1 > m_3.$$

By utilizing rods having this type of integrated magnetic arrangement, substantially symmetrical interacting magnetic fields are formed to influence convergence positioning of the beams in converging directions to an intermediate plane.

To illustrate the magnetic principles utilized in the improved vertical static convergence means in relation to prior devices, reference is made to FIGS. **3** and **5** wherein the primary characteristics of the respective magnetic fields are shown. To simplify the comparison, the structure of the convergence electrode **39** is eliminated and only representative lines of magnetic force applied to one side of the in-line beam arrangement are shown. In referring to FIG. 3, a known concept utilizes a substantially E-shaped core element **131** comprising a C-shaped element **133** and a central element **135** with a cylindrical magnet **137** rotatably located therebetween. It is evident that rotational adjustment of the magnet **137** will produce substantially nonsymmetrical magnetic fields within the region of beam influence on each side of the beam plane **139** as the magnetic pole is rotated offcenter relative to the central core element **135**. As an example, the aforementioned green beam G, which is proximal P to the core elements, is subjected to the stronger magnetic flux and is moved the greater distance, the red R or center C beam is moved a lesser amount, and movement of the blue B or distal D is influenced the least. Since the magnetic force exerted upon each beam is perpendicular to the direction of the magnetic field, all beams are moved by varying amounts in the same general direction, the direction being determined by the polar positioning of the rotatable magnet **137**. As shown, the magnetic field is nonsymmetrical about the core element **133**, i.e. one portion of the magnetic field **138** on one side of the common beam plane **139** differs from another portion of the field **140** on the other side of the plane. The two pole magnet, as adjusted, tends to influence the respective beam movements in elliptical paths which is a further hindrance to achieving desired static convergence. To converge the beams by moving them in a common direction usually results in a convergence appreciably removed from the common beam plane of the assembly **139**. The only times the field is symmetrical above and below the common beam plane **139** occurs when the plane of the poles substantially coincides with the common beam plane **139**.

With reference to FIG. **5**, which is a simplification of FIG. **4**, it is clearly evident that the three magnetic fields of the integrated magnets designated, for example, as M_1, M_2 and M_3 of the rod member **125** interact to provide substantially symmetrical fields above and below the common beam plane **79** for influencing movement of the several beams P, C, and D respectively in substantially vertical directions.

Because of the symmetry of the magnetic fields within the region of beam influence, there is no elliptical beam movement and convergence is facilitated. As shown, the magnetic flux lines emanating from intermediate magnet M_1 are represented by the lines **141** which exert a directional force **143** on beam P. The pole flux density m_1 of the intermediate magnet M_1 in relation to the flux densities m_2, m_3 of its associated end magnets M_2 and M_3 in such that the outward directed field **141** approaches zero at a region intermediate the beams P and C. The magnetic flux fields emanating from M_2 and M_3, being represented by lines **145** and **147** respectively, move in a direction counter to field **141** and influence beams C and D accordingly by existing directional forces **149** and **151**. Consequently, beams C and D move toward beam P which necessitates minimal beam movements to achieve convergence of the beam in a plane at or near the common beam plane of the gun assembly **79**. As illustrated in FIG. **5**, the magnetic fields emanating from magnetic rod **125** effect the greatest vertical convergence movement to beam P, a smaller amount of movement to beam C and a very minimal amount of movement to beam D.

Any desired proportion of beam movements for beams P and C can be obtained by varying the relative pole strengths of the related magnets. With reference to FIG. **6**, which diagrammatically presents the vector quantities influencing the vertical static convergence means illustrated in FIGS. **4** and **5**, the relationship between intermediate magnet M_1 and end magnet M_2 is shown. Since M_2 and M_3 are of equal magnetization, a similar relationship also holds for magnet M_3. If, for example, it is desired to move beam P three times as far as beam C, but in opposite directions in a converging manner, the ratio of the sum of flux at beam P (μ_p) to the sum of flux at beam C (μ_c) would be represented as $\frac{\mu_p}{\mu_p}=-3$ By way of illustration, it has been found that to achieve this ratio, the intermediate magnet M_1 should have a pole flux density m_1 that is 10 percent greater than the pole flux density m_2 of the end magnet M_2; such being determined by the subsequent formulation in terms of the dimensioning as denoted in FIG. **6** wherein the triangulations S_2 N_1 P relates to the magnetic influences on beam P, and S_2 N_1 C pertains to beam C. For example, the following terms and values are considered:

$X_p=1.11$ inches = the distance from the pole facing of the intermediate magnet M_1 to the proximal electron beam P nearest thereto

$X_c=1.47$ inches = the distance from the pole facing of the intermediate magnet M_1 to the center electron beam C

$r_p=1.22$ inches = the distance from the pole facing of the end magnet M_2 to the proximal electron beam P nearest thereto

$r_c=1.55$ inches = the distance from the pole facing of the end magnet M_2 to the center electron beam C

$h=0.50$ inches = the distance between the pole centers of the intermediate magnet M_1 and the end of magnet M_2

$$\cos\theta_p=\frac{X_p}{r_p}$$

$$\cos\theta_c=\frac{X_c}{r_c}$$

μ_p = sum of flux at beam P

μ_c = sum of flux at beam C

$\frac{\mu_p}{\mu_c}=-3$ = the desired ratio of movement of beam P to beam C

K_{1p} = a constant dependent upon permeance in the flux path through intermediate magnet M_1 and beam P

K_{1c} = a constant dependent upon permeance in the flux path through intermediate magnet M_1 and beam C

K_{2p} = a constant dependent upon permeance in the flux path through end magnet M_2 and beam P

K_{2c} = a constant dependent upon permeance in the flux path through end magnet M_2 and beam C

The ratios of the above noted K values may be determined by using, for example, three test magnetic members having known pole flux densities and thence noting the corresponding beam movements effected by the differing flux density ratios. By utilizing the values obtained therefrom in known simultaneous equations, the following ratio values are obtained:

$$\frac{K_{1p}}{K_{1c}}=5.45 \qquad \frac{K_{1p}}{K_{2p}}=1.79$$

$$\frac{K_{1c}}{K_{2c}}=.89 \qquad \frac{K_{2p}}{K_{2c}}=2.70$$

To determine the relationship of the pole flux density m_2 of the end magnetized portion M_2 with the pole flux density m_1 of the related intermediate magnetized portion M_1 when

$$\frac{u_p}{u_c}=-3$$

the following formula is utilized:

$$\frac{m_2}{m_1}=-\frac{1}{2\cos\theta_c}\frac{K_{1c}}{K_{2c}}\frac{r_c^2}{X_c^2}\left(\frac{\frac{K_{1p}}{K_{1c}}\frac{X_c^2}{X_p^2}-\frac{\mu_p}{\mu_c}}{\frac{K_{2p}}{K_{2c}}\frac{\cos\theta_p}{\cos\theta_c}\frac{r_c^2}{r_p^2}-\frac{\mu_p}{\mu_c}}\right)$$

$$\frac{m_2}{m_1}=-.518\left(\frac{9.55-\frac{\mu_p}{\mu_c}}{4.15-\frac{\mu_p}{\mu_c}}\right)$$

$$\frac{m_2}{m_1}=-.518\left(\frac{9.55+3}{4.15+3}\right)=-.91$$

meaning that the pole flux density m_2 of magnet M_2 is .9 of the pole flux density m_1 of magnet M_1 and of opposite polarity. An example of the foregoing ratio are pole flux densities m_1 and m_2 of substantially 0.0260 and 0.0286 webers/m^2 respectively.

An example of achieving vertical static convergence by utilizing the vertical static convergence means **55**, illustrated in FIG. **4**, is further described by referring to FIG. **7** wherein only representative lines of flux of the adjustable static magnetic fields provided by magnetic members **125** and **127** are shown. In this example, it is desired to vertically move the three beams from positions designated as 23′, 25′ and 27′ to positions substantially in or near the common beam plane 79 denoted by 23, 25 and 27 respectively. Since beam 23′ is to be moved vertically upward, the magnetic member 125 is adjusted so that poles S_2, N_1 and S_3 of magnets M_2, M_1 and M_3 are contiguous to the core elements 119, 120 and 121 respectively. A portion of the lines of magnetic flux 141, emanating from magnet M_1 through core element 120 and the outer pole piece 115 move beam 23′ upward toward the common beam plane 79. Some of the lines of magnetic flux 145 and 147 which extend from magnets M_2 and M_3 are directed toward the inner pole piece 111, which substantially represents the region of zero field potential. Since the flux lines 145 and 147 are directionally counter to flux lines 141, the movement of beam 25′ will be downward toward the common beam plane 79. Beam 27′ tends to be shielded from the significant influence of magnetic member 125 by the inner pole piece 113.

To move beam 27′ downward toward the common beam plane 79, adjustable magnetic member 127 is the predominant controlling factor. As shown, the beam 27′ requires a smaller amount of repositioning than does beam 23′, consequently, the magnetic fields emanating from magnetic member 127 need not be of the strength of those emanating from magnetic member 125. Magnetic member 127 is adjusted in a manner that poles S_2, N_1 and S_3 of magnets M_2', M_1', and M_3' are adjacent, but not contiguous, to the core elements 122, 123, and 124 respectively. Some of the resulting lines of magnetic flux 141′ issuing from magnet M_1' through core element 123 and the outer pole piece 113 move beam 27′ downward toward the common beam plane 79. The representative lines of magnetic flux 145′ and 147′ extending from magnets M_2' and M_3', through core elements 122 and 124, are weaker than the interacting flux lines 145 and 147 and exert a lesser influence on the positioning of center beam 25. A slight readjustment of magnetic member 125 is usually necessary to finalize vertical static convergence of all beams at or near the common beam plane 79. The foregoing is only one illustration of vertical beam repositioning. In those instances where greater or lesser amounts of beam repositioning are required, the magnetic members 125 and 127 may require more or fewer readjustments.

For clarity of illustration, FIG. 7 is an exaggeration of beam misalignment. Actually, the beams are moved within the magnetic fields that are parallel with the common beam plane 79 and the beam movements are perpendicular or vertical thereto. Since the adjustable magnetic fields emanating from each of the respective magnetic members 125 and 127 are substantially symmetrical within the region of beam influence, relative to the common beam plane 79, the vertical static convergence movements of the beams 23′, 25′ and 27′ are advantageously vertical with reference to the beam plane 79 rather than elliptical.

With continued reference to FIG. 4, the vertical dynamic convergence means, as illustrated therein, is in the form of two series connected windings 155 and 157 disposed on intermediate core elements 120 and 123 respectively. These windings 155 and 157 are connected in a discrete manner with vertical circuit terminals 167 and 168 which enable the windings 155 and 157 to be connected in series relationship between the vertical output signal source 75 and the vertical deflection winding in the yoke 71. Each of the two windings 155 and 157 has three connections 159, 160, 161 and 162, 163, 164 of which 159 and 161, and 162 and 164 are end connections and 160 and 163 tap connections respectively. Top oriented jumper means 166 is utilized to interconnect the respective winding connections to achieve the desired magnetic flux densities in the intermediate core elements 120 and 123. For example, if a reduction in flux density is required, a change in the number of ampere-turns is effected by moving the jumper 166 connections from 164 to 163 and from 161 to 160. If it is desired to change the direction of the magnetic flux emanating from the windings 155 and 157, the jumper 166 is moved, for example, to connections 159 and 162, whereupon connections with the vertical circuit 167, 168 are moved from 159 and 162 to either 163 or 164 and 160 or 161 respectively, depending on the density of magnetic flux required. While two windings 155 and 157 are each shown to have tap connections 160 and 163 respectively, a greater number of tap connections means can be utilized to effect a greater diversification of dynamic flux densities if such is required to achieve the desired dynamic convergence.

Thus, there is provided an improved vertical convergence device wherein the static and dynamic convergence adjustments can be facilely accomplished. Reference is made to FIG. 9, wherein the core elements 119—124, the rotatable adjustable magnetic members 125 and 127 associated therewith, and the jumper means 166 are shown.

In referring to FIGS. 1, 8 and 9, there is shown an electron beam controlling assembly 171 which delineates the horizontal and dynamic convergence means as being related with a common supporting body member 77 of an insulative material, such as nylon. This member is formed to have an aperture 173 therein of a dimensional size to accommodate positioning of the body member on the tube neck 19. The body member proper has substantially equal portions extending on either side of the tube neck in a manner substantially normal thereto. A tubular crown 175 is affixed to substantially one side of the body member extending from the aperture 173 in a manner to encompass the tube neck, which for simplification is not shown in FIGS. 8 and 9. The crown has a substantially slotted terminal portion 176, whereabout a compressive ring member 177 effects positional clamping of the crown on the tube neck.

Horizontal static and dynamic convergence means, of the type aforedescribed, are illustrated in FIG. 8 as being associated and affixed to substantially the side of the body member whereon the tubular crown is affixed. The rotatable permanent magnets 49 and 53 have suitable knob portions 178 and 179 which facilitate rotational adjustments. Associated with each knob is a resilient magnet retention member 181, 183, each of which is affixed to the body member in a manner to retain each magnet in the desired functional position. The transformers 99 and 101 which are part of the horizontal dynamic convergence means, are shown as being oriented on a shelf support 187 located atop said body member.

Vertical static and dynamic convergence means, of the type aforedescribed, are illustrated particularly in FIG. 9 as being associated and affixed to substantially the side of the body member opposite to the positioning of the horizontal convergence means. The core elements 119 to 124 are shown in conjunction with their respective magnetic members 125 and 127. Adjustment knobs 191, 193 which are affixed to the magnetic members, are illustrated as being top oriented in the body member. It is also evident that such knobs could be bottom oriented if large knobs were utilized. Traverse resilient means 195, 197 each exert side pressure against the respective magnetic members to retain the positioning thereof.

A rotational purity ring device 41 is shown oriented on the crown member between the body and compressive ring members.

The described positionings of the purity rings and the horizontal and vertical convergence means relative to particular sides of the insulative body member in relation to the yoke are not intended to be limiting, as the purity rings and either convergence means can be oriented on either side of the body member and still be in keeping with the concept of the invention.

Thus, there is provided an electron beam controlling assembly that presents distinct improvements in making all adjustments at fixed and easily accessible locations.

While there have been shown and described what are at present considered the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the scope of the invention as defined by the appended claims.

I claim:

1. An electron beam deflection system for use in a dynamic display apparatus employing circuitry including horizontal and vertical output sources supplying deflection signals for operating a plural in-line beam color cathode ray tube having an envelope including a viewing panel with a related cathodoluminescent screen and a neck portion traversed by said plurality of in-line electron beams emitted from an electron gun assembly oriented in a substantially common plane therein, said deflection system comprising:

a beam deflection yoke positioned on said tube neck portion between said screen and said electron guns, said yoke having vertical and horizontal deflection windings arranged therein;

horizontal convergence means positioned on said tube neck portion adjacent said yoke in a position relative to said electron gun assembly, said horizontal convergence means having a pair of stationary magnetic core elements oriented on either side of said gun assembly to effect both static and dynamic horizontal convergence of said beams, said horizontal static convergence means comprising an adjustable magnet positioned in each pair of said core elements, said horizontal dynamic convergence means comprising a pair of windings disposed on each pair of said stationary core elements and an adjustable inductance means coupled to each pair of said windings, said plural inductance means being connected to said horizontal output signal source and said horizontal deflection winding in said yoke in a manner to supply an induced signal to each pair of said windings; and

vertical convergence means positioned on said tube neck portion adjacent said yoke in a position relative to said electron gun assembly, said vertical convergence means having a set of three stationary core elements oriented on either side of said gun assembly to effect both static and dynamic vertical convergence of said beams, said vertical static convergence means comprising a plurality of diametrically oriented magnets integrated in stacked relationship to form two similar magnetic members, one being adjustably contiguous to each set of said stationary core elements, said vertical dynamic convergence means comprising a winding disposed on one core element of each of said sets, said windings being connected to said vertical output signal source and said vertical deflection winding in said yoke.

2. A horizontal convergence device for use with a plural in-line beam color cathode ray tube having a cathodoluminescent screen and a related electron gun assembly emitting said plurality of in-line beams in a substantially common plane, said device comprising:

horizontal static and dynamic convergence means oriented relative to said electron gun assembly in a common plane substantially normal to said substantially common beam plane, said static and dynamic convergence means having a common set of stationary core elements oriented on each side of said electron gun assembly, each set of side-oriented core elements having individual static and dynamic adjustment means for independently regulating the respective horizontal static and dynamic magnetic flux densities separately associated therewith; and

an insulative horizontal convergence support medium formed to locate and support said convergence means relative to said in-line beams.

3. In a dynamic display apparatus, horizontal dynamic convergence means for use with a plural in-line beam color cathode ray tube in conjunction with a deflection yoke including a horizontal winding for utilizing a horizontal output signal from an appropriate source, said dynamic convergence means comprising:

a pair of series connected inductive coupling means interconnecting said horizontal output signal source and said horizontal winding in said yoke; and

a pair of series connected convergence windings forming loads coupled to each one of said pair of inductive coupling means.

4. In a dynamic display apparatus, horizontal dynamic convergence means according to claim 3 wherein said inductive coupling means are in the form of a pair of adjustable transformers having primary and secondary windings, and wherein said primary windings are series connected with each other and in series relationship with said horizontal output signal source and said horizontal winding in said yoke, and wherein each of said pairs of series connected convergence windings are coupled to the secondary winding of one of said transformers.

5. In a dynamic display apparatus, horizontal dynamic convergence means according to claim 4 wherein the phase of the current induced in the secondary winding of each transformer is in phase with the current in the primary winding thereof.

6. In a dynamic display apparatus, horizontal dynamic convergence means according to claim 5 wherein the resistance of the secondary winding does not exceed 10 percent of the inductance of that winding, and wherein the resistance of said load connected across each secondary winding does not exceed 10 percent of the inductance of the load.

7. A horizontal convergence device for use with a plural in-line beam color cathode ray tube in conjunction with a deflection yoke having a horizontal deflection winding for utilizing a horizontal output signal from an appropriate source in a dynamic display apparatus, said horizontal convergence device being formed for positioning on the exterior of the neck portion of said tube relative to the terminal electrode of an electron gun assembly oriented within said neck portion, said device comprising:

horizontal static convergence means in the form of a pair of stationary magnetic core elements positioned on said neck portion on either side of said gun assembly to effect static convergence of said in-line beams, each pair of core elements having a permanent magnet adjustably positioned therebetween to regulate the static flux density therein;

horizontal dynamic convergence means comprising the aforementioned pairs of stationary core elements with individual core windings disposed on each element of each pair of said stationary core elements and a plurality of adjustable inductive coupling means having primary and secondary windings, each pair of said core windings being series connected to a secondary winding of a separate inductive coupling means whereof the primary windings of said plural inductive coupling means are series connected to said horizontal output signal source and said horizontal deflection winding in said yoke; and

an insulative horizontal convergence support medium formed to locate and support said convergence means relative to said tube neck portion in spaced adjacency to the electron gun assembly oriented therein.

8. A horizontal convergence device according to claim 7 wherein the inductive coupling in said horizontal dynamic convergence means is in the form of a transformer having primary and secondary windings and an adjustable core associated with said windings on each pair of stationary core elements, the primaries of said transformers being series connected with each other in series relationship between said horizontal output signal source and the horizontal deflection winding in said yoke, the secondary of each transformer being series connected to the two windings on each respective pair of core elements, each of said transformer cores being individually adjustable to provide in the secondaries thereof a modification of the amplitude of said output signal applied across the primaries and through the associated windings to produce the magnetic flux densities required for dynamic beam convergence.

9. A horizontal convergence device according to claim 8 wherein said transformer utilized for effecting dynamic convergence is a stepdown type of transformer and wherein the impedance of the load across the secondary winding of said transformer is less than the impedance of said secondary winding.

10. A horizontal convergence device according to claim 8 wherein the total number of turns on each pair of stationary core elements is less than the turns in the secondary winding of each of said respective transformers.

11. A vertical convergence device for use with a plural in-line beam color cathode ray tube in conjunction with a deflection yoke having a vertical deflection winding for utilizing the vertical output signal in a dynamic display apparatus to achieve convergence of the moving electron beams, said vertical convergence device being formed for positioning on the exterior of the neck portion of said tube relative to the terminal electrode of an electron gun assembly emitting three in-line beams and oriented within said neck portion, said device comprising:

vertical static convergence means in the form of a set of three stationary spaced apart core elements oriented on said neck portion on each side of said gun assembly in a plane substantially normal thereto, an adjustable magnetic member positioned contiguous to each set of core elements and comprising a plurality of diametrically oriented magnetized portions arranged to provide an individual magnetized portion for each core element in each set to effect interacting substantially symmetrical magnetic fields within the region of beam influence;

vertical dynamic convergence means in the form of a winding disposed on at least one of said stationary core elements in each set thereof and connected to the vertical deflection winding in said yoke, each of said windings providing magnetic flux to effect dynamic convergence of said beams; and

an insulative vertical convergence support medium formed to locate and support said convergence means relative to said tube neck portion in spaced adjacency to the electron gun assembly oriented therein.

12. A vertical convergence device having dynamic convergence means according to claim 11 wherein said core windings each have a plurality of connections with tap means to provide the required magnetic flux density and flux direction to effect vertical dynamic convergence.

13. A vertical convergence device according to claim 11 wherein each of said separate adjustable magnetic members in said vertical static convergence means is in the form of a rod of magnetizable material having a longitudinal axis, said rod having a plurality of diametrical portions magnetized in a radial manner to provide a plurality of separate diametrically defined magnets each having a pair of circumferentially oriented north and south poles, said poles being aligned in a common plane containing said axis.

14. A vertical convergence device having static convergence means according to claim 13 wherein each of said magnetic members has six poles in the form of three magnetized diametrical portions longitudinally adjacent to one another to form an integration of related magnets adapted to be rotatably adjustable in a manner contiguous to related core elements, said three integrated magnets being referenced as an intermediate magnet M_1 with an end magnet M_2, M_3 on either side thereof, said intermediate magnet having a polarity opposite that of said end magnets.

15. A vertical convergence device having static convergence means according to claim 14 wherein said magnetic members are formed of a material having the property of magnetic retention, and wherein said diametrical portions are permanently magnetized, said magnetic members being substantially similar in the respective magnetic orientations and substantially equal in respective flux densities.

16 A vertical convergence device having static convergence means according to claim 14 wherein said end magnets M_2, M_3 in each of said magnetic members are magnetized to have substantially equal pole flux densities m_2, m_3 and wherein said intermediate magnet (M_1 is magnetized to have a pole flux density m_1 greater than the pole flux densities m_2, m_3 of either of said end magnets M_2, M_3:

$$m_2 = m_3$$

$$m_1 > m_2$$

$$m_1 > m_3$$

17. A vertical convergence device having static convergence means according to claim 14 wherein the three in-line electron beams subjected to convergence are referenced in relation to a magnetic member as being proximal P, center C, and distal D beams thereto, and wherein the pole flux density m_2 of an end magnetized portion M_2 of the respective magnetic member has a relationship with the pole flux density m_1 of the related intermediate magnetized portion M_1 according to the related intermediate magnetized portion M_1 according to the ratio derived in the formula:

$$\frac{m_2}{m_1} = -\frac{1}{2\cos\theta_c}\,\frac{K_{1c}}{K_{2c}}\,\frac{r_c^2}{X_c^2}\left(\frac{\dfrac{K_{1p}}{K_{1c}}\dfrac{X_c^2}{X_p^2}-\dfrac{\mu_p}{\mu_c}}{\dfrac{K_{2p}}{K_{2c}}\dfrac{\cos\theta_p}{\cos\theta_c}\dfrac{r_c^2}{r_p^2}-\dfrac{\mu_p}{\mu_c}}\right)$$

wherein:

X_p = the distance from the pole facing of the intermediate magnet (M_1) to the proximal electron beam (P) nearest thereto

X_c = the distance from the pole facing of the intermediate magnet (M_1) to the center electron beam (C)

r_p = the distance from the pole facing of the end magnet (M_2) to the proximal electron beam (P) nearest thereto

r_c = the distance from the pole facing of the end magnet (M_2) to the center electron beam (C)

$$\cos\theta_p = \frac{X_p}{r_p}$$

$$\cos\theta_c = \frac{X_c}{r_c}$$

K_{1p} = a constant dependent upon permeance in the flux path through magnet M_1 and beam P

K_{1c} = a constant dependent upon permeance in the flux path through magnet M_1 and beam C

K_{2p} = a constant dependent upon permeance in the flux path through magnet M_2 and beam P

K_{2c} = a constant dependent upon permeance in the flux path through magnet M_2 and beam C

μ_p = sum of flux at beam P

μ_c = sum of flux at beam C

18. An electron beam convergence assembly formed for utilization with a deflection yoke on a plural in-line beam color cathode ray tube having an envelope neck portion traversed by said plurality of in-line electron beams emitted from an electron gun assembly oriented therein relative to the closed end thereof, said convergence assembly comprising:

an insulative body member having an aperture therein of a dimensional size to accommodate the positioning of said body member on said tube neck, said body member having substantially equal portions extending on either side of said tube neck in a manner substantially normal thereto;

a tubular crown affixed to substantially one side of said body member and extended substantially from the aperture thereof in a manner to encompass the tube neck extending therethrough, said tubular crown having a substantially slotted terminal portion;

horizontal static and dynamic convergence means affixed to substantially one side of said body member relative to said electron gun assembly in said tube neck portion, said horizontal static and dynamic convergence means having a common pair of stationary core elements with separate and independent static and dynamic magnetic adjustments oriented in said body member relative to both sides of said electron gun assembly, said horizontal dynamic convergence means employing individual core windings disposed on each core element of each pair of said stationary core elements, each pair of said core windings having an adjustable inductive coupling means connected thereto;

vertical static and dynamic convergence means affixed to substantially the side of said body member opposite to the positioning of said horizontal convergence means, said vertical convergence means having a set of three stationary spaced apart magnetic core elements positioned in said body member relative to both sides of said electron gun assembly, an adjustable magnetic member comprising a plurality of diametrically oriented magnetized portions positioned contiguous to each set of said core elements, each of said magnetic members having means for rotational adjustment protruding from said body member to regulate the flux density in relation to said contiguous core elements; and

a compressive ring member oriented about the slotted terminal portion of said tubular crown to effect positional clamping of said tubular member on said tube neck portion.

19. An electron beam convergence assembly according to claim **18** wherein said vertical dynamic convergence means is in the form of a winding disposed on the intermediate core element in each set of three stationary spaced apart core elements and wherein each of said core windings has a plurality of connections with movable tap means to provide the required magnetic flux density and flux direction to effect vertical dynamic convergence.

20. An electron beam convergence assembly according to claim **18** wherein said tubular crown is oriented toward said closed end of said tube neck, and wherein said horizontal convergence means are affixed on the side of said body member adjacent said tubular crown.

21. An electron beam convergence assembly according to claim **18** wherein said tubular crown is oriented toward said closed end of said tube neck, and wherein said vertical convergence means are affixed on the side of said body member adjacent said tubular crown.

22. An electron beam controlling assembly having a plurality of beam controlling means contained therein for utilization with a deflection yoke on a plural in-line beam color cathode ray tube having an envelope neck portion traversed by said plurality of in-line electron beams emitted from an electron gun assembly oriented therein relative to the closed end thereof, said beam controlling assembly comprising the combination of:

an insulative body member having an aperture therein of a dimensioned size to accommodate the positioning of said body member on said tube neck, said body member having substantially equal portions extending on either side of said tube neck in a manner substantially normal thereto;

a tubular crown affixed to substantially one side of said body member and extended substantially from the aperture thereof in a manner to encompass the tube neck extending therethrough, said tubular crown having a substantially slotted terminal portion;

horizontal static and dynamic convergence means affixed to substantially one side of said body member relative to said electron gun assembly in said tube neck portion, said horizontal static and dynamic convergence means having a common pair of stationary core elements and separate and independent static and dynamic magnetic adjustments positioned in said body member relative to both sides of said electron gun assembly, said horizontal dynamic convergence means employing individual core windings disposed on each core element of each pair of said stationary core elements, each pair of said core windings having an adjustable inductive coupling means connected thereto;

vertical static and dynamic convergence means affixed to substantially the side of said body member opposite to the positioning of said horizontal convergence means, said vertical convergence means having a set of three stationary spaced apart magnetic core elements positioned in said body member relative to both sides of said electron gun assembly, an adjustable magnetic member comprising a plurality of diametrically oriented magnetized portions positioned contiguous to each set of said core elements; each of said magnetic members having rotational adjustment means protruding from said body member to regulate the flux density in relation to said contiguous core elements;

a compressive ring member oriented about the slotted terminal portion of said tubular crown to effect positional clamping of said tubular member on said tube neck portion; and

a purity ring device positioned in a manner to allow rotation on said tubular crown between said body and said compressive ring members.

23. An electron beam controlling assembly according to claim **22** wherein said horizontal convergence means are affixed on the side of said body member adjacent to said purity ring device.

24. An electron beam controlling assembly according to claim **22** wherein said vertical convergence means are affixed on the side of said body member adjacent to said purity ring device.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,553,523 Dated January 5, 1971

Inventor(s) Raymond A. Budd

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 72, of the specification, the following was omitted--electrode assembly 39. Adjacent to the horizontal convergence--.

Column 4, line 39 "continuous" should read--contiguous--.

Column 5, line 11 "not" should read--no--.

Column 5, line 41 "024GA" should read--#24GA--.

Column 6, line 47 "a_2, m_3" should read--m_2, m_3--.

Column 7, line 35 "in" should read--is--.

Column 8, line 42 "$\frac{K_{1p}}{K_{1c}} = 5.45$" should read-- $\frac{K_{1c}}{K_{2c}} = .89$--.

Column 8, line 45 "$\frac{K_{1c}}{K_{2c}} = .89$" should read-- $\frac{K_{1p}}{K_{1c}} = 5.45$--.

Column 8, line 50 "$\frac{u_p}{u_c} = -3$" should read-- $\frac{\gamma_p}{\gamma_c} = -3$--.

Column 13, Claim 10, line 3 "the turns" should read--the number of turns--.

Signed and sealed this 27th day of April 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR
Commissioner of Patents