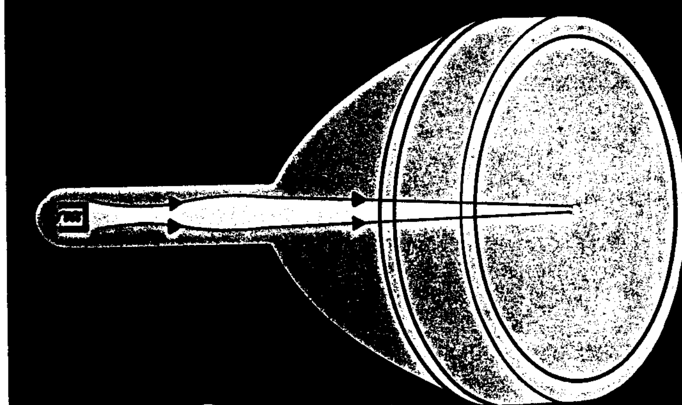
Tech-notes

Vol. 1, No. 3, May/June 1974

The Laminar Flow Gun CRT



New Concepts for the Electron Beam

For the past 40 years the industry standard for Cathode-Ray Tube (CRT) displays has been the crossover electron gun. In fact, almost every CRT manufactured today incorporates this type of gun.

Recently, the Watkins-Johnson Company accomplished a breakthrough in CRT technology with the development of the laminar flow electron gun. Cathode-ray tubes employing the laminar flow gun exhibit a clearer, brighter display because of improvements in resolution and reduced grid drive requirements. These CRT advantages result from the laminar flow gun's basic design advancements of a more intense and uniform electron source, lower beam noise, elimination of the space-charge effect at the crossover, and a higher perveance structure.

This issue answers some of the questions concerning the laminar flow gun CRT's characteristics and its effect on resolution.

WATKINS-JOHNSON CO.
PALO ALTO, CALIFORNIA

WJ WATKINS-JOHNSON

Manufacturing and Office Locations

UNITED STATES

CALIFORNIA

Watkins-Johnson
3333 Hillview Avenue
Palo Alto 94304
Telephone: (415) 493-4141

Watkins-Johnson
440 Mount Hermon Road
Scotts Valley 95066
Telephone: (408) 438-2100

Watkins-Johnson
11222 La Cienega Blvd.
Inglewood 90304
Telephone: (213) 670-4850

FLORIDA

Watkins-Johnson
7001 Lake Ellenor Drive
Orlando 32809
Telephone: (305) 851-2391

MARYLAND

Watkins-Johnson
700 Quince Orchard Road
Gaithersburg 20760
Telephone: (301) 948-7550

MASSACHUSETTS

Watkins-Johnson
279 Cambridge St., Ste. 113
Burlington 01803
Telephone: (617) 272-7235

NEW YORK

Watkins-Johnson
808 Shrewsbury Avenue
New Shrewsbury, N.J. 07724
Telephone: (201) 842-2422

OHIO

Watkins-Johnson
2500 National Rd., Ste. 200
Fairborn, Ohio 45324
Telephone: (513) 426-8303

TEXAS

Watkins-Johnson
4230 LBJ Freeway
Dallas 75234
Telephone: (214) 289-9131

INTERNATIONAL

ITALY

Watkins-Johnson Italiana
S.p.A.
Piazza G. Marconi, 25
00144 Roma-EUR
Telephone: 59 45 54
Telex: 60117
Cable: WJROM-ROMA

UNITED KINGDOM

Watkins-Johnson
Shirley Avenue
Windsor, Berkshire SL4 5JU
Telephone: Windsor 69241
Telex: 847578
Cable: WJUKW-WINDSOR

WEST GERMANY

Watkins-Johnson
8033 Planegg
Münchenerstr. 17
Telephone: (089) 859-9441
Telex: 529401
Cable: WJDBM-MUENCHEN

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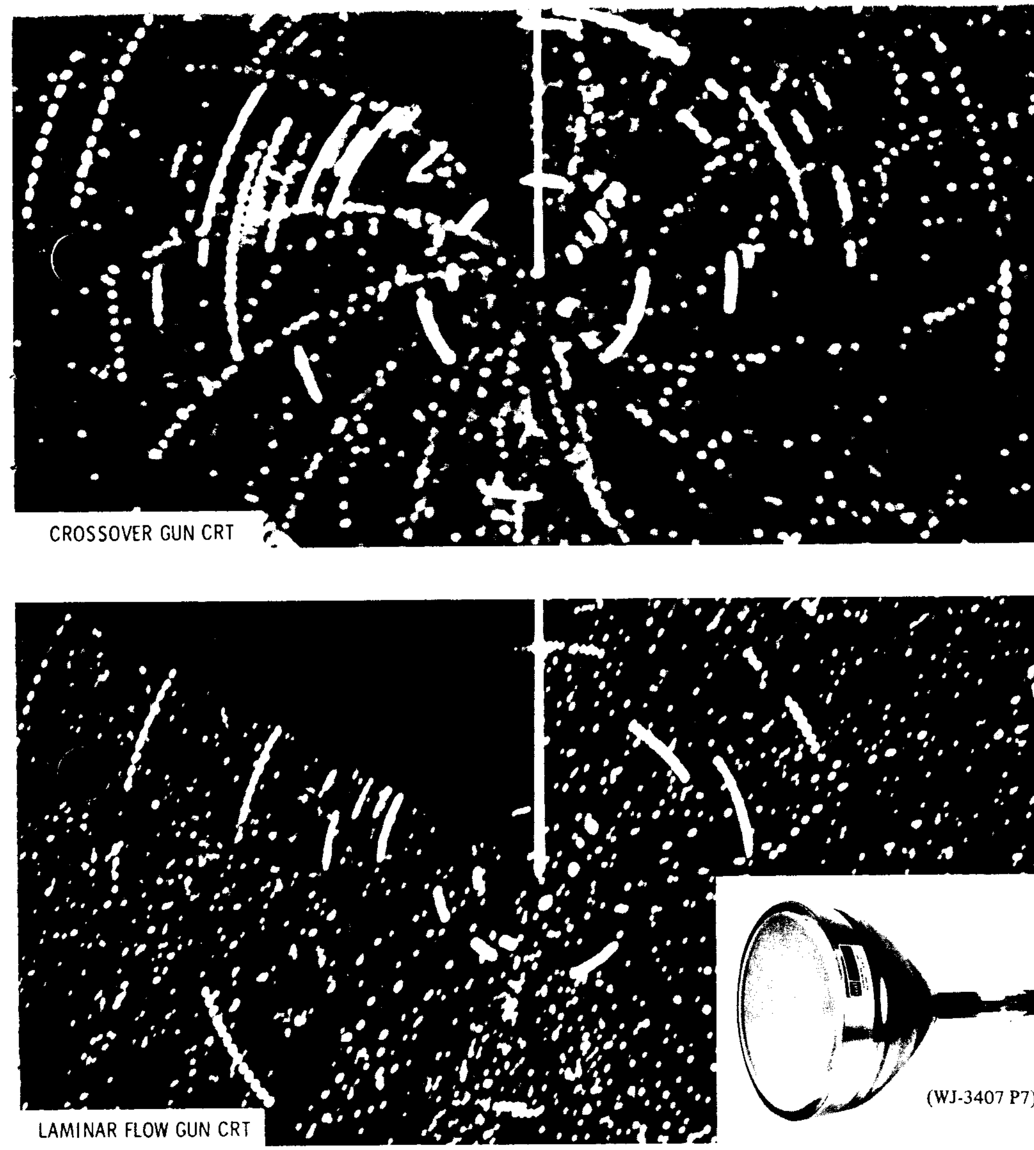


Fig. 1 – Comparison photos of crossover and laminar flow CRT displays in a PPI radar system. Actual size of each display is 10 inches in diameter. The diagonal of each photo is approximately 1/2 that distance.

An Example of Resolution

A superior electron gun is one that exhibits improved resolution under the same operating conditions without any change in the physical or electrical parameters used to describe the display system. An example of these conditions and the visual improvement in resolution is shown in the photos of Fig. 1.

Two PPI (Plan-Position-Indicator) displays are connected to the same radar system which is used to monitor an airport. A standard crossover CRT (10 WP 7) is connected to one console and a laminarflo* CRT (WJ-3407 P7) is

*Laminarflo is the registered trademark for the Watkins-Johnson Company's Cathode-Ray Tube employing the laminar flow electron gun.

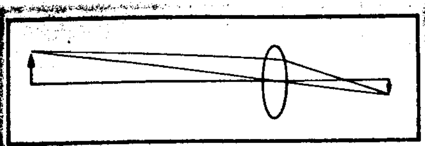


Fig. 2 – Concentrating optical system.

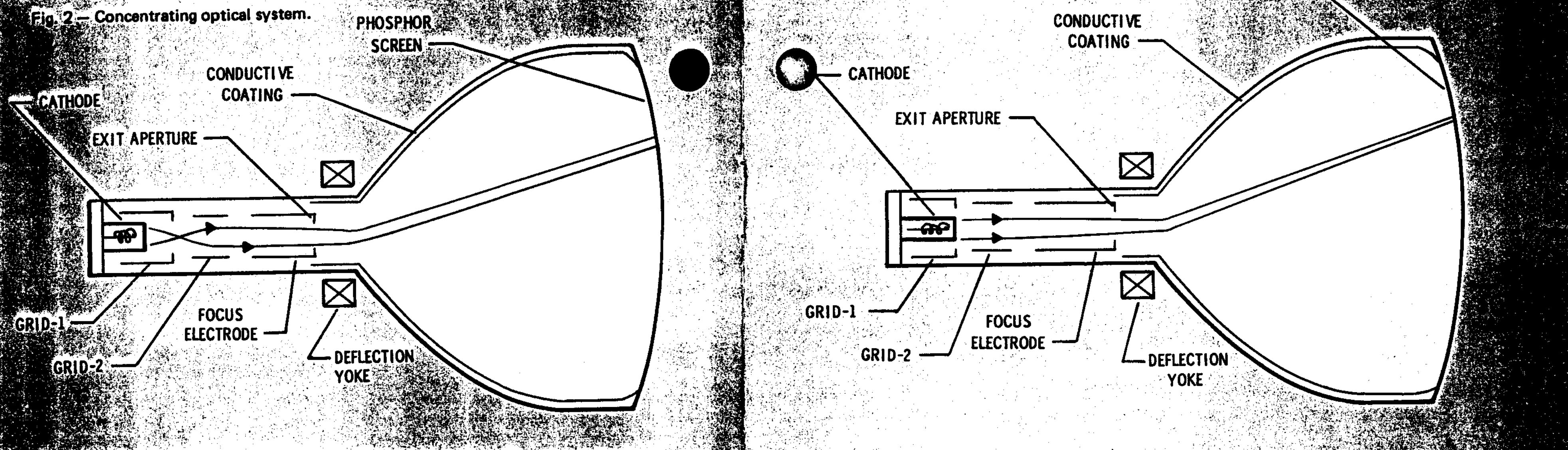


Fig. 3 – Electron beam trajectory for the a) crossover and b) laminar flow gun cathode-ray tubes. Both CRTs are electrostatic focus-magnetic deflection-type tubes.

connected to another identical console. The unprocessed video and computer generated information can be seen in both polaroid photos. The random white dot pattern is the radar receiver output (unprocessed video), while the regular arc-like arrays are simulated aircraft that have been stored in the computer and synthetically expanded for easier identification and tracking. Improved resolution is shown by the clearer and brighter laminar flow gun CRT display taken with the same camera moments after the crossover display.

Producing a Bright Spot – Optics

The role of an electron gun is similar to an optical system that produces an intense image from a bright object, Fig. 2. A bright source serves as the object of the glass convergent lens, which focuses its image into a small spot. In the case of the optical system, the image brightness is dependent upon source intensity and distribution. In this simple comparison, the spot size produced by an electron gun is also dependent upon source intensity (cathode current density) and distribution.

Conceptual Comparison Between Crossover and Laminar Flow

The electron gun's function is to produce a small intense spot of controlled brightness on the phosphor viewing screen. The term "brightness" is used here to denote luminance, which is the luminous flux per unit area of the emitting surface measured in lumens per ft^2. In order to produce the brightest display, the electron gun must produce the largest current density in the smallest possible area.

The crossover CRT, Fig. 3a, attempts to provide an intense source by shaping the electric field lines in the triode region (cathode, grid-1, grid-2) so that the emitted electrons converge to a crossover almost immediately upon leaving the cathode. It is this crossover which serves as the object that is imaged on the phosphor screen. The emitted current density approximates a conical shape for a circular cathode, and it is this conical distribution that is converged into a crossover and then reimaged on the screen. The intensity distribution at the cathode is also reflected at the crossover and ultimately in the spot.

By using this crossover source with an "ideal imaging system", the best that can be achieved is a spot with an intense center surrounded by a region of less intensity, rapidly decreasing with radius. Passing the beam through an aperture improves the uniformity of the spot by masking the outermost portion of the beam. However, this requires increased signal strength (grid drive) since more cathode current must be supplied to compensate for the reduced screen current.

In contrast, electrons emitted from the cathode of the laminar flow CRT tend to flow in streamline paths until they converge to a focus at the viewing screen, Fig. 3b. Because of the shape of the electric field lines, the current density across the cathode is relatively constant and may be considered to be cylindrical in shape for a circular cathode. For the same peak cathode loading, in the ideal case, the laminar flow gun provides three times the current density from the same cathode area, since the volume of a cylinder is three times the volume of a cone.

This comparison yields the following results. The laminar flow gun can produce the same total current using only 60 percent of the crossover gun cathode diameter, thereby reducing the diameter of the emitting region by 40 percent. Thus, for a given beam current and emitter diameter, the peak cathode loading is considerably less using the laminar flow gun.

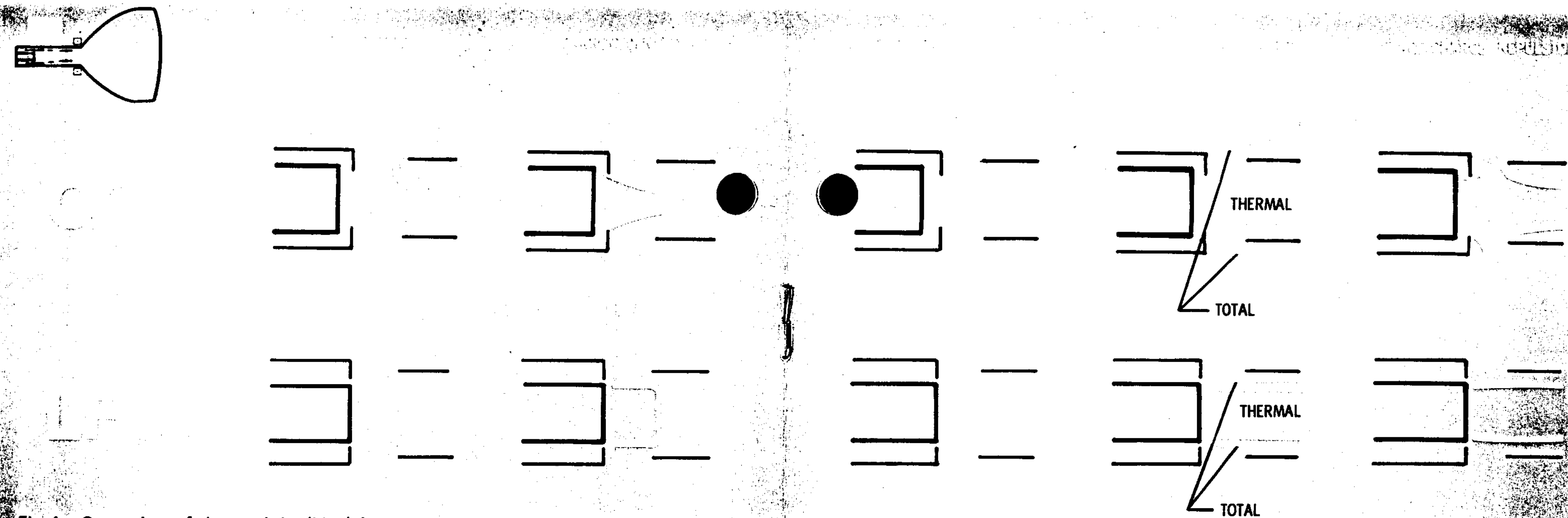


Fig. 4 — Comparison of characteristics (ideal) for the crossover gun (COG) and laminar flow gun (LFG) cathode-ray tubes.

The basic design of the laminar flow gun is to produce a higher perveance (transconductance) structure than the crossover gun. This higher perveance structure allows a given change in grid voltage to result in a larger change in cathode current. Since the laminar flow gun produces three times the current from a cathode the same size as a crossover gun, it can supply three times the current for the same change in grid voltage.

Gun Characteristics – Inside the Triode Region

To produce a crossover, the electric field of the crossover gun (COG) is made very high at the cathode center and falls off rapidly with radial distance, Fig. 4. The current density becomes conical-like in shape for a circular cathode. In contrast, the electric field across the cathode surface in the laminar flow gun (LFG) is uniform, and the current density is relatively constant with a cylindrical shape. Because of this uniform cathode loading, the LFG provides a two to three times stronger source of electrons.

Electrons are emitted from each cathode with certain energy distributions. Electrons with energy components transverse to the tube axis move radially from their origin as they proceed toward the screen. These transverse velocities cause a spreading of the image at the screen. The aberrations (lens failure to produce exact point-to-point correspondènce between object and its image) present in short focal length lenses further degrade the energy distribution, as is the case with the crossover gun. By using a longer focal length lens in the laminar flow gun, less aberration occurs in the cathode region, thus reducing the noise (normal velocity components) in the electron beam.

Space-charge, or the electrons mutual repulsion, occurs at the crossover and in the beam as it is brought to focus at the viewing screen. By eliminating the crossover repulsion force, the LFG avoids one source of degradation effecting resolution.

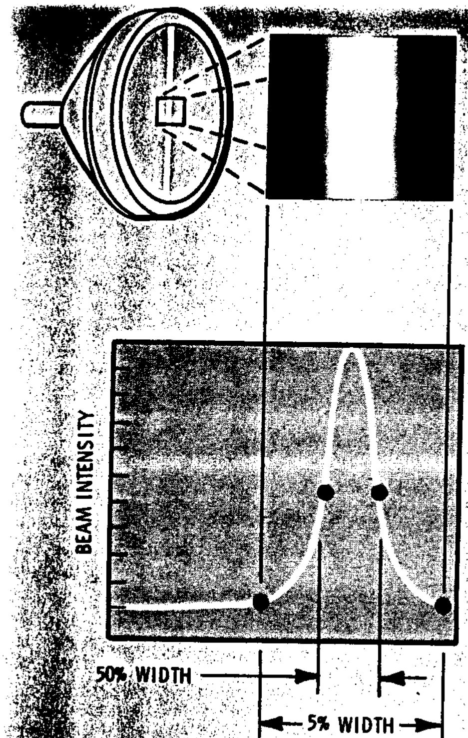
Spot at the Screen – Trade-offs in Parameters

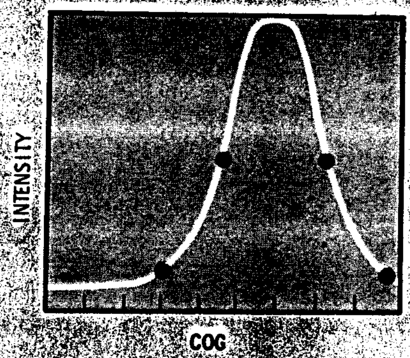
A comparison of electron gun performance (resolution) must be based on consideration of all those parameters which characterize the gun. It is usually possible to improve the resolution of any given gun by lengthening its focus structure. This improved resolution is obtained at the expense of tube length and, generally, current efficiency, since less of the cathode current reaches the screen. This lengthened gun is not actually better than the shortened gun because it gives higher resolution, but rather, different, because it has been optimized for a different set of parameters.

The LFG makes it possible to furnish a CRT whose performance can be optimized in several ways and, at the same time, be interchangeable with an existing crossover gun CRT. By "interchangeable" is meant that the laminar flow gun is the same length and width as the crossover gun and operates at the same voltages. Therefore, it is possible to output a tube incorporating a laminar flow gun which is a direct physical and electrical replacement for a tube containing a crossover gun. This concept of interchangeability is important when comparing the laminar flow gun with the crossover gun tube.

The LFG characteristics improve CRT performance in several parameters in one or more ways, however, optimum improvement can not be realized simultaneously for all parameters. Some of the improvements in CRT performance are:

- RESOLUTION: Because factors such as space-charge in the beam, electron energy distribution and lens



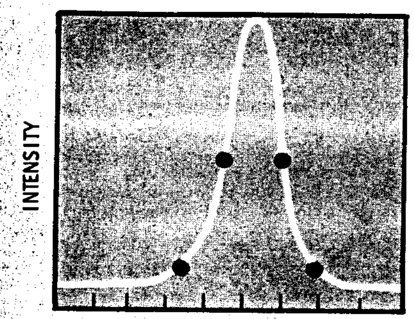


COG

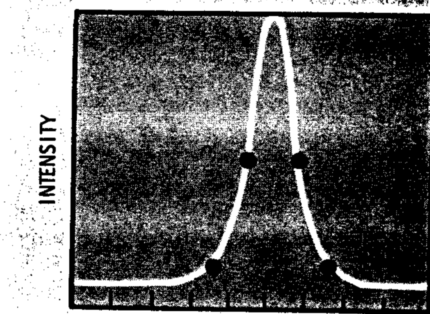
Fig. 5 — Typical trace width profiles of crossover and laminar flow CRTs. The horizontal axis, which measures the width of the spot, is calibrated at .002 inches per division and the vertical axis is in arbitrary brightness (luminance) units. The curves are obtained by using the single slit analyzer technique with a writing speed (vertical line) of 10 microseconds per inch and at a repetition rate of 60 Hz.

CRT TYPE	EXIT APERATURE DIAMETER	SPOT WIDTH		POTENTIAL			CURRENT		
		AT 50%	AT 5%	GRID-2	GRID-1 CUT-OFF	GRID-1 DRIVE FOR 30µA SCREEN CURRENT	CATHODE	SCREEN	"0" BIAS
	(INCHES)	(INCHES)	(INCHES)	(VOLTS)	(VOLTS)	(VOLTS)	(µA)	(µA)	(mA)
COG	0.070	0.0057	0.0114	300	-70	26	68	30	1.7
LFG	0.050	0.0040	0.0076	300	-30	15	65	30	0.65
		0.0030	0.0062	916	-70	24	85	30	2.6+

TABLE 1



LFG (GRID-2, 300 VOLTS)



LFG (GRID-2, 916 VOLTS)

aberrations limit the resolution as well as source intensity, the anticipated reduction in spot size is less than the reduction in the source size. As much as a 30% reduction in spot size, or double the current density in the spot at the screen, is a reasonable expectation when a crossover gun is replaced with an interchangeable laminar flow gun.

- INCREASED BRIGHTNESS: The brightness of phosphor generally increases with the current density of the electron beam excitation over a wide range of densities. However, increased brightness is not always directly proportional to current density because of saturation effects in the phosphor. Depending upon the phosphor coating used, the ability of the laminar flow gun to produce an increase of two times the current density could result in a similar increase in the peak line brightness, without a corresponding reduction in resolution.

- REDUCED GRID DRIVE: The laminar flow gun's higher transconductance means that for the same change in grid potential, much larger screen currents are produced. This allows either a reduction in signal amplitude, or a brighter picture for the same input signal level.

Spot Width Measurement — An Explanation of Data

Figure 5 illustrates the technique for measuring the spot width as it moves vertically down the screen. The COG tube used in the example is an 8-inch diagonal, high resolution, 70 degree deflection electrostatic focus-magnetic deflection device. The LFG tube uses different electrode shapes, but the electrode diameters, focus electrode and overall gun lengths are identical. To achieve the same current efficiency in both guns at 30 microampere (μA) screen current, the final aperture of the LFG has been changed from .075 inches to .050 inches.

The significance of the resolution data (listed in Table 1) is derived by observing the change in spot width (area) with variation in grid drive (grid-2). For the same grid-2 potential (300V), the LFG indicates a 30 percent higher resolution at less than one half the grid-1 cut-off voltage. By changing the LFG grid-2 potential to 916 volts produces a cut-off voltage at -70 volts, the same as that of the crossover gun. The resolution of the laminar flow CRT is almost twice that of the crossover CRT, but the current efficiency (screen current divided by cathode current) of the laminar flow gun is now only 35 percent as opposed to 46 percent for the crossover gun.

At a LFG grid-2 potential of 300 volts the current efficiency is comparable for both tubes even though the exit aperture of the LFG is 30% smaller in diameter. In this condition, the laminar flow gun produces twice the current density in the exit aperture than the crossover gun. This results in an approximate 30% decrease in the deflection defocusing, which is proportional to the beam bundle diameter. In the case of electrostatic deflection tubes, it may mean up to twice the brightness plus higher current efficiency. The grid drive is only 15 volts using the laminar flow gun as opposed to 26 volts using the crossover gun.

The grid drive of the laminar flow gun at 24 volts is still smaller than that of the crossover gun if only by 2 volts. Note that the "0" bias current (maximum cathode current available) of the laminar flow gun is about 50% greater than the crossover gun, with equal cut-offs. This higher value of "0" bias current results in a much smaller grid drive for the laminar flow gun and allows a corresponding reduction in video drive requirements when cathode modulation is used. Space-charge limitations are theoretically encountered at higher values of beam current, or as the exit aperture is reduced in size. Thus, the use of a smaller aperture in the laminar flow gun suggests that at a sufficiently high value of beam current, the resolution of the crossover gun is better than that of the laminar flow gun. However, this is true only if the space-charge limitation in the crossover region is small compared to the beam after it leaves the final aperture.

Although the data presented is only for one value of screen current, similar results can be obtained over a wide range. Also, the concept of the laminar flow gun design can be advantageously applied to all types of CRTs, including: magnetic deflection-electrostatic focus, magnetic deflection-magnetic focus, and electrostatic deflection and electrostatic focus.

Conclusion

The basic design of the laminar flow gun CRT offers improvements over the crossover gun CRT. These include a more intense and uniform source, lower beam noise, elimination of space-charge effect at the crossover, and a higher perveance structure. Although this article reports on only one type of CRT (electrostatic focus-magnetic deflection), the laminar flow gun can be placed into many types of CRTs resulting in higher resolution, increased brightness, and reduced grid drive requirements. Furthermore, these improved CRTs can be interchangeable with existing CRTs using the crossover gun.

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