May 30, 1961 A. L. TIRICO 2,986,667

ELECTRON BEAM DEFLECTION

Original Filed July 10, 1952

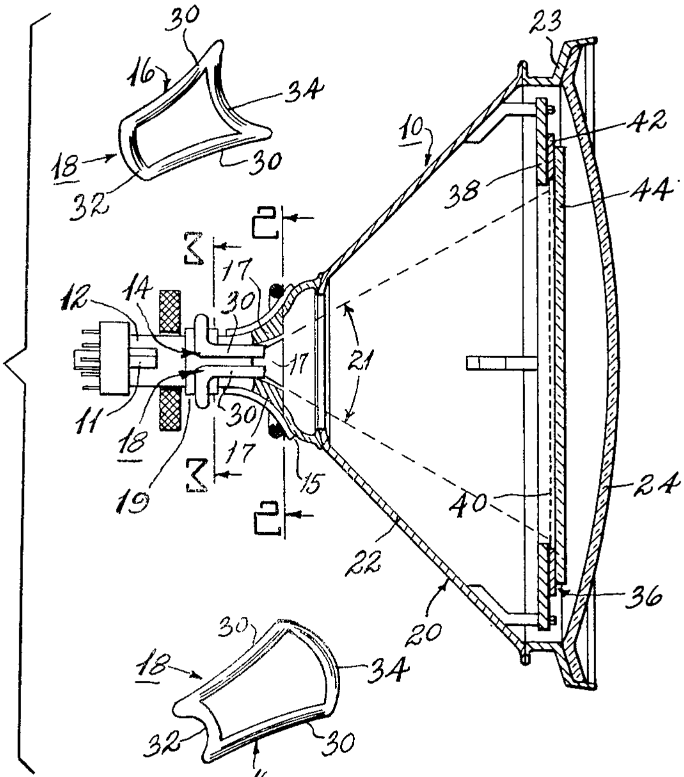

Fig.1.

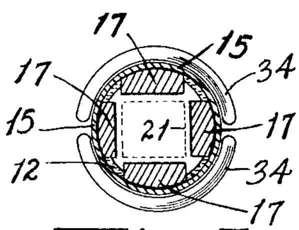

Fig.2.

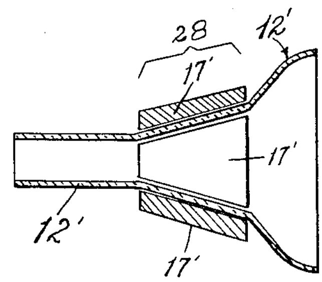

Fig.4.

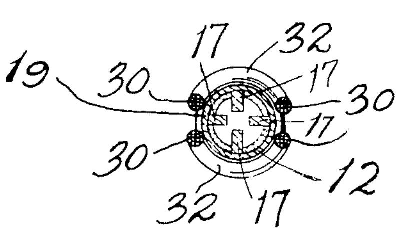

Fig.3.

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ELECTRON BEAM DEFLECTION

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Original application July 10, 1952, Ser. No. 298,118, now Patent No. 2,785,329, dated Mar. 12, 1957. Divided and this application Mar. 8, 1957, Ser. No. 644,801

9 Claims. (Cl. 313—76)

This application is a division of my co-pending application Serial No. 298,118 which was filed on July 10, 1952, and is to issue as a U.S. Patent 2,785,329 on March 12, 1957.

This invention relates to multiple beam cathode ray devices and/or single beam devices so operated as to constitute the equivalent thereof. More particularly it relates to "directional" color-television picture and pick-up tubes, such as those described in U.S. Patent 2,581,487, in which color-selective cooperation between an electron beam and a color-image transducing surface depends on the direction of convergence of the beam onto said surface.

One very serious problem which has been encountered in developing directional types of color television transducer tubes has been the attainment of uniformity of convergence of a number of electron beams, or of a single beam operated sequentially as the equivalent thereof, toward all parts of an image transducing surface, e.g., toward all parts of a directional dot-phosphor fluorescent screen. Thus whereas the individual beams of a three beam directional kinescope (or individual successive bursts of electrons in the single nutating beam of an equivalent kinescope, like that shown in the above-mentioned patent) may converge accurately upon a picture-element-size area when they are proceeding toward some central portion of the screen, they may fail to do so when proceeding toward a peripheral portion of the screen such as toward one of the corners of the image area. As a result the video information concerning the respective component-colors of a single full-color picture element may reproduced at the locations of different picture element areas which may actually be dozens of picture-element areas apart. The effect which this causes might be compared to what would happen in color-printing (with inks) if the component images were printed on a somewhat elastic paper and if the paper were slightly and unevenly stretched or, otherwise changed to a slightly different shape, before each additional color was applied to it.

Early in the development of these tubes it was found that one reason for non-uniformity of convergence is that inasmuch as the image-transducing surface is flat, rather than spherical, all points thereof are not equidistant from the tube's center (or "centeroid") of deflection, and a way of compensating for this was quickly devised. This consisted of providing of dynamic convergence correction in which focusing is varied in synchronism with scanning. While this was very helpful, it still did not result in satisfactory uniformity of convergence. Although great efforts have been made to attain a more complete solution they have been rather unsatisfactory. They involved resort to complicated devices adapted to permit extremely painstaking adjustments requiring great skill and intended to offer a trial-and-error way of eliminating, or compensating for, myriads of aberrations supposedly randomly occurring in the magnetic fields. Besides often being ineffectual this was not a practical solu-

tion because of the excessively high initial cost of color receivers using the devices and maintenance needs which cannot be met at all with available personnel.

Accordingly it is an object of this invention to provide devices of the kind in question which inherently have greatly improved uniformity of convergence and therefore do not require resort to complicated field adjustments thereof.

The attainment of this and other objects has been based on the following principles: (1) that the electron optical requirements for accurate and uniform convergence of one or more "directional" beams are similar to, but on a dimensionally larger scale than, those for accurate uniform focus for a single axial beam; (2) that a principal one among these requirements is that a magnetic deflection yoke have a sufficiently large throat to avoid excessively close skirting of its interior surfaces by any of the electrons in a convergent cone thereof or any of the beams in a convergent bundle thereof, as the case may be; and (3) that in preferred embodiments (but not necessarily) the yoke may be provided with such a sufficiently large throat with a minimum loss in efficiency if it is formed with a tapered-configuration approximately conforming to the intended solid angle of deflection.

It should be borne in mind that even the electrons comprising a single axial beam do not constitute a fine pencil-like stream as they pass through the deflection region. Instead they are quite spread out as a result of having diverged for a considerable distance after leaving the gun and then converged for only a short distance after focusing. Thus the beam constitutes a cone of electrons whose dimensionally-finite base-end occupies the deflection region while its sharp apex is directed at the screen where all of the electrons should pass through a small cross-over point if sharp focus is to be achieved. Because of the base of the cone subtending a significant amount of space in the deflection region any substantial non-uniformity in the magnetic deflection flux across that region will divert some of the electrons more than others and therefore will prevent them from all meeting at the intended common cross-over point. Such non-uniformity exists close to the inside of the throat of the yoke since magnetic field gradients within a solenoid increase at increasing rates within successive small increments of space nearer and nearer to its inside surface, i.e., nearer and nearer to its actual wires. This is particularly important in the case of directional color transducer tubes wherein the thickness of the entire bundle of convergent beams of beam paths is necessarily quite substantial. However those principles and their relationship do not seem to have been understood or at least, judging by the above-mentioned painstaking expedients which were resorted to in the past, little use was made of them if they were.

In the drawing:

Fig. 1 represents a side view, partially in longitudinal section, of an embodiment of the present invention comprising a directional color-television transducer having a tapered throat neck and a tapered throat magnetic deflection yoke one half of which is shown in position on the neck, namely one of the two pairs of coils which are used for deflecting the beam in rectangularly coördinate directions to produce a television picture raster, and with the two coils comprising the other pair removed to clarify the showing;

Figs. 2 and 3 are transverse sectional views of the embodiment of Fig. 1 taken respectively along the lines **2—2** and **3—3** therein; and

Fig. 4 represents a longitudinal sectional view of an alternate embodiment of the present invention.

The apparatus shown in Fig. 1 comprises a three gun wide-angle directional color kinescope **10** having a gun assembly **11** mounted near the closed or socket end of the neck 12 and carrying on said neck a pair of coils (pair 14) of two pairs thereof (14, 16) which together constitute a tapered throat deflection yoke 18 which is shown herein in a dissassembled or "exploded" condition. The kinescope 10 shown herein by way of example is of the composite glass-and-metal type. As such it includes a bulb-portion 20, consisting of a metal cone 22, a frame 23 which comprises an extension of the cone 22 and is welded to the large end thereof, a face plate 24 sealed into the frame 23, and a glass neck portion 12 sealed to the small end of the cone. This structure is often to be preferred since besides providing a mechanically excellent vacuum envelope and offering commercial advantages such as reduced weight, greater safety, and economy of manufacture, it has characteristics which render it capable of performing certain desired electrical functions and of assisting cooperating components in performing others. For example, the metal cone 22, by being conductive, can function as the final accelerating electrode (or part thereof) and, by being para-magnetic can function as a magnetic shield, while the glass neck 12, by having appropriate properties, e.g., by being non-magnetic, can assist the yoke 18 in performing its function. However it is not essential that the kinescope envelope be of any particular type for the purposes of the present invention so long as it is large enough and appropriately-shaped, to accommodate the solid-angle locus of the intended paths of the convergent group of beams and does not interfere with the mounting and function of a suitable tapered-throat deflection means. Thus, the following are examples of alternative types of kinescope envelopes with which an external magnetic deflection means can be used: all glass envelopes or different types of composite envelopes in which, like it, the portion which surrounds the beam deflection region has the requisite tapered-throat configuration and is of such material, or is so arranged, that it does not short-circuit the deflection flux or otherwise magnetically shield the beam deflection region.

In the present application the tapered-throat portion of the envelope is deemed to be, and is referred to as, a portion of the envelope neck, e.g., the portion of the neck 12 which in Fig. 1 lies between the reference lines 2—2 and 3—3, and the corresponding portion 28 in the embodiment of Fig. 4.

While glass is the material shown herein for making the tapered-throat neck portions of Figs. 1–3 and 4, it is only because at present glass is accepted as the preferred and the most practical material for this purpose and not because there is not other suitable material. As an alternative, for example, one may use copper, provided it can be suitably insulated from the cone 22 (to keep the high final anode voltage away from the yoke 18) or that at least the yoke 18 can be suitably insulated from it. In fact if desired the tapered portion may even comprise segments 19 or 19′ of low-reluctance para-magnetic material to serve as pole pieces for the respective four coils of the yoke, so long as they are separated by gaps or segments of high reluctance to avoid magnetically short-circuiting the deflecting flux around the deflection region.

As noted above the throat of the yoke 18 should be sufficiently larger than the intended solid angle of deflection 21 so that no beam in the convergent bundle thereof will so closely skirt the windings of the yoke near its inside surface as to impart substantially more deflection to it than to any other.

Since the actual spacing in any single case will depend on a plurality of factors such as the amount of convergence to be employed; the focal length of the tube, the size of the emissive cathode area(s), the distance between the focusing electron optic and the deflection yoke, the velocity of the beam electrons, the average flux density within the yoke, etc., it is inadvisable to relay on mathematical computations for determining the minimum and optimum spacings which must be maintained between the inside of the yoke throat and the periphery of the intended solid angle of deflection. In preference thereto an empirical procedure, such as the following, may be followed: using any suitable trial yoke the dynamic convergence correction should be adjusted to secure the best possible uniformity of convergence; the widths of the side and corner areas wherein the convergence is still poor should be measured; a scale drawing made be made to represent the paths of the electrons from the centroid of deflection to points on the screen at the boundaries of the areas of poor convergence; the distance between these paths may be measured in the region of the yoke (wherein 1½ to 3 inches at the screen may correspond to perhaps a very small fraction of an inch); and a new yoke may be made which is larger than the trial one in accordance with these measurements. Where the trial yoke is of a tapered throat configuration conforming to the shape of the intended solid angle of deflection, then it would be advisable simply to enlarge all of its inside dimensions without employing any change in configuration. On the other hand where the trial yoke is one having a cylindrical throat (i.e., one in which the factor of efficiency is being to some extent disregarded) then it would be possible either to increase its internal dimensions over all of its length or do so only over the forward end of its throat thereby employing a change in configuration as well as in size. As a result of this procedure a minimum throat size will be obtained which will in effect afford a substantially uniform deflection flux across the entire solid angle of deflection. In practical utilization of this invention this is important since good deflection efficiency will not be possible if the throat is excessively large. From the foregoing it follows that preferred embodiments of a yoke according to the present invention should utilize the tapered-throat type of configuration and should employ dimensions for the tapered throat which are neither too small nor too large.

If it should happen that a production model yoke, i.e., one which has already been designed and built, is a little too small under particular circumstances in which it is used, its tapered configuration will make it possible, and in fact easy, to correct for this in a very simple manner by shimming-back the yoke from the neck as shown at 15 in Fig. 1 and inserting a tubular element 19 inside the rear-end of the yoke to short-circuit the deflection flux for a distance equal to that by which the yoke was moved rearward. This will have the effect of moving the yoke backward along the neck of the tube without doing the same thing to the intended solid angle of deflection and therefore it will effectively increase the clearances between the yoke and said angle. These adjustments may necessitate slight readjustments of the input currents fed to the yoke to preserve the size of the picture.

Where the tapered throat of a yoke has circular cross sections, i.e., has the approximately frusto conical shape shown in Fig. 1, the lumped conductor comprising each coil will be shaped with two nearly straight sides 30, 30 which diverge from ane another at points progressively further along the yoke in the mean direction of beam travel, to an extent dependent on the desired steepness of taper, two substantially semi-circular ends 32, 34 of different inside diameters corresponding to the diameters of the end openings of the tapered throat.

Incidentally if it is desired to have the shape of the deflection region conform even more closely to that of the solid angle of deflection used for television scansion, as contrasted for example to the scansion in polar coordinates used for radar plan-position indicators, both the envelope (as in Fig. 4) and the deflection yoke may have their throats shaped to approximately correspond to a truncated rectangular pyramid rather than to a frustum.

As indicated above it would not be the best practice of the present invention to go to extremes in providing abundant space within the throat of the deflection means and therefore a tapered throat configuration should be used so that this space will be relatively small in regions where deflection of the beams has not progressed very far. In fact the ideal configuration is one in which the intersection of the sides of the throat with a flat plane passing through the neck axis, in either of the directions of deflection, will be a line parallel to; spaced away from; and having the same curvature as the trajectory of a peripheral electron moving through the deflection region under the maximum influence of the total deflection forces which are effective in directions parallel to that plane.

The following formulas are of interest in that they mathematically describe the path of an electron in a magnetic field:

$$R=\frac{2m}{e}v.\frac{1}{H}=\frac{Dd}{y} \quad (1)$$

$$y=DdH=\frac{Dd}{R} \quad (2)$$

$$\frac{2m}{e}v$$

Where:

v=anode potential E.M.U.
H=the magnetic field in gauss
$\frac{m}{e}$=the reciprocal of 1.77×10^{7} E.M.U. w./g. i.e., a constant concerning the electron
D=distance to face plate from the centroid of the deflection system in centimeters
d=total effective length of the deflection system in centimeters
y=the deflection or displacement of the beam at the screen from the central axis of the system
R=the approximate radius of the trajectory

From the foregoing it can be mathematically demonstrated that, as is well known in the art, the path of an electron moving through a magnetic field is along a curved line very closely approximating the closely similar shapes of either a parabola or a hyperbola.

Thus a theoretically ideal throat shape, where it is desired to use a neck having circular, rather than rectangular cross sections, is substantially that of a surface of revolution of a parabola (or hyperbola) about an axis from which it is spaced away at one end by the smallest diameter of the neck; toward which it is convex; and with respect to which a tangent to its said end will be parallel.

As a practical matter, however, excellent results may be obtained if the tapered throat is actually frusto-conical or truncated-pyramidal instead of approximately so. Moreover, since either a parabola or a hyperbola comprises portions which are respectively: (1) substantially circular; and (2) substantially straight, according to non-rigorous standards which suffice for the purposes at hand, a good compromise shape for a tapered throat is that of a surface of revolution of a line which has a portion which is substantially straight and is divergent from the axis of revolution and a substantially circular portion as a continuation of the divergent end of the straight portion. An advantage of using a tapered-throat neck such as of either the frusto-conical or truncated-pyramidal type is that it will afford accurate centering of the yoke on the neck, since two such tapered surfaces, when pushed together, tend automatically to center with respect to each other, this being true whether or not spacing-shims **15** are used between the yoke and the neck.

A target assembly **36** is mounted in the large end of the bulb portion **20** directly behind the face plate **24**. It comprises a rigid support frame **38**; a foraminous masking electrode **40** stretched tautly over the frame **38** in the fashion of a drum head bridging the large picture-area opening surrounded by the frame; a shim-spacer **42** for establishing and maintaining a predetermined spacing between the front surface of the masking electrode and the luminescent screen of the kinescope; a screen plate **44**; and a "dot-phosphor" luminescent screen (not shown) carried on the rear surface of the screen plate. The entire assembly **36** is carried on a number of lugs **46** which in turn are welded to the interior surface of the cone **22**. As is known such an arrangement offers one of a number of possible ways of affording color-selective cooperation between an electron beam and a luminescent screen in accordance with the direction of convergence of the former onto the latter.

Fig. 4 shows a modification which employs a neck **12'** whose portion **28**, corresponding to the deflection region, is of approximately truncated-pyramidal shape.

Of course where the deflection forces are not to be applied through the envelope walls from elements which are mounted outside thereof the envelope does not have to have any particular shape in the beam deflection region so long as it provides enough space to contain the deflection arrangement. Thus a tapered throat magnetic deflection yoke may be mounted within the envelope and, in such a case, no tapered throat neck would be necessary.

While they are not shown herein because they do not comprise an inventive feature of the apparatus shown herein and are now known in the art, it is to be understood that a tapered throat yoke such as the yoke **18** should preferably be provided with the usual para-magnetic wrappings and/or cores to restrict external fringing of the fields which they produce when in operation and to low the reluctance of their magnetic return paths.

The term transducer has been employed herein to indicate that the present invention is applicable to multiple beam (or equivalent) pick-up tubes as well as multiple beam (or equivalent) picture tubes.

It is to be understood that while particularly great advantages may be gained by using the present invention in directional color television transducers nevertheless very significant advantages can also be gained by using it in multiple gun cathode ray devices having nondirectional screens such as in certain cathode ray oscilloscopes employing convergently trained guns for presenting a plurality of wave-forms in superposed plot on the same coordinate axis.

According to another procedure for empirically approximating the amount of increase required for the throat size of an experimental yoke, measurements are made to determine over what percentage of a given dimension of the screen area the convergence is unsatisfactory, for example if corner areas of poor convergence each measure 1½ inches along a 15 inch diagonal, this being the smallest in the above-mentioned range and, as is well known, a representative example of the best uniformity of convergence obtained in the past under the then standard conditions of a tight-fitting yoke on a neck two inches in diameter with a one-eighth inch wall thickness, the percentage in question will be 20. If a new yoke is then made with a 20% larger throat, the result will be a 20% increase in the size of the relatively uniform density central portion of the magnetic flux field provided within the yoke.. If the first yoke was of the cylindrical throat type commonly used in the prior art the increase in size could be limited to the front end of its throat. In fact it is entirely possible that the width of the back end could at the same time be so reduced as to fully compensate for the loss of efficiency occasioned by the increase in the width of its front end.

Obviously, many modifications and variations of the invention, as hereinbefore set forth, may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated in the appended claims.

I claim:

1. A cathode ray transducer comprising an envelope including a neck having a central axis and a bulb attached to an open forward end of the neck, a source of electrons in said neck near its other end, a focal surface having an image area in said bulb, means for projecting electrons from said source toward said area through a deflection region in the neck along radially-spaced-apart plural beam paths so convergently that if laterally deflected with suitable uniformity throughout a predetermined solid angle in said region they will systematically scan said area over respective terminal portions of said paths and said terminal portions of the paths will continuously overlap at some point on the area during the scansion thereof, said neck being adapted to support on the transducer a deflection yoke comprising an assembly of coils defining the interior surface of a hollow throat which surrounds the part of the neck containing said deflection region and the apex of said angle when the yoke is supported on the transducer, said assembly being adapted to produce in said throat cyclically varying magnetic fields having suitable intensities to deflect the electrons throughout said angle but the inherent characteristic that the fields will do so with said suitable uniformity in only a limited central portion of the space within said throat as measured in transverse directions therein, said central portion being surrounded by an annular peripheral portion wherein the fields will not do so with said uniformity, said peripheral portion comprising a very substantial percentage of the volume of said space, said assembly being wide enough in all of its interior dimensions for the limited central portion of the space within said throat alone to fully accommodate the apex of the angle and all of its portions forward thereof within said region provided the assembly is positioned on the neck with said throat substantially symmetrically disposed about said axis thereof, the transducer being characterized in that said part of the neck has suitably wide exterior dimensions and an exterior configuration which suitably mates with said interior configuration of said throat to alone position said assembly substantially symmetrically about said axis when the yoke is supported on the transducer.

2. A transducer as in claim 1 wherein at least a forwardmost portion of said hollow throat is progressively wider in the same direction as said angle to at least partly conform to the widening shape thereof and flares smoothly-outwardly in a configuration adapted to aid in symmetrically disposing said throat about said axis and said transducer is further characterized in that a forwardmost portion of said part of the neck has suitably increasing widths at points progressively nearer to said bulb and a suitable exterior configuration to enable it to mate with the outwardly-flaring portions of the throat when the yoke is positioned far enough forward thereon to abut tightly against it.

3. A magnetic deflection yoke for systematically sweeping a beam of electrons through a predetermined solid angle comprising: an assembly of coils surrounding and defining the interior surfaces of a hollow throat through which said electrons move in the use of the yoke, and a quantity of high-permeability low-loss material occupying a plurality of segments of peripheral throat space within the yoke each segment lying between a different side of the solid angle and a respective portion of said surfaces of the throat which faces inwardly toward it.

4. A magnetic deflection yoke for systematically sweeping a beam of electrons through a predetermined solid angle comprising: an assembly of coils surrounding and

defining the interior surfaces of a hollow throat through which said electrons move in a given general direction in the use of the yoke, said throat being of such configuration that its intersections with imaginary transverse planes at successive positions along a central axis which extends through the yoke in said direction are arcuate where they extend around respective sides of said angle, for example because said intersections are circular, while corresponding intersections of said respective sides of the solid angle with said planes are substantially straight; and a quantity of high-permeability low-loss material occupying a plurality of segments of peripheral space within the throat each lying between at least a portion of a respective one of the sides of the said solid angle and the succession of arcuate portions of said intersections which extend around it.

5. A yoke as in claim 4 wherein transverse cross sections of said pole pieces are arcuate on their sides toward said throat and substantially straight on their sides toward the said angle.

6. Apparatus comprising a magnetic yoke for systematically sweeping a beam of electrons through a predetermined solid angle comprising an assembly of coils surrounding and defining the interior surfaces of a hollow throat through which said electrons move in the use of the yoke, a neck portion of the envelope of a cathode ray transducer, the said neck portion positioned within and extending through said throat, and pole pieces of high-permeability low-loss material associated with said neck portion each occupying a segment of the space within said throat which lies between a portion of the interior surface thereof and a respective side of said angle toward which it faces.

7. Apparatus as in claim 6 in which said pole pieces are integral segments of said neck portion, each of them having an outer surface which is a portion of the outside of said neck and has transverse cross sections which are arcuate convexly toward a portion of the interior of said throat and an inner surface which faces toward a respective side of said angle, is a portion of the inside of said neck and has substantially straight transverse cross sections.

8. Apparatus as in claim 6 in which said neck portion has at least partially rectangularized cross sections over at least a part of its length within said throat and each of the said pole pieces is located between one of the transversely relatively flat sides of the outside surface of said part of said neck portion and a corresponding part of the inwardly-facing surface of said hollow throat.

9. A deflection yoke for systematically sweeping a beam of electrons through a predetermined solid angle, said yoke having a hollow throat which is progressively wider in the direction in which electrons travel through it in the use of the yoke whereby it conforms at least partially to the trajectories of those of the electrons which are subjected to the greatest amount of deflection during said use, a tubular magnetic-flux short-circuiting element positionable within the smaller end of said throat, said element being axially moveable therewithin for effectively axially moving the apex of said solid angle of deflection within the throat to thereby change the clearance between the outermost portions of the solid angle and the inwardly-facing portions of said hollow throat to which they are most proximate.

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