CRT CERAMIC STYLE...

MANY COMPANIES' completed products are far less complicated than some components for oscilloscopes.

Our most complex probably is the cathode-ray tube. To make one, you need to employ a wide variety of technical and scientific disciplines, from physics to biochemistry.

The CRT was one of the earliest Tek-made components. We started building our own in 1953. Those then commercially available didn't meet our needs for increased sensitivity and writing speed and for displays free of geometric distortion.

Technology advanced, bringing with it increased demands on oscilloscopes and their components. As scopes grew in complexity, the limits for further performance improvement would be found in a particular part or piece. And, more recently, the limits to some component's development have often been found in the material of which it is made.

This has been true of CRTs.

Most of our new tubes and over half of our tube production are ceramic

The CRT bulb (also referred to at Tek as "bottle" or "jug"), which houses the cathode and gun assembly in a vacuum, was first made of glass. (Most CRTs in industry still are.) But several years ago we began to suspect that glass itself had inherent limitations that impeded the kind of advances we needed to make. We began to investigate other materials.

A likely possibility seemed ceramic. At least, we could find out. Tektronix already possessed not only a large, well-equipped ceramic plant but also a sophisticated ceramic technology, including expertise in isostatic pressing, a fairly uncommon skill.

Our first ceramic tube was produced in 1962-63 for the type 564 oscilloscope. Now most of our new tubes use that material, and over half of our tube production is ceramic. No other scope maker has followed suit—yet—but at least one is experimenting in this direction.

When you talk about the advantages of ceramic envelopes, the first thing to admit is that Tek isn't yet realizing all of them. Many will depend on increased automation and addition of new processes (and others still probably remain to be discovered). But what we **have** achieved is substantial, and the benefits already are considerable.

In actuality, the total advantage of ceramic results from an accumulation of a great many subtleties. We'll discuss here only some of the more pronounced ones.

For one thing, ceramic is very strong. Our characteristic funnel glass has a flexural modulus, or bending strength, of 6500-7000 p.s.i. (pounds per square inch); forsteritic porcelain, our ceramic material, 20,000 p.s.i.

This means you can build lighter-weight tubes, with thinner walls. Also, scratches in the tube's surface have little effect on its strength. Glass, which has a different crystalline structure, may become greatly weakened by even minor scratches.

Scope faceplates used to be round, simply because glass CRT bottles were round, and the faceplate was part of the bottle. Today, most faceplates are rectangular, to provide maximum display area; thus they require tubes that are rectangular in cross-section. In ceramic tubes, the glass faceplate is fused (or "fritted") onto the ceramic envelope.

That is, glass bottles **are** truly "bottles"; ceramic envelopes are more like sleeves, or funnels, open at both ends. Such a rectangular envelope requires great structural strength; to make one of glass would mean very thick walls, thus a much heavier tube. (TV cathode-ray tubes, for example, are not rectangular, but bowed on all four sides to achieve the necessary strength. That's why your screen is the shape it is.)

Another benefit of ceramic, to us, is that we're our own supplier. This offers a lot of advantages:

1. The supply is reliable. Last year, strikes in the glass industry cost us delays and a lot of grief and dollars.

2. We can provide envelopes that meet Tek's exact needs, rather than have to accept the characteristics of commercially available bottles and build around them. By controlling the specifications of the finished material, we can match the material to the scope system in which it will be used. The electrical characteristics of ceramic may be modified in a variety of ways. This is not true of glass.

3. We do away with the need for incoming inspection. We trust our "supplier" to meet our specifications.

But the biggest gain from using ceramic and having our own plant is this: Speed of introducing new tube designs.

Tektronix can get a new design built for evaluation very quickly because ceramic is so easy to work with and requires such simple tooling. A precision, close-tolerance tube can be built in a matter of days, whereas it might well take months with glass, and the tooling would be very costly.

The nature of ceramic, and of ceramic processing, gives us increased ability to hold close tolerances—and tolerances are getting tighter all the time. A glass bottle is spun, or blown, **inside** a cavity; a ceramic one is formed **outside** of a mold. This gives us control over the internal geometry of the tube—particularly important in post-accelerator (helix-type) CRTs.

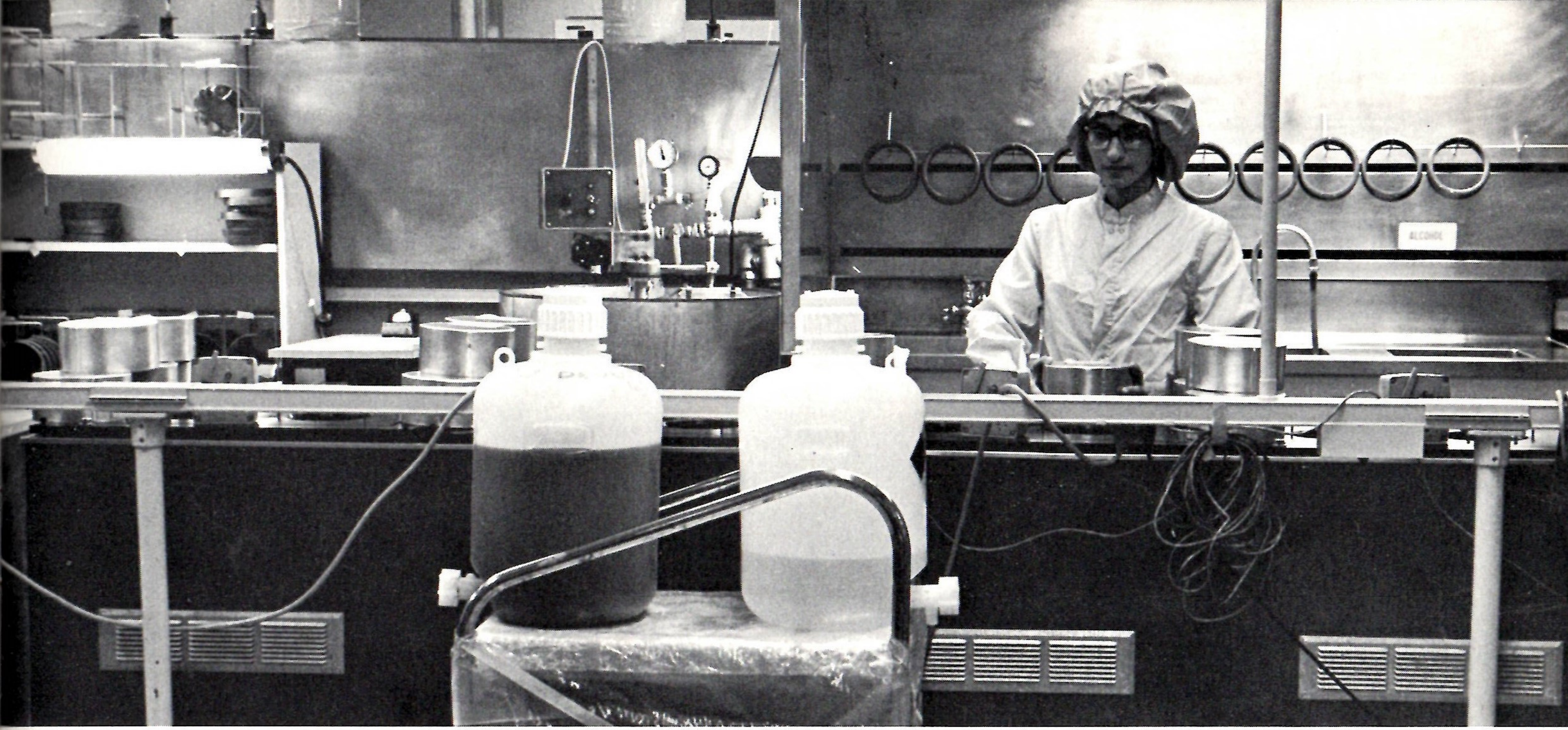
Because ceramic is so strong, we can cut sharp corners, allowing us to conserve space within the instrument.

Because ceramic can stand high temperatures, we're able to fuse special materials (for instance, high-reflective glass coatings) onto the funnel walls. Glass bottles subjected to the same temperatures would themselves melt.

In particular, the large-screen CRTs required for our display units and computer terminals rely on ceramic envelopes for the necessary strength, fidelity of image, close-tolerance geometry and reasonable cost.

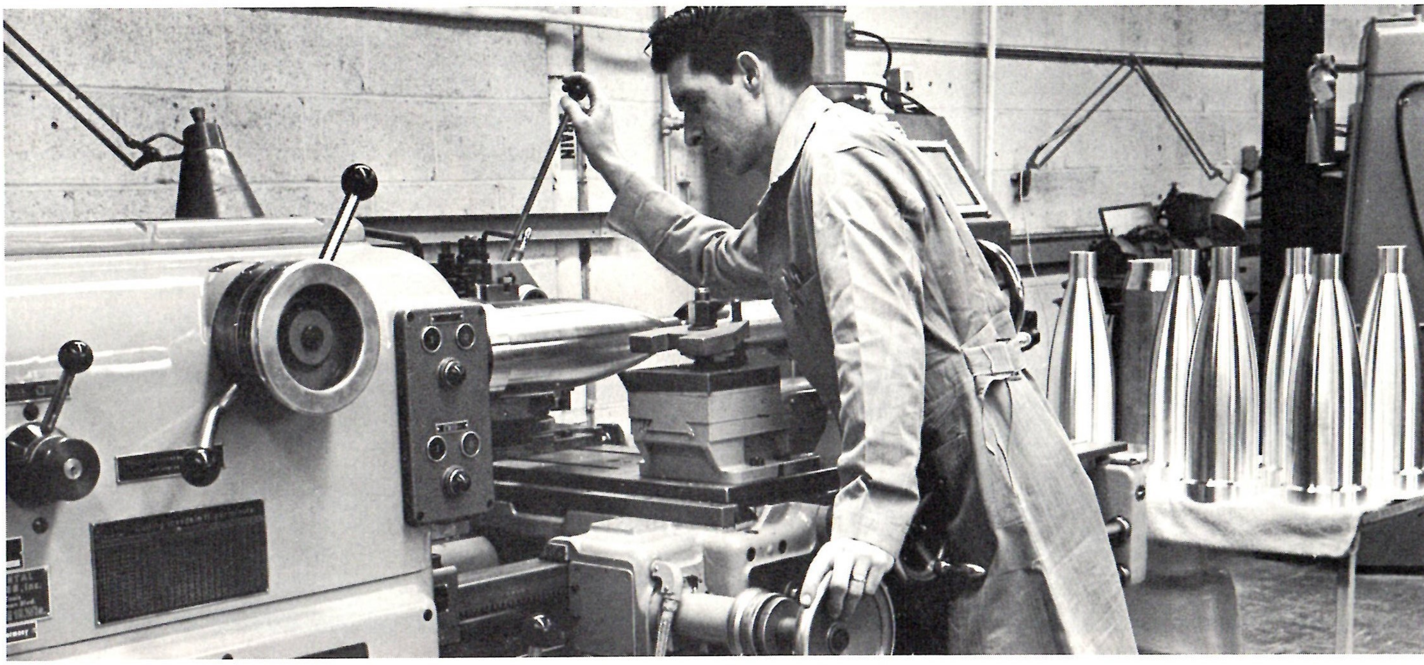
In our CRTs, the internal graticule is lighted from the edges of the screen. Ceramic envelopes, being opaque, provide a better contrast between edge-lit graticule and phosphor screen. Glass tubes, transparent, allow some of the light to "leak out" through the glass sides.

One benefit of the two-piece ceramic tube is that the envelope and faceplate may be made separately. Although we haven't used this advantage in our conventional tubes yet, we plan to; and



PRECISION NOZZLES (bottom photo) are fabricated for sand-blasting lines in metal-coated funnels. A "clean room" (top photo) is required for fabricating storage-type targets.

Ceramic offers more ability for close tolerances




OIL
KEEP THIS NUT TIGHT AGAINST SPINDLE

PRODUCTION OF CERAMIC FUNNELS involves a tracer lathe (opposite page top photo) to insure duplication of size and tolerance on funnel pressing mandrils and a diamond grinder (opposite page bottom photo) for parallelism and perpendicularity to center line of funnel's neck and bell end. Green (unfired) funnels are processed (this page bottom left); some are hand-painted with gold resonate (top photo) and others are glazed. All are visually inspected after firing (bottom right).

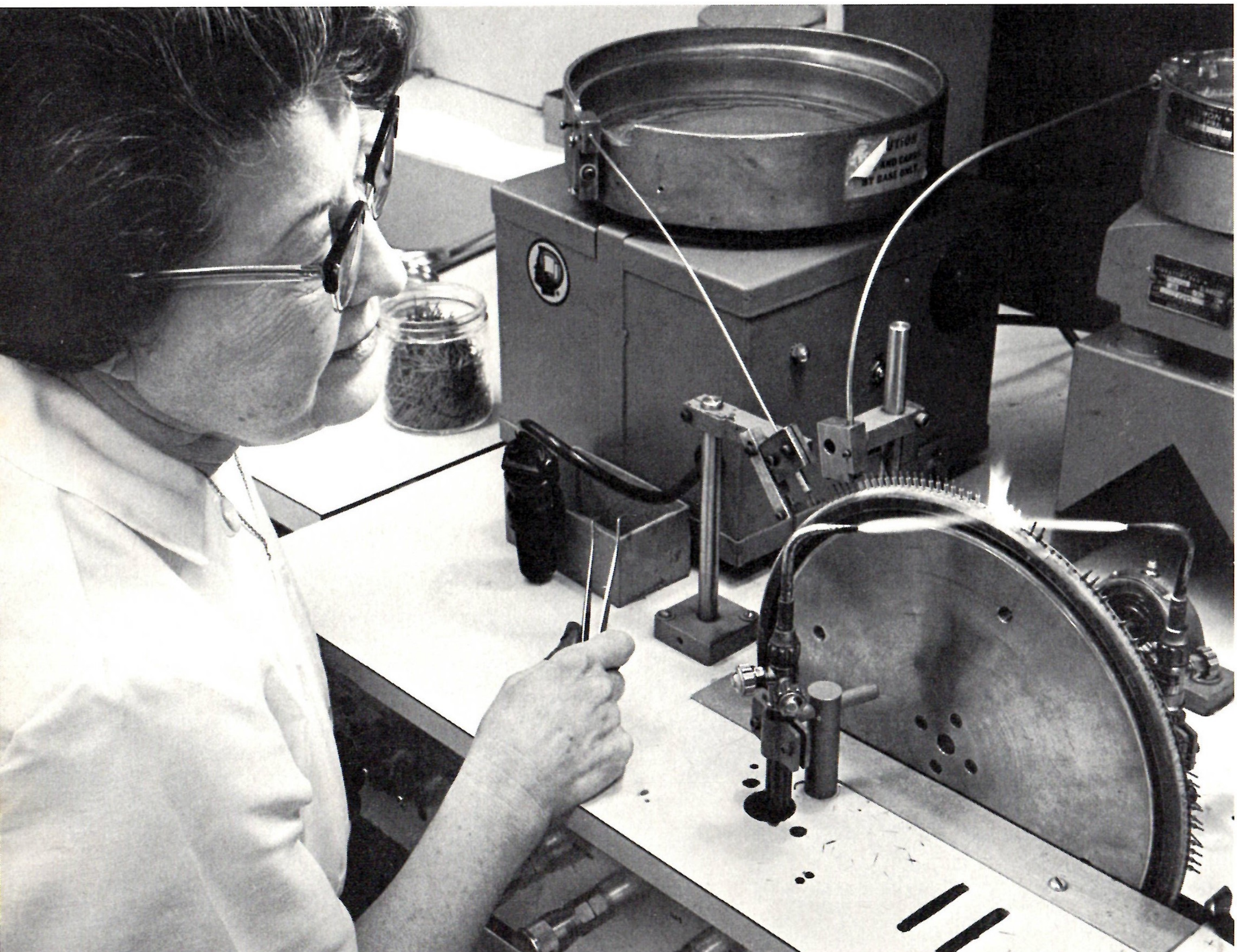
These processes lend themselves well to automation for less costly tubes...

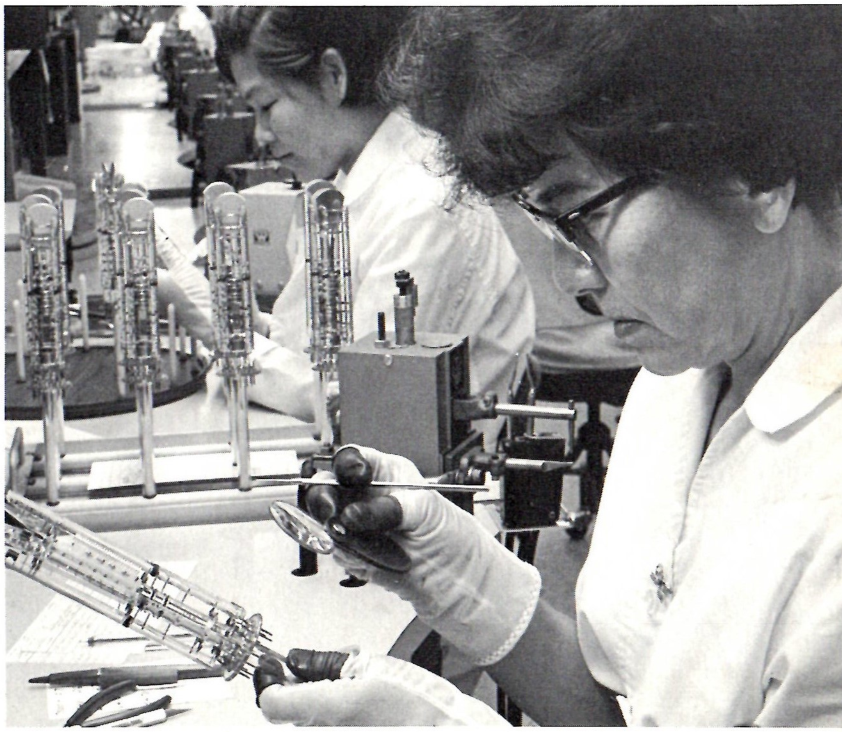
our storage CRTs, both for scopes and for our computer terminals, would have been impossible to build had we not been able to make the faceplate separately. A storage tube requires an extremely uniform phosphor target, which would have been impossible to obtain if we'd had to deposit the phosphor inside a glass "bottle."

In addition to designing most new tubes of ceramic, we're also in the process of converting several of our older glass tubes. This process doesn't let us capitalize on all the advantages of ceramic, in that we can't change the design itself. But it **does** let us take advantage of the material's strength and light weight; put the raw-material supply under our own control, and get improved internal-graticule lighting.

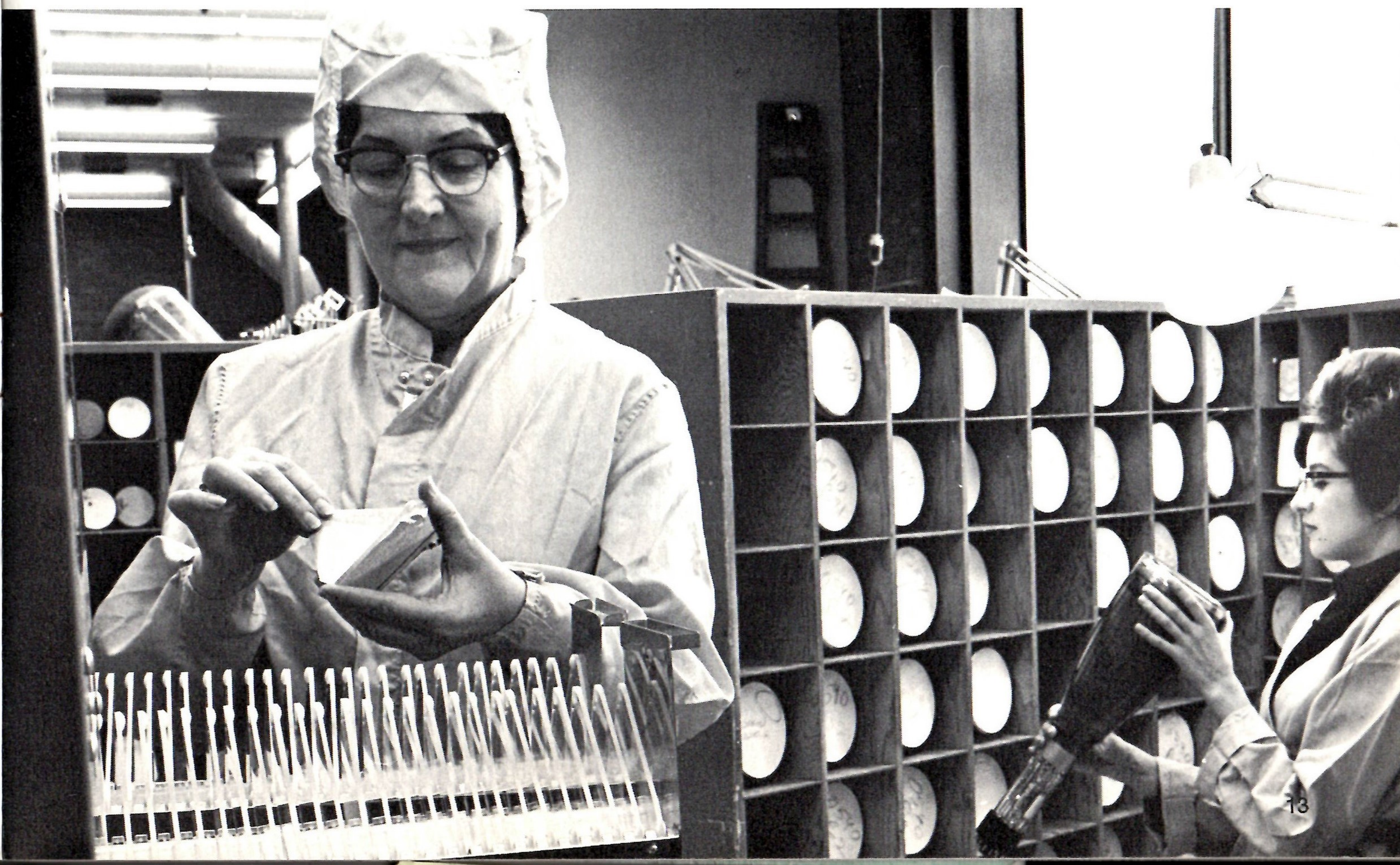
Are there any disadvantages or problems in ceramic CRT manufacture? Some—partly because we're less advanced in ceramic tube making than we were in glass tubes.

Here's the sort of problem that comes up: In a glass tube, you can **watch** the helix (the conductive spiral) as it's applied inside the bottle; in a ceramic envelope, you can't see through the walls. So we had to develop a machine to electronically monitor the helix winding. The upshot is that the new method





MELTING OF GLASS pre-form (opposite page) around funnel's metal pin is shown in this neck-pin beading operation. Funnels are held in jig (top left) during faceplate-seal firing, and weldings on gun assembly are inspected after stem attachments (top right). CRT targets (bottom) are inspected and covered by plastic faceplates prior to "potting."



NUMEROUS ELECTRICAL measurements are made during final testing of ceramic CRTs.

is considerably more reliable than "eye-balling" ever was.

Another disadvantage was that reclaiming ceramic tubes required processes we didn't have. Ninety-five per cent of our glass bulbs are eventually used, compared with about 70 per cent in ceramic. But we're getting better, and our ceramic reclaim figure is improving.

The most important things to say about ceramic tube making are:

1. We don't use **every** ceramic advantage in **every** tube. Rather, we optimize those characteristics needed in the particular design.

2. Most of the advantages of ceramic are still to come, as we increasingly tailor our processes to the new material. These processes lend themselves well to automation, which means less and less expensive tubes.

The result will be stronger, lighter-weight, more reliable tubes, ones that can be inexpensively built and rapidly put into production.

And these tubes will be needed, as the pressures of economics demand continuously increasing efficiency and as the requirements of technology insist on oscilloscopes that deliver higher and higher performance. □