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INFORMATION DISPLAY

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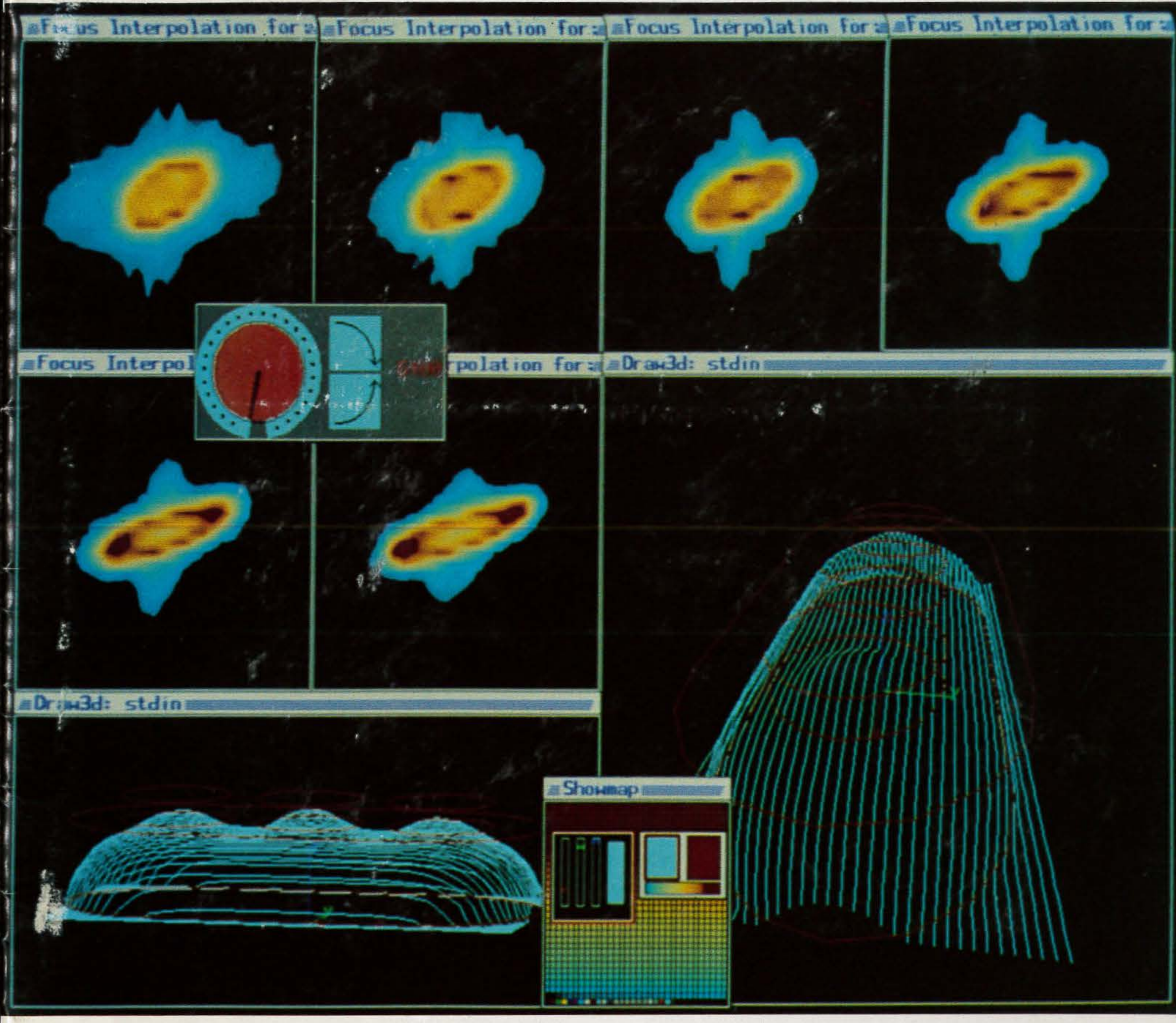

CRT technology issue
Guns and yokes
Bulb design
Automated CRT testing

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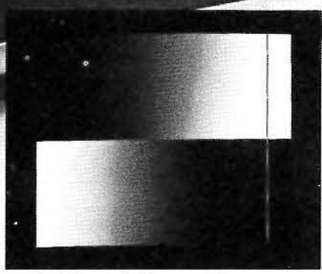
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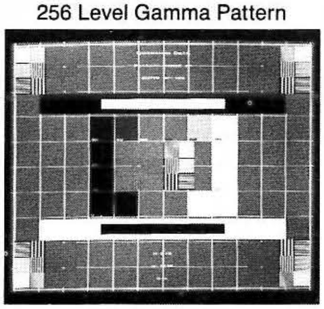
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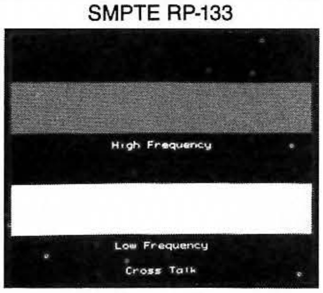

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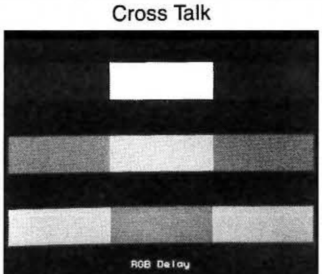

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INFORMATION DISPLAY

JUNE 1988
VOL. 4, NO. 6

Cover: A multiwindow graphics workstation shows corner spots at differnt settings of the focus voltage and two views of an equipotential surface in the XL lens. Data was generated by David Sarnoff Research Center's BEAM3D software program for CRT design. (page 10)

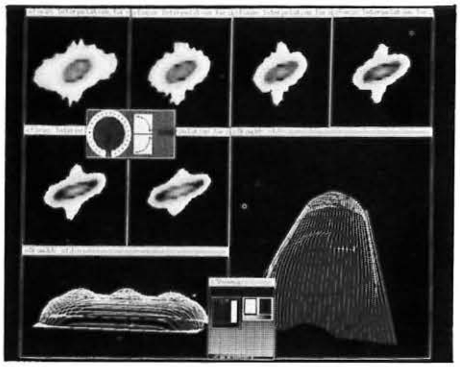

Photo: David Sarnoff Research Center

5 Editorial

9 President's Message

10 Guns and yokes—computer aid for modern designs
Computer modeling keeps the color CRT young and dynamic, even at the age of 40.
Dennis J. Bechis

16 Automated CRT inspection and alignment
Machine vision and interactive graphics speed CRT testing and calibration.
Robert Lin, Jr.

18 Without glass, it's not a tube
New CRT designs challenge the glassmaker's art.
R. L. Mathew

24 Call for Awards Nominations: 1989

27 ID Classified

28 Sustaining Members

28 Index to Advertisers

Next Month in Information Display

Emissive Flat Panels

- Plasma displays
- Electroluminescent displays
- Large masks for flat panels

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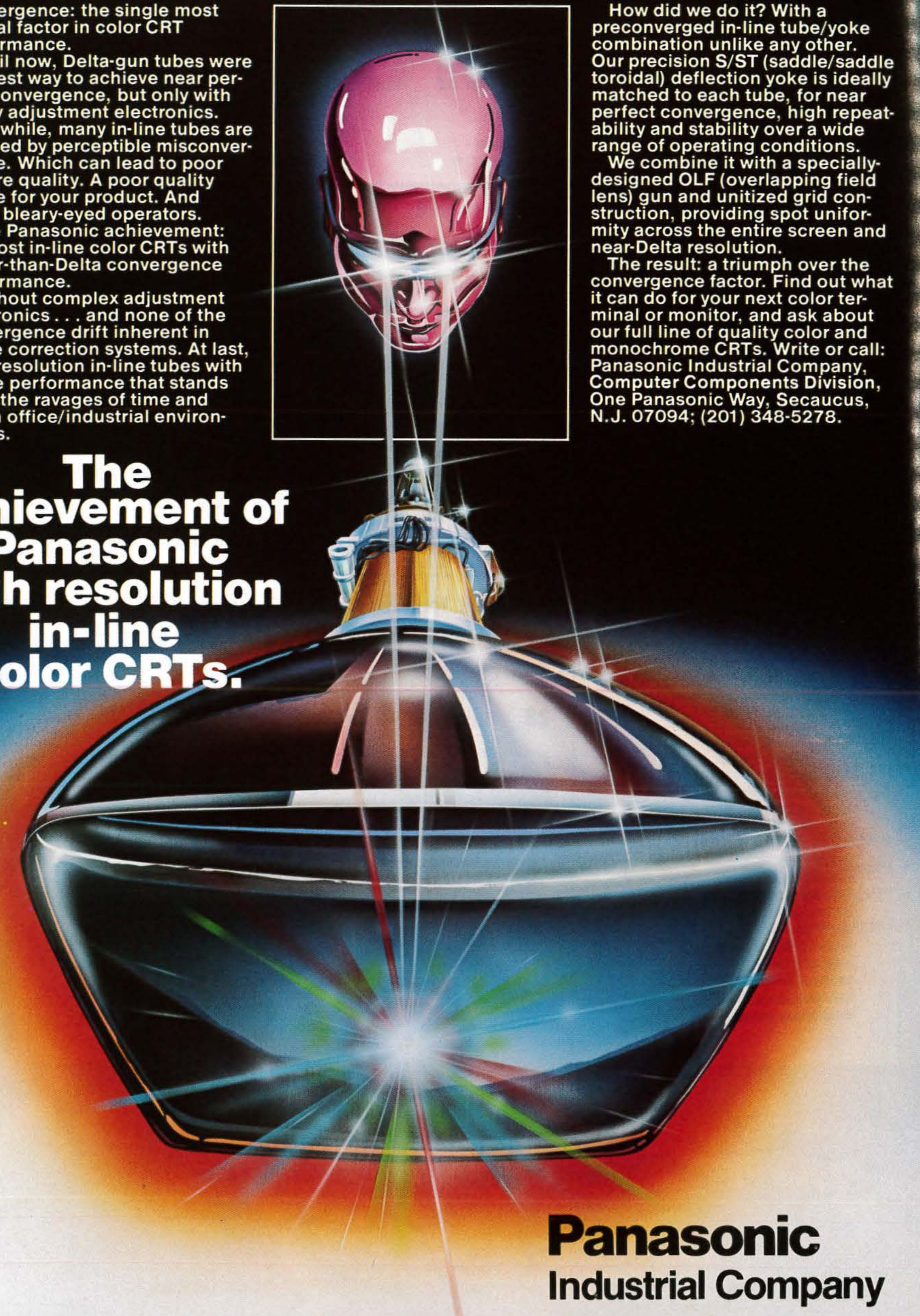

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editorial

Bulls in the glass shop

"The news of my death," said Mark Twain, "has been greatly exaggerated." Much the same can be said of the cathode-ray tube; but at the age of 91 (counting from Karl Ferdinand Braun's invention of a "cathode-ray indicator tube" in 1897), the CRT not only refuses to die, it refuses to get old.

With remarkable grace, the CRT has confronted the challenges placed before it: color, increasing resolution, increasing (and variable) scan rate, squarer and flatter screens, dramatically larger sizes, and (on a developmental basis) wider aspect ratios. Except for very small and very large displays, or where volume, weight, or power consumption are overriding factors, CRTs provide the highest level of performance and the lowest cost of all available technologies.

This remarkable record stems from the basic nature of the device and a great deal of creative science and engineering that has gone into CRT development. The most recent advances would have been impossible without advanced computer-aided engineering tools that incorporate a sophisticated understanding of electron physics, electromagnetics, materials, finite-element analysis, mathematical programming, and computer graphics.

In this issue, Dennis Bechis discusses modern gun, lens, and yoke design, and how these now depend on computer models. Bob Mathew looks at the problems new CRT applications and market directions present to bulb designers and manufacturers. And Bob Lin discusses the increasing use of automated testing and calibration in CRT manufacturing.

The CRT's mastery of new applications results in projections of a remarkably stable share of the information-display market, despite the impressive technical advances of flat displays. In a panel discussion on the future of displays held at the March meeting of the National Computer Graphics Association in Anaheim, chairman Carl Machover noted that the CRT market share today is 85%, with flat panels having 15%. He then challenged panel members Tom Maloney, Alan Sobel, Larry Tannas, and Jim Wurtz to present their projections of CRT market share in 1998. There was some variation, but Jim Wurtz's estimate of 75% seemed to be the median response. Larry Tannas diplomatically refused to make a projection but did say that, in light of the typical 10:1 price differential, "for any task, flat panels will be used only where CRTs won't fit."

With good reason, CRT manufacturers and system integrators can bullishly look forward to their immediate technical and commercial futures.

—Kenneth I. Werner

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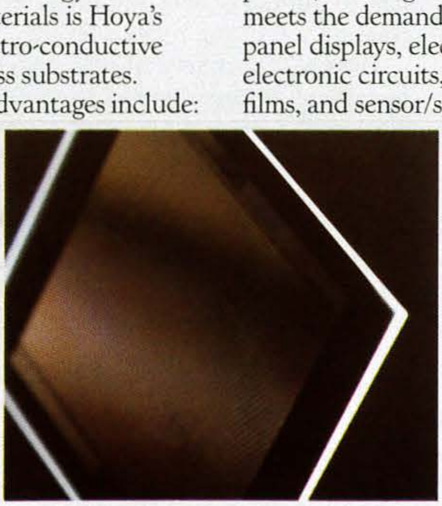

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president's message

I am very pleased and honored to have been elected president of the Society for Information Display. I have some ideas that I believe will further strengthen our society.

First is strengthening the chapters. On the morning before the May meeting of SID's board, I scheduled a seminar for organizing good chapter meetings. Peter Baron (Los Angeles Chapter chairman) and William Hamilton (New England Chapter chairman) shared some tricks with all who came. Additionally, we proposed having the chapters host the January and September SID board/symposium meetings with a one-day technical session like the one held in New England last year. We also inaugurated at the SID Symposium the first annual off-shore chapter luncheon. I see this as a very important event at future symposia.

The second item is our national office. I dare say that for our size we have the finest headquarters of any professional organization. Mrs. Bettye Burdett has done an excellent job in managing it. I believe, however, that the board has understaffed the office and has grown accustomed to not asking for the services that a national office could provide. But one doesn't miss the services one never had. Our need for growth is more subtle, and exists primarily in the need for more directories, more mailings, more promotion and sales of our publications, and more support to the society's executives.

The third item is to strengthen the role of the board itself. This is more in spirit than in deed. The society's bylaws clearly define the role of the board. I am implementing them to the fullest extent. A specific point that requires attention is that a board member and, therefore, the whole chapter he represents, loses his vote when he can not come to a meeting. I have initiated a change in our bylaws to enable the board member's chapter chairman to exercise his proxy vote when appropriate.

The fourth issue is the most critical. If you have been watching the SID budget, you are aware that the SID journal's financial situation has been unacceptable. I don't believe the solution is to throw in the towel, but to find remedies—and promising new remedies are in place. I had previously thought we could not afford a journal of the scope to which we had become accustomed. Our experience level is now much higher and I believe substantial progress toward solving the affordability problem was made by our previous publications chairman Phil Heyman. Our new publications chairman Tom Curran will bring new ideas and experience to the task of ensuring we meet our budget and publication objectives.

I have given each of the committees new goals and am looking forward to a vigorous year. I need your support and advice. Tell me what the society needs and/or how you would like to help. SID has been an exciting and vital organization. Together we can enhance its vitality even further.

—Larry E. Tannas, Jr.

Guns and yokes—computer aid for modern designs

BY DENNIS J. BECHIS

THE DEVELOPMENT of sophisticated computer tools is keeping the standard direct-view shadow-mask color CRT young and dynamic, even at nearly 40 years of age. Driven by rapidly expanding markets for high-resolution color graphics, computer monitors, and giant-screen consumer televisions, and by the realization that higher definition television systems are coming, a number of companies have recently used computer modeling to design electron guns and deflection yokes that yield greatly improved resolution with designs that are more manufacturable and cost effective.

Computer potentials

Every CRT engineer has wished, after viewing a poorly performing CRT, that he had used a different grid in the electron gun. With the advent of computer programs that accurately simulate electron optics in three dimensions, a gun designer can calculate in less than 20 min the effect of a new grid on the high-current corner spot. If he has already simulated a large number of different gun geometries, he can rapidly view the corner spots that result from different grid thicknesses or shapes, and change from one gun design to another as if the stainless-steel grid were as malleable as putty.

The advent of three-dimensional electron-optical computer codes in the late 1970s and early 1980s led to startling innovations in electron gun designs for CRTs. The software called POT3D, for

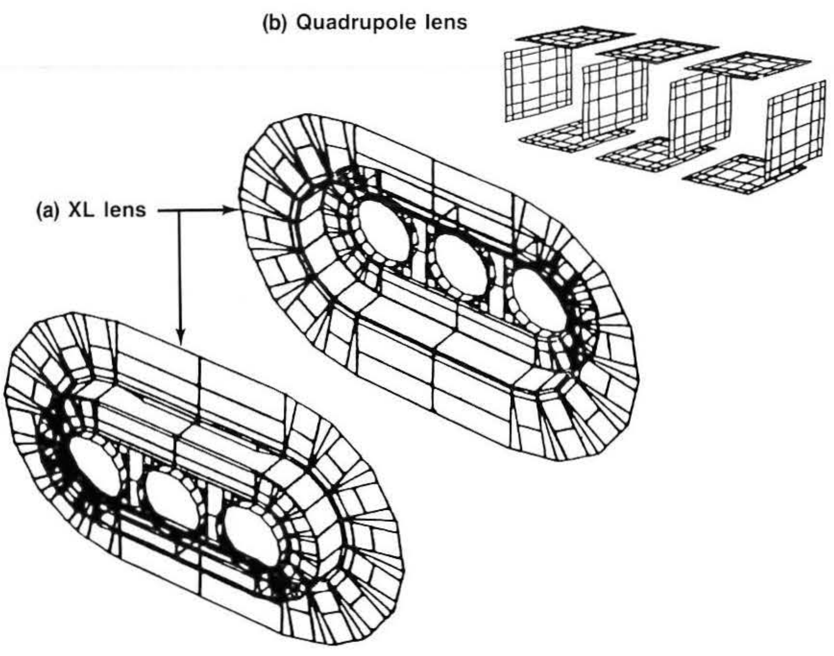

Fig. 1: Computer models of (a) RCA's XL lens, and (b) a three-beam quadrupole lens.

***Dennis J. Bechis** is a member of the technical staff at the David Sarnoff Research Center, a Subsidiary of SRI International, Princeton, New Jersey. In the early 1980s, he was a member of the team that designed and developed the COTY family of electron guns and yokes for RCA's color picture tubes. He has an undergraduate degree in astronomy from Harvard College and a doctorate in high-energy physics from the University of Maryland.*

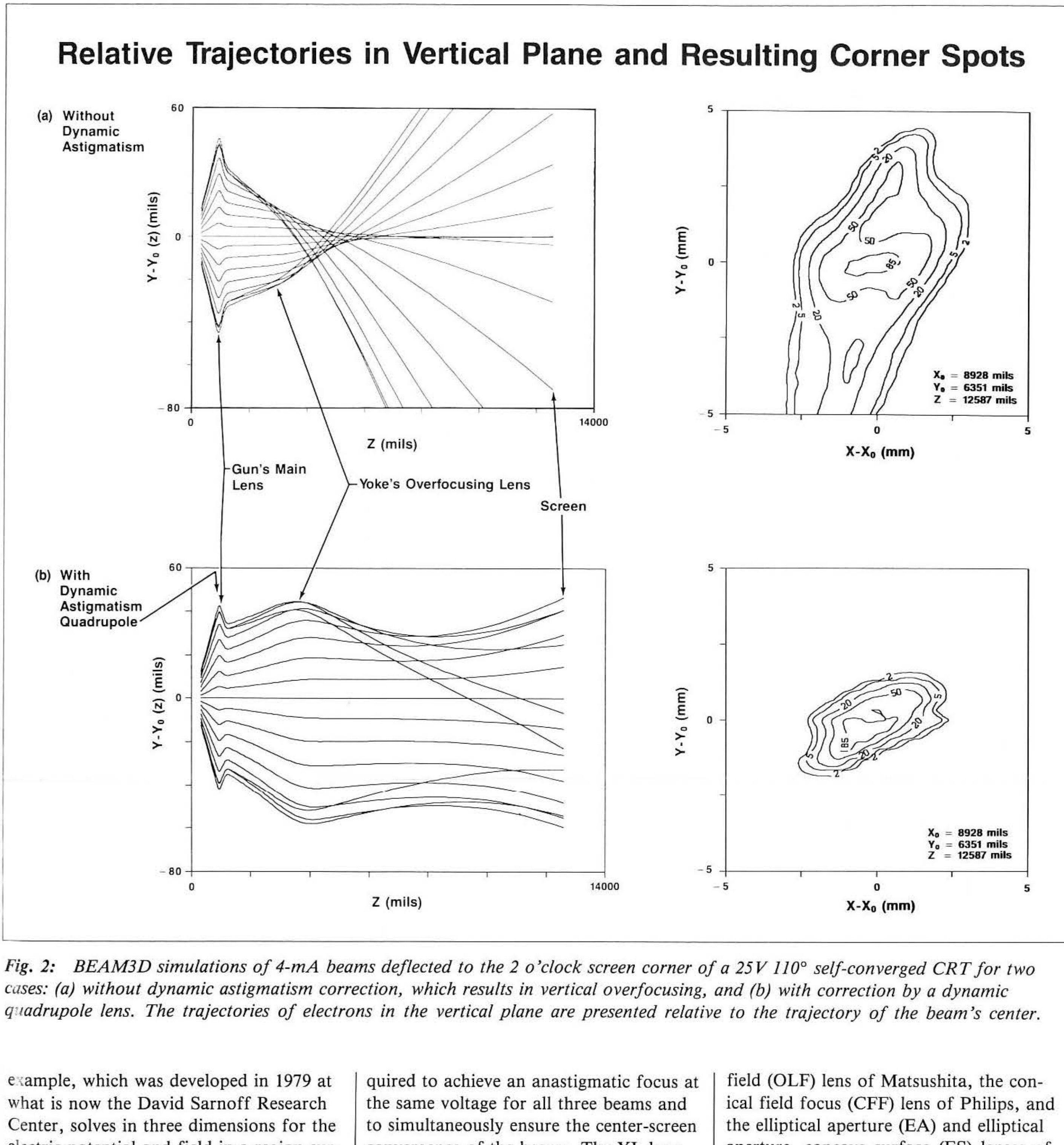

Fig. 2: BEAM3D simulations of 4-mA beams deflected to the 2 o'clock screen corner of a 25V 110° self-converged CRT for two cases: (a) without dynamic astigmatism correction, which results in vertical overfocusing, and (b) with correction by a dynamic quadrupole lens. The trajectories of electrons in the vertical plane are presented relative to the trajectory of the beam's center.

example, which was developed in 1979 at what is now the David Sarnoff Research Center, solves in three dimensions for the electric potential and field in a region surrounded by conductors. POT3D was a major tool in the design of the noncylindrically symmetric XL lens for RCA's COTY guns. In the XL (for "expanded lens"), the three electron beams are focused and converged by the electric field in an open, bathtub-shaped region that lies between two planes of round apertures [Fig. 1a]. Without POT3D, enormous time and effort would have been required to achieve an anastigmatic focus at the same voltage for all three beams and to simultaneously ensure the center-screen convergence of the beams. The XL lens was revolutionary because it realized two goals that common wisdom held could not be achieved simultaneously. First, it reduced convergence errors at the screen by decreasing the beam-to-beam spacing in the gun and, second, it reduced the best-focus spot size by lowering the spherical aberration of the main lens.

Many of the nonsymmetric lenses that have been developed—the overlapping field (OLF) lens of Matsushita, the conical field focus (CFF) lens of Philips, and the elliptical aperture (EA) and elliptical aperture, concave surface (ES) lenses of Hitachi—were designed with the assistance of three-dimensional electrostatic field- and potential-solving codes.

But the early computer programs used to design these lenses could not accurately predict the size of deflected spots at the screen because they could not perform the complicated three-dimensional computation of space-charge forces arising from the mutual repulsion of electrons. Programs that ignore space charge predict spots that may be 2 or 3 times smaller than measured spots. So, although many of these codes were (and still are) powerful tools, detailed design optimization of CRTs still required the construction and evaluation of many CRT prototypes.

Dynamic quadrupole lenses

Recently, a number of companies have developed electron guns that employ dynamic electrostatic quadrupole lenses to greatly improve resolution along the sides of the screen [Fig. 1b]. These lenses dynamically correct the severe vertical astigmatic overfocusing suffered by electrons in a beam as the beam is deflected horizontally by a self-converged yoke [Fig. 2a]. If uncorrected, the overfocusing leads to a very tall spot at the screen's corner and a significant loss in vertical resolution. In many of today's CRTs, this major drawback of self-converged yokes is alleviated by putting slots in the gun's triode, and/or "stigmators" into the gun's main lens. But these fixes have the undesirable side effect of increasing the height of spots at the center of the screen.

Dynamic quadrupole lenses, on the other hand, make it possible to achieve excellent resolution at the corner and sides of the screen without sacrificing resolution at the screen center. By applying a voltage to the six horizontal plates [Fig. 1b] that is higher than that on the four vertical plates, beams passing through the quadrupole on their way to the main lens are made to diverge in the vertical plane with sufficient speed to compensate for the yoke's strong overfocusing [Fig. 2b]. Because the amount of overfocusing depends on the beam's landing position on the screen, the voltages on the correcting quadrupole and on the neighboring grids must be modulated dynamically at both horizontal line and vertical field frequencies by special circuitry.

Computer modeling has led the way to electron-gun designs that require only a single dynamic voltage waveform, that reduce the necessary voltage modulation, that do not dynamically upset the center-screen convergence, and/or that reduce the likelihood of damage from arcing.

Improved triodes

Significant improvements in resolution have also been achieved through the development of higher performance triodes. The split G2 triode of Thomson Consumer Electronics and the aberration-reducing triode (ART) of Philips and Matsushita both employ strong focusing lenses in the triode to improve the focusing quality of a beam [Fig. 3]. These lenses reduce the effective source size by shortening the region along the z-axis in which the electrons cross. In turn, the smaller source is imaged to a smaller spot at the CRT's screen.

Another way these novel triodes improve resolution is by fanning the electron trajectories apart. When the beam reaches the main lens, the current distribution along the beam's diameter is nearly uniform, without the "hot core" of beams created by conventional triodes. These hot core electrons are very close

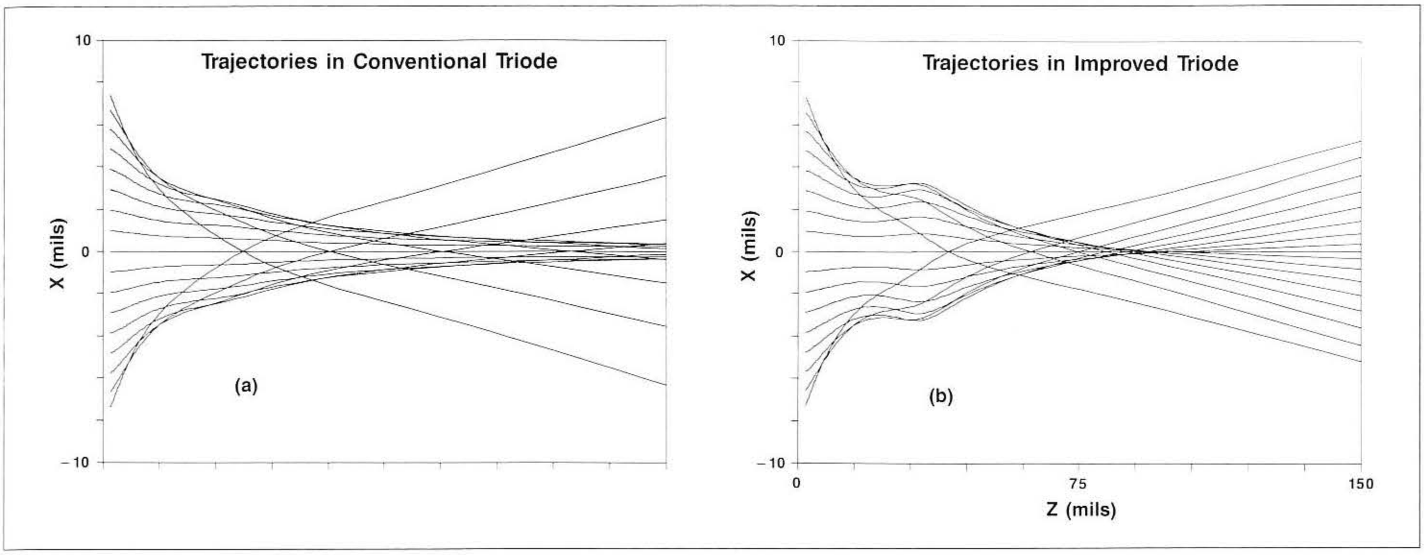

Fig. 3: BEAM3D simulations of 4-mA beams in (a) a conventional triode, and (b) an improved triode, showing the more concentrated z-axis electron crossings.

together, so space-charge forces are high and the beam spreads severely as it drifts from the main lens to the screen. At beam currents over 2 mA, the novel triodes yield spots 30–50% smaller than those generated by conventional triodes.

Reduced space-charge spreading is a very important issue for giant-screen tubes because the spreading's contribution to spot size scales as the square of the gun-to-screen distance. Moreover, to make giant-screen tubes as bright as smaller

CRTs, higher beam currents are used. This increases the space-charge spreading even more and, in addition, overloads conventional cathodes. In response to these issues, Matsushita, for instance, is introducing into its 45-in. tube an ART triode and a dispenser cathode, which can provide the higher current required without shortening cathode life.

Computer simulation has aided the design of high-performance triodes. With their computer tools, Philips designed a vertical slit in the G1 electrode of the 45AX gun to provide a static partial compensation for deflection defocusing; the design was optimized to achieve simultaneous ART behavior in both the horizontal and vertical planes. Using the BEAM3D program created at the Sarnoff Center, Thomson Consumer Electronics learned that the improved performance of a split G2 triode is lost with only very small misalignments of the grids. Since then, BEAM3D has helped to find designs whose performance is much less sensitive to grid misalignment.

Yoke developments

Sophisticated programs to calculate the magnetic field generated by a deflection yoke have also had a major impact on CRT development. YOKE, software developed in the early 1970s at the Sarnoff Center, calculates the magnetic potential created by a cylindrically symmetric ferrite core with windings lying in planes. Since RCA's yokes were then mostly "planar-wound" toroidal, YOKE successfully analyzed them and corrected their deflection problems. A new YOKE program was completed in 1979 that could model fully three-dimensional windings adjacent to the ferrite core. This program is now the mainstay of yoke design activity at Thomson Consumer Electronics, where engineers also use it to design the arbors for winding saddle yokes.

Computer-aided field fudging

A number of companies have written computer programs to design magnetically permeable pieces of metal that shape the yoke's magnetic field in a specific way. The Sarnoff Center's COMA program greatly speeded up the process of designing the small field-forming permeable parts called shunts and enhancers, which are positioned at the end of the gun to correct vertical coma—a deflection error in which the green beam does not land vertically on the centroid of the red and blue beams at the 6 and 12 o'clock positions on the CRT's screen.

Shunts and enhancers correct coma well in consumer picture tubes of conventional size, but they face severe limitations in giant-screen CRTs and computer monitors. The very long gun-to-screen distance in giant CRTs magnifies any residual coma error from slight misalignments between shunts, enhancers, and the yoke field. At the high horizontal scan rates used in computer monitors, shunts and enhancers can no longer correct coma because of the long recovery time of eddy currents. So, in these applications, shunts and enhancers are being replaced by coma-correcting field-formers that attach to the rear of the yoke and couple only to the slowly varying vertical magnetic field. Using computer simulation, Matsushita designed coma-free deflection yokes of this type for their 26–33-in. picture tubes.

Large permeable pieces on the front of the yoke can shape the vertical deflection field to correct east-west raster distortion, which is aggravated by the flatter faceplates of today's CRTs. Computer programs that model permeable pieces in magnetic fields promise to streamline this work.

Design optimization by computer simulation

BEAM3D, a software system produced by Sarnoff physicists and mathematicians in 1983, simulates the motion of an electron beam from the cathode to the screen and incorporates a rigorous three-dimensional treatment of space-charge forces. Comparing hundreds of simulations with measurements of real picture tubes has convinced BEAM3D's developers and users of the program's accuracy and ease of use.

Engineers at Thomson Consumer Electronics use BEAM3D predictions with confidence. Because corner spot simulations take less than 20 CPU min on an IBM 3090, engineers use the program to develop and evaluate novel designs—and to quickly traverse the optimization path of a particular design before building an expensive prototype. By assembling simulated guns in the computer with misaligned, tilted, or incorrectly spaced grids, engineers can determine how these errors degrade a design's performance. This information is used to find less sensitive designs and to specify part and alignment tolerances. Both approaches minimize factory scrap rates.

The future

Engineers, scientists, and mathematicians have successfully developed a wide range of computer tools and demonstrated their basic capabilities. As these design tools become more fully integrated, facilitating the exchange of information among them and their users, they will lead to more sophisticated CRT systems. The 1990s will bring CRT system designs in which the capabilities of guns, yokes, shadow masks, bulbs, and circuitry are more thoroughly utilized, and in which the components are designed to perform together in more optimal ways. To speed the handling, comparison, and visual interpretation of this data, convenient interfaces are being developed for use on multiwindow graphics workstations. Such an interface enables the user to create and arrange windows showing color-coded images of BEAM3D-simulated corner spots at different settings of the focus voltage, for example, while examining two views of an equipotential surface in the XL lens in other windows [see cover photo]. Workstations with rapid updating would allow a designer to use a "mouse" to slide up and down scales of voltage and grid thickness and see the corresponding spot in real time. At the David Sarnoff Research Center, our goal is to develop an integrated easy-to-use system of design software that will be useful for many years to come. We feel the time and effort is well worthwhile because color CRT technology still has a long and technically interesting future ahead of it.

Acknowledgments

My thanks to Walter Paul, Roger Alig, Joanna Alexander, and Nurit Binenbaum of the David Sarnoff Research Center for the computer graphics; to David Laur and Kirk Alexander of the Princeton University Graphics Laboratory for the use of their equipment in generating the cover photograph; and to Robert Barbin of Thomson Consumer Electronics for steering our software to usability by his cooperation, encouragement, and support.

Notes

More information on these topics can be found in the following paper and its references: D. Bechis et al., "BEAM3D: Computer Simulation of CRT Electron Beams with Full Three-Dimensional Space Charge, Thermal Spread, and Electrostatic/Magnetic Fields," *Digest of Technical Papers, 1988 SID International Symposium* (May 1988), paper 8.1. ■

Automated CRT inspection and alignment

BY ROBERT LIN, JR.

As CRT MANUFACTURERS strive for higher standards of product quality, they are finding traditional testing and calibration procedures to be too slow, too inconsistent, and too resistant to statistical analysis. One approach to these problems, now being used by some companies, is advanced automated test systems incorporating machine vision.

The machine-vision portion of such a system typically incorporates one or more CCD cameras, a video monitor so the operator can see the test images, and a vision processor (probably integrated with the system controller) for digitizing and manipulating captured or live images. Special software packages can program the system to perform image analysis, gray-scale processing, image enhancement, frame testing, character recognition, brightness readings, and color determination, as appropriate for various applications.

In the systems built by CR Technology, we have found PC-AT compatible microcomputers to be effective programmable system controllers that perform the needed functions well. Communications and network software are readily available, making it easy to implement communication and interface functions. Existing statistical packages can work with the system software for documentation, data logging, and failure analysis right on the controller.

Robert Lin, Jr., is an applications engineer at CR Technology, Inc., Laguna Hills, California.

In the old-fashioned way

Manual CRT adjustments to the yoke, magnets, and various potentiometers are still widely used on CRT manufacturing lines. Here, operators visually inspect images on the CRT under test and adjust the test image so it conforms to a template that is laid over the screen. This process is used to regulate raster height, width, rotation, and centering, and both pincushion and barrel distortion. In addition, the monitor is generally inspected for alignment, focus, linearity, brightness, color purity, and convergence. Because of control location, the inspector must often make the adjustments while viewing the CRT image in a mirror. In many cases the inspection and adjustment criteria depend heavily upon the operator's judgement, which varies with fatigue, experience, discretion, and eyesight.

Manual adjustment and inspection is a bottleneck in automated production environments and presents other difficulties as well. First among these is that the template/overlay approach does not easily give quantitative data on the pass-fail results of a given CRT. Second, operator fatigue and variations between operators make it impossible to guarantee adjustment repeatability. Third, throughput and quality of adjustment are directly related to the operators' individual experience and judgement.

Automated solutions

The limitations of manual CRT alignment systems are obvious, but fully automated systems are often too costly because of current CRT designs. The locations of the magnets and yoke do not usually allow easy robotic access; most existing CRTs were designed for manual adjustment and require the dexterity of a human operator. (It is only recently that manufacturers have begun incorporating electronic adjustments in their new CRTs to permit fully automated adjustment).

A semiautomated approach seems to offer the most generally applicable solution at this time [Fig. 1]. It addresses the drawbacks of overlay/template CRT adjustment and inspection by enhancing the capabilities of the operator rather than by replacing him. In addition, it can provide a powerful engineering tool by accurately recording quantitative data for product evaluation and failure analysis. Though semiautomated for adjustment and calibration, such a system can function as a fully automated accept-reject inspection system.

Our system—one example

CR Technology's CRT-480 is a semiautomated adjustment and calibration system built along these lines. In this system, interactive graphics and menus guide an operator through systematic procedures that bring the CRT's various adjustments within predetermined tolerances. Systems already installed have succeeded in helping their operators obtain consistently precise adjustments, quantitative data, higher throughput, and better operator learning curves. Total adjustment time is generally less than 2 min, with test tolerances between 0.5 and 2.0 mm. Comparable figures for manual systems are 3–7 min and 2 or more mm. In its automated inspection mode, the

Fig. 1: Semiautomated CRT adjustment uses machine vision and a graphic interface to enhance the operator's performance. In this adjustment for image height, the screen of the CRT under test is imaged by CCD cameras and sent to an image processor and an Intel 80386-based microcomputer. When the operator has set the height to within the programmed tolerance, the test system provides visual and audio confirmations. In a manufacturing environment, such a test system would be placed on the production line.

semiautomated system can usually verify all test criteria and log the data in less than 15 sec.

Making semiautomated adjustments

One key to enhanced productivity is a graphic interface that clearly correlates different visual prompts with specific adjustments [Fig. 2]. These visual indicators are displayed on the system's monitor. When the CRT under test is in proper adjustment, the operator receives both visual and audio confirmation. A typical adjustment sequence brings up visual prompts for the operator to adjust the CRT for brightness, rotation, tilt, centering, vertical height, horizontal width, pincushion and barrel distortion, linearity, and focus, in that order.

The first parameter, brightness, is adjusted to the factory's setting for the CRT. Rotation/tilt and centering are adjusted by the centering rings of the yoke, so that the center of the raster is centered with respect to the monitor bezel. The yoke is also rotated to assure that the CRT image is not tilted, which can be determined to $\pm 0.5°$. Vertical height and horizontal width are usually adjusted with potentiometers that control the appropriate electronic circuitry. These measurements are taken with respect to the monitor's bezel.

Pincushion and barrel distortion require adjustments to the magnets of the yoke in order to correct distortion seen at the corners and sides of the raster, which can be kept under 1.5%. This, also, is measured with respect to the monitor bezel. Focus is generally corrected by a potentiometer adjustment. The final prompt is for a linearity check, which examines relative image size over different areas of the CRT's face.

Go, no-go

In the inspection mode, the system determines whether the selected parameters fall within allowable tolerances. For color monitors, these parameters include color purity and convergence. The color purity test assures that the colors produced by the CRT are correct for hue, intensity, and saturation. Optionally, the location of any impurity can be included in the test data.

The convergence test determines whether the beams from all three electron guns are, at any instant, striking the same location on the CRT shadow mask to within 0.05 mm. Failures are generally due to defects in the shadow mask, the electron gun, or the associated electronics.

Directions

Manufacturers of both moderate-volume computer monitors and high-volume television sets are using semiautomated adjustment and testing systems, and are expressing satisfaction with the productivity and flexibility of the approach. Electronic adjustments will eventually make fully automated systems the preferred choice for high-volume manufacturers who are not required to do very many different combinations of functional tests or to test to different tolerances by their various customers. But for moderate-volume manufacturers with customers who desire special testing sequences, semiautomated systems should remain the most effective solution. ■

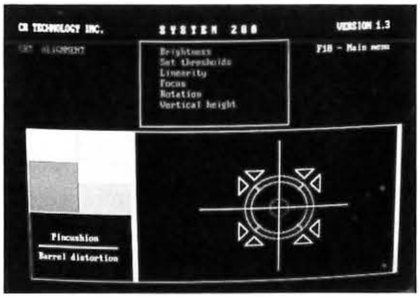

Fig. 2: The graphic interface for adjusting pincushion and barrel distortion speeds one of the more time-consuming CRT adjustments. When the raster outline is completely within the programmed tolerances, as it is here, the adjustment is complete. Occasional CRT units resist adjustment—bringing one corner within tolerance throws out another corner. An appropriately programmed test system can record the time taken to complete each adjustment, providing early warning of developing production difficulties.

Without glass, it's not a tube

BY R. L. MATHEW

THE GLASS BULB of a color cathode-ray tube (CRT) is much more than a "bottle" for containing the electronics and screen. Rather, it is a carefully designed pressure vessel consisting of three parts: the panel (face), the funnel (main body), and the neck (electron gun enclosure).

Each of these parts is engineered from a different glass composition to meet specific requirements [Fig. 1]. The different glasses must closely match each others' physical properties over the wide temperature range they must withstand during the transition from glass bulb to TV tube [Table 1]. The parts will be frit sealed at a temperature of 445°C for 35 min and reheated to almost 400°C during the exhaust (or evacuation) process.

And these are precision parts. The face, in addition to being a window for viewing the phosphor screen, is a carefully designed member of the pressure vessel that must withstand impact and serve as the structural support for the aperture mask and frame. The inside curvature is specified to a tolerance of 0.012 in. for a 27V screen, and the roughness of the inside surface is held to $\pm 3 \times 10^{-6}$ in.

Modeling the bulb

The customer's dimensional requirements for a bulb drive the physical design. These requirements stem from such tube attributes as deflection angle, face contour, yoke contour, and overall size. The bulb designer must incorporate these into a vessel that meets the criteria for bulb strength, ease of manufacture, and processability.

The variables that control bulb strength are shape and thickness. Areas commonly left unspecified by the customer's basic requirements are panel thickness distribution and funnel-body shape and thickness. These constitute "degrees of freedom" for the glass designer.

Computer programs created at Corning can produce a three-dimensional representation of virtually any bulb configuration, including the polynomial face-contour descriptions that characterize many of the new-generation designs. Funnel shapes and thicknesses can be easily manipulated, as can the size, height, and thickness of the panel. For any given geometry, the stress at every location on the bulb can be evaluated using the finite-element method. The designer can adjust shape and thickness through an interactive process until he achieves a satisfactory design [Fig. 2a and b].

At this stage, the customer approves the analysis and the resulting design. Sometimes a viable design can not be generated within the scope of the initial specification. In that case, the glass designer and the customer must work together to arrive at a satisfactory alternative, which was the case in the early stages of bulb development for Zenith's flat tension-mask tube.

After design approval, the same data used to describe the bulb for analysis is used to generate the detailed shape information needed by the customer for chassis and cabinet design. Simultaneously, the information required for the final-product drawing, dimensional specification, and gauge design is extracted from this data. The same data generate the mold shape. The mold size is determined by adjusting the glass dimensions by the appropriate shrinkage factors.

Using the desired glass shape and thickness, as well as the metal thickness profiles required for optimum mold performance, the programs generate detailed three-dimensional descriptions of all the mold parts. This data is used to define the numerical-control machining and inspection of the molds and is transferred to the computer-aided design (CAD) system for inclusion in the mold drawings.

New products—new challenges

New products featuring flatter faces, squarer corners, larger sizes, different mask-frame suspension systems, different surface coatings, higher voltages, varying tints, and differently shaped yokes are forcing glass design into uncharted waters; far more radical demands are being placed upon the glass parts than ever before.

The glass manufacturer has a responsibility to provide a CRT envelope that is unquestionably safe to use, can be converted into a tube at profitable processing rates, has the requisite electrical and optical characteristics, and gives the setmaker a tube shape with consumer appeal. This is a tall order, but not an impossible one.

R. L. Mathew is manager of market development for video products at Corning Glass Works, Corning, New York. P. J. Goldman, D. J. Lopata, and G. D. Wightman made significant contributions to the article.

Strength and safety

Bulbs must withstand a nearly perfect vacuum for several years, which means they must have sufficient mechanical strength. Bulb strength is tested by applying hydrostatic pressure of at least 3 times atmospheric pressure to a bulb whose surface has been abraded to simulate long-term aging.

The bulb must, of course, be hermetic and not become "gassy" after a period of time. This is evaluated by testing the glass and the fired sealing glass with a high-voltage breakdown and other tests that exceed operational levels.

In addition to sufficient mechanical strength, the tube must have a design that allows the tubemaker to place a safety device, such as a tension strap, on the tube. Should the tube break through contact with an errant baseball bat, for instance, the safety device would prevent the glass from injuring someone in front of the set. Underwriters Laboratories and the Canadian Standards Association insure that these safety devices work.

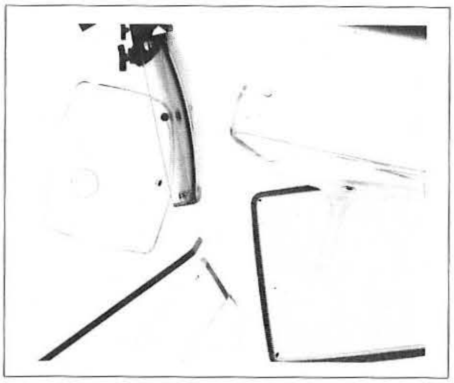

Fig. 1: CRT funnels and faceplates are carefully engineered parts that must perform a variety of mechanical, optical, and electronic functions.

Photons, glass, and electrons

Color CRTs operate at accelerating voltages in excess of 25 kV. With the iron aperture mask and barium-getter materials as targets, x-radiation is produced inside the tube. X-ray leakage beyond the TV set must not exceed U.S. government

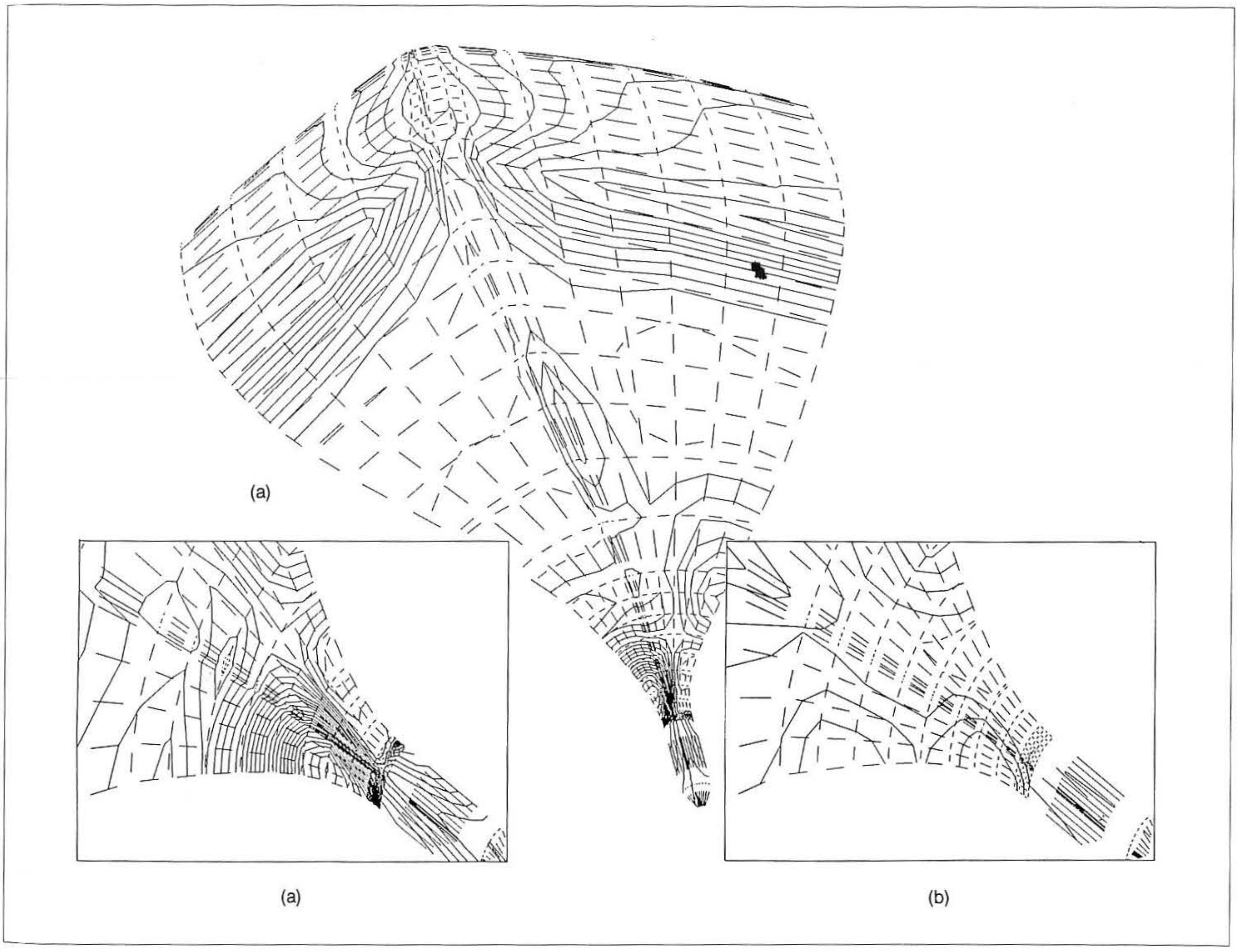

Fig. 2: (a) The surface stress contours for the first analysis of a new 31V bulb design showed that redesign was necessary. The high density of the stress contour lines indicates a stress of greater than 2300 psi in the yoke area [see inset], which exceeded the design criteria. (b) In the final design, bulb maximum stress was reduced by 50% and is now below the design stress limit. The high stress in the yoke area was eliminated by a change in the funnel shape.

Table 1: Properties of Video Glasses in Current Use

	Glass/Corning Code				
	Panel 9061	**Funnel 0138**	**Neck 0137**	**Projection Panel 9039**	**Monochrome 9008**
Thermal expansion coefficient × 10^{-7} cm/cm/ at 0°C to 300°C	99.0	97.0	97.0	96.4	89.0
Viscosity data					
Strain point, °C	460	435	436	458	406
Annealing point, °C	501	474	478	500	444
Softening point, °C	688	654	661	680	646
Linear absorption coefficient at 0.6 Å min (cm^{-1})	28.0	62.0	90.0	35.0	21.5
Density, gm/cc	2.695	2.980	3.180	2.900	2.640
Poisson's ratio	0.23	0.24	0.23	0.24	0.24
Refractive index Na D line (0.5893 μm)	1.518	1.565	1.550	1.553	1.506
Log_{10} of dc volume resistivity					
25°C	17+	17+	17+	18+	17+
250°C	9.2	9.7	10.1	9.59	9.4
350°C	7.5	7.6	8.3	7.67	7.4
Dielectric properties at 1 MHz and 20°C					
Dielectric constant	6.97	7.92	8.60	5.44	6.3
Loss tangent	0.0013	0.0011	0.0011	0.0007	0.0017

maximum-radiation levels, which are 0.5 mR/hour at failure-mode conditions. The glass composition is designed to absorb the x-rays, and the glass's absorption coefficient is routinely tested. The glass must also not discolor as a result of being bombarded by the electrons and x-rays.

Glass composition also determines color, transmissivity, and dielectric strength. Color is important because it affects the color of light transmitted from the tube's phosphor screen. Together with transmissivity, it determines contrast ratio. Dielectric strength must be high because the CRT acts much like a capacitor and must withstand high operating voltages without breaking down.

Surviving production

The glass parts of the bulb must be able to endure the tubemaker's manufacturing processes without breaking. The most demanding operations are the rapid high-temperature thermal processes, such as the one in which the faceplate is joined to the funnel by melting a layer of glass frit that has been deposited between them. Another is the exhaust bakeout process, which heats the bulb to a high temperature while simultaneously imposing high-vacuum stresses upon it. As tubes become larger, flatter, thicker, and more square, developing glass envelopes that will survive at standard production rates is becoming more difficult.

Another process that can not be neglected is the take-apart, in which defective tubes are disassembled to salvage good components. By simulating the process under laboratory conditions, the designer can often modify the disassembly steps to salvage the newer, more radical designs.

Looking into the crystal bulb

Future CRT enclosure designs will certainly offer challenges to glass system designers and manufacturers. Three new directions currently in developmental or early commercial phases are: very large sizes of over 40V; high-definition television (HDTV), which will require a 3:5 aspect ratio and tighter specifications; and thin flat CRTs.

Large sizes and flat faces each require greater strength. The simple solution—increasing glass thickness—is not always the cost-effective one because increased thickness causes increased thermal-processing time, not to mention increased weight. When these considerations are combined with others, it is clear that more sophisticated designs will be required. The physical constraints of current technology may limit the manufacturability and cost-effectiveness of some of these new designs, making new glass systems and manufacturing processes necessary. ■

40 years of Corning CRTs

Corning Glass Works has worked with the technology and manufacturing of glass for CRTs for 40 years and has made many contributions to the technology, such as non-browning x-ray absorbing glass compositions; solder glass (frit) for color CRT sealing; multiform parts for electron guns; and many glass melting, forming, and finishing processes. Development projects included radar bulbs in the early 1940s, monochrome television in the late 1940s and 1950s, and color CRTs in the 1960s.

Corning began making parts for black-and-white picture tubes in 1948 in Corning, New York. It currently operates CRT glass-manufacturing operations in the United States, North and South America, and Korea, and has built turn-key plants in Eastern Europe and Asia.

During the past few years, great efforts have been made to improve image appearance by flattening the faces of CRTs. These attempts range from the flatter squarer shapes first introduced by the Japanese in 1983 and 1984 to RCA's development of the square-planar tube and, most recently, to Zenith's development of the flat tension-mask (FTM) tube. Corning was heavily involved in the development of the Zenith tube. With its absolutely flat face, skirtless (rimless) panel design, and thicker glass sections, it is the most significant change to have taken place in CRT construction in the past 30 years.

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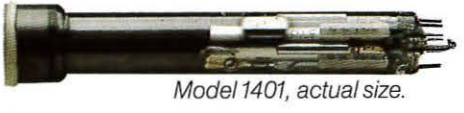

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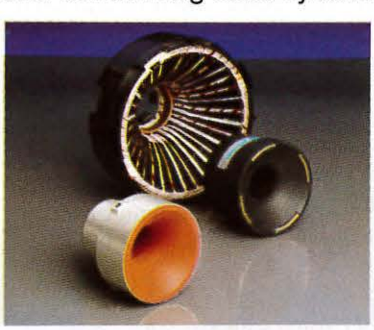

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continued on page 27

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awards

continued from page 24

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7. Specific statement by the nominator concerning the most significant achievement or achievements or outstanding technical leadership which qualifies the candidate for the award. This is the most important consideration for the awards committee, and it should be specific (citing references when necessary) and concise.
8. Supportive material. Cite specific evidence such as patents, publications, SID activities, other technical and/or professional society activities, evidence of outstanding leadership, etc. Please be specific and concise. Cite material that directly supports the citation and statement in (7) above. Limit the evidence to the most important patents, publications, or service—do not generalize. (The nominee may be asked by the nominator to supply information for his candidacy.)
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Send the complete nomination—including all the above material—to the Honors and Awards Chairman by **October 1, 1988.**

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index to advertisers

	Page
AEG Corp.	C2
Apple Computer	27
CELCO (Constantine Engineering Labs. Co.)	24
Clinton Electronics Corp.	8
CompEuro '89	26
Corning Glass Works	21
EG&G Gamma Scientific	7
Hoya Electronics Corp.	6
Hughes Aircraft Co.	22
International High Voltage Electronics, Inc.	24
Leader Instruments Corp.	C3
Microvision	2
Minolta Corp.	13
Panasonic Industrial Co.	4
Penn-Tran Corp.	12
Plasmaco	C4
Precision Electronic Glass, Inc.	20
Quantum Data	1
Raytheon Co.	15
Syntronic Instruments, Inc.	23
Teltron	2
Thomson-CSF	25
VuTek Systems, Inc.	28

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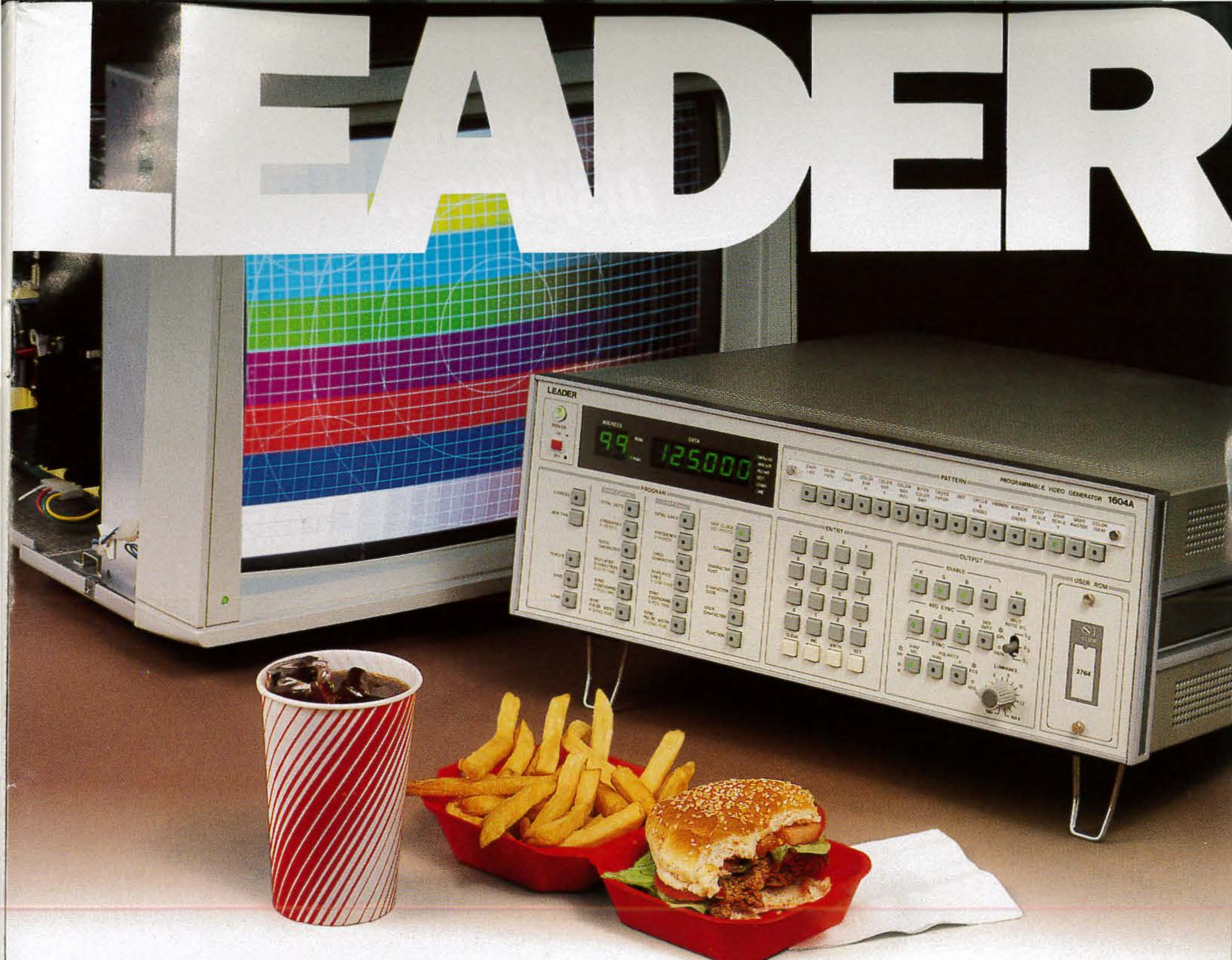

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