James Dandy Diode Tester

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If you've wondered how to check the condition and characteristics of junk box diodes, here's an article for you. It's a simple, inexpensive tester for low voltage diodes.

I think that semiconductor diodes are almost as useful in circuit construction as resistors and capacitors. Used properly, diodes are good for all sorts of tricks beyond detecting rf and rectifying ac. Well, I recently saw a chance to acquire a huge batch of assorted computer types at an irresistible price (five dollars), and my resistance being what it is, I bought them all. But when I got them into my lab, a new perspective emerged: which ones are good? As I was sorting out the color coded varieties, I developed an idea.

Like Topsy, the idea growed up! It became a schematic and some simple calculations. It developed into a mess of clip leads and components attached to a Heathkit oscilloscope. And finally I built . . . a James Dandy Diode Tester.

This simple circuit tells which end of the diode is which, what its reverse breakdown characteristics are, and it gives you a rough indication of quality. You'll have to try something else if you're interested in determining rf performance or pulse risetime and turnoff characteristics, but you can tell if it's worth further attention. The Tester also checks zeners and transistors by observing the properties of their inherent diodes. And maybe there are one or two other uses we can find for it.

Theory

If we pare all the trimmings off the James Dandy Tester schematic, we end up with **Fig. 1.** This shows a high-voltage transformer in series with a resistor and a diode, and an output terminal added across the diode. Note that the diode points up. A second winding which provides the scope sweep voltage is not needed for a basic explanation. So let's work out what happens when the circuit is turned on. The key lies in the diode properties of reverse breakdown, forward conduction, and internal resistance.

The dotted box in **Fig. 1** represents the shell of the real diode. Electronically we can never open up this shell and find something inside that visibly accounts for what the diode does. But we can suppose there's a perfect diode inside the shell, and a resistor that somewhat spoils the diode's properties. Then we can describe the real diode's behavior in terms of this model. My diode-

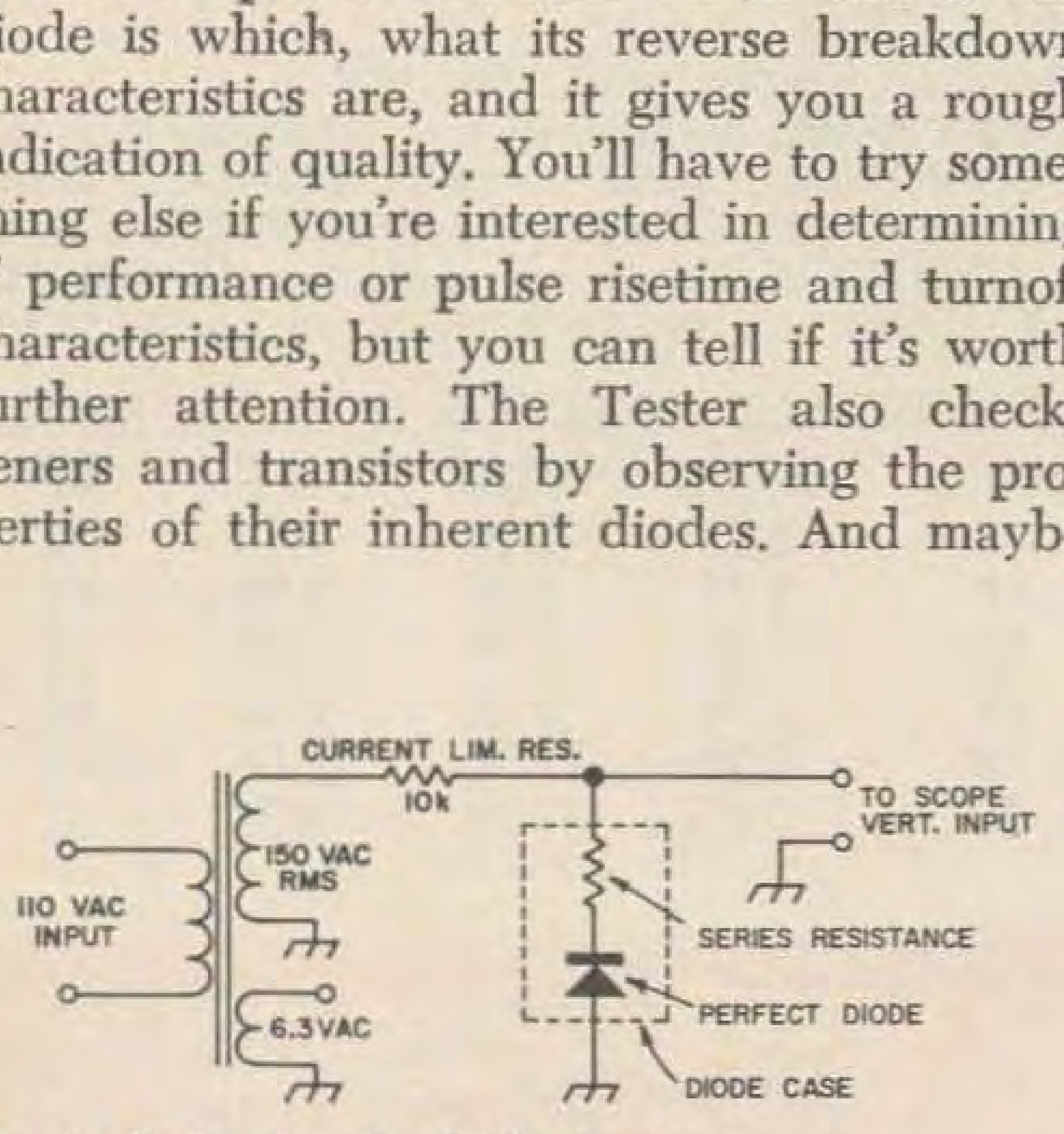

Fig. 1. Basic circuit of the Tester.

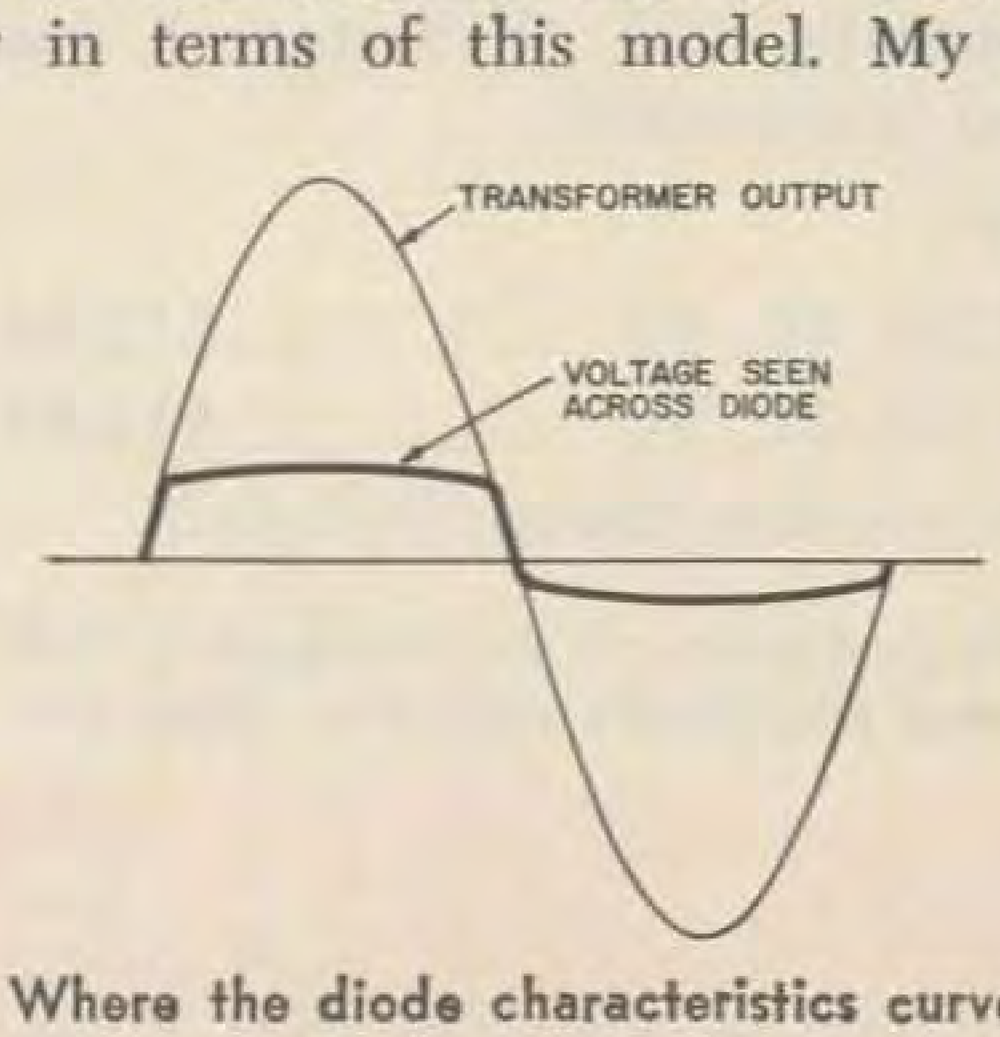

Fig. 2. Where the diode characteristics curve comes from.

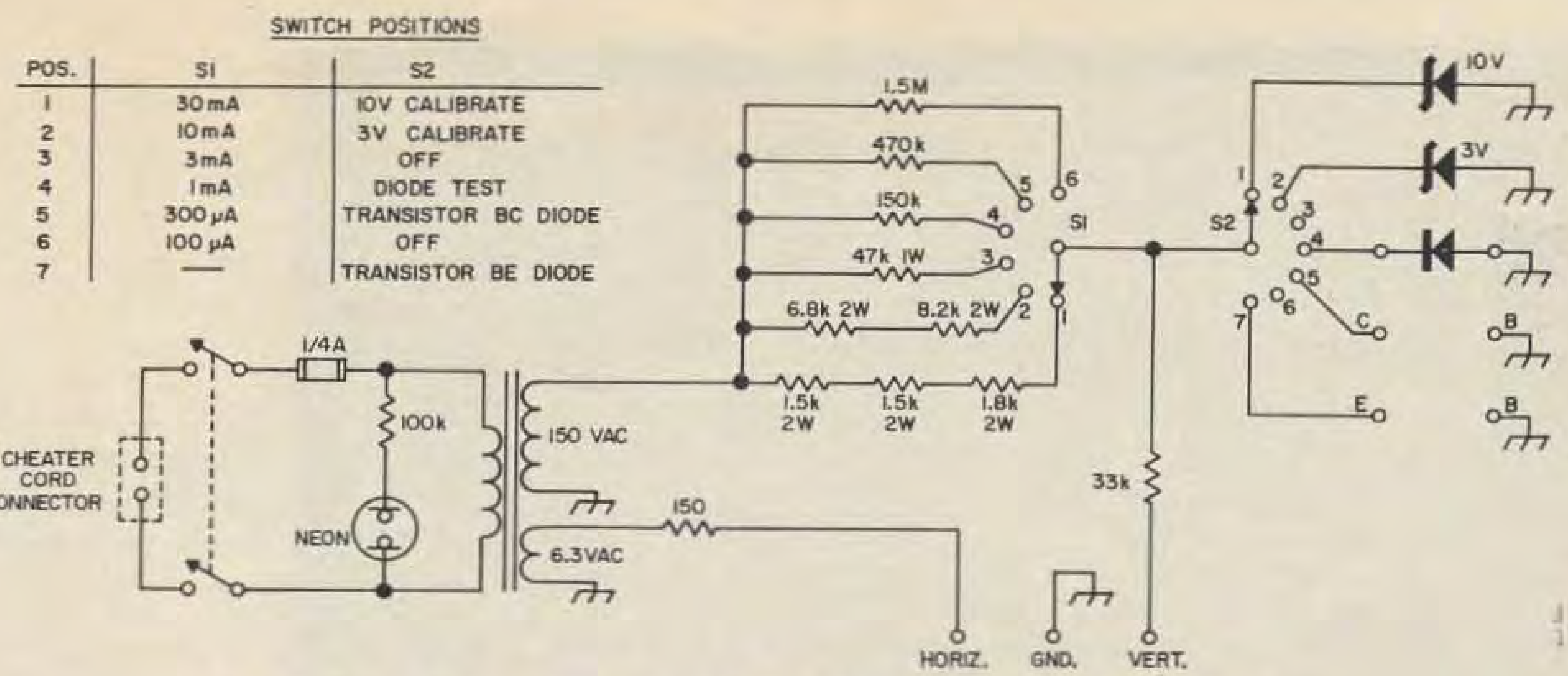

Fig. 3. Complete schematic of the James Dandy Diode Tester.

resistor model is very simple but it'll get by for now. So let's say the perfect diode goes into reverse breakdown at 20 volts, forward conduction at 0.7 volts (appropriate for sili-
resistor has the rather high value of 100
con, choose 0.2 volts for germanium) and the
ohms.

Fig. 2 illustrates the resulting situation with two superimposed curves. The upper curve represents the 150 volt RMS sine wave, always seen at the transformer terminals. The lower curve shows what we see at the diode terminals, generally a much lower voltage. Let's follow this through a complete cycle.

Starting at zero volts and going in the positive direction, we follow the sine wave along its natural course until it reaches 20 volts. At this level the diode goes into conduction, and the circuit sees the 100-ohm resistor as a heavy load with its bottom end held at 20 volts. This state continues until the transformer's sine wave returns to the 20 volt level on its downward swing. Then the diode goes off, we return to the sine curve, and follow its natural course back to zero.

The 150 volt RMS wave goes to 212 volts peak at the center of the half-cycle. We see roughly 200 volts across 10 Kilohms, or about 20 mA at this instant. Passing through the diode's 100 ohms, this current adds 2 volts to the perfect diode's 20 volts. We will have to push the top of the diode voltage curve up a little bit, and we should round off the corners since that's what we expect to find in a real circuit. This is how we get **Fig. 2**, which very closely resembles the real curves you will observe using a triggered or sawtooth sweep.

The negative half-cycle closely resembles the positive curve, but the break points are very much closer to zero. The (silicon) diode takes over at 0.7 volts rather than 20 volts, and the curve bulges in the opposite direction because the current flow is reversed.

My transformer has a 6-volt heater winding which I put to use as a horizontal sweep source. This gives a linear presentation. That is, starting at the center of the trace, which should rise towards the right, percentage of distance to the end equals percentage of peak applied voltage. This eliminates using a simple trig equation if you want to know the diode current at any part of the curve. And it gives a presentation closely resembling the manual and textbook illustrations. By changing some output connections you can get an exact correspondence.

Depending upon conditions of operation, 200 volts or more can appear at the Tester output terminals. If you're looking at fine detail in the diode characteristics, this could be applied directly to your scope's input tube. The 33k resistor in series with the vertical output terminal limits current flow under these and short-circuits conditions to

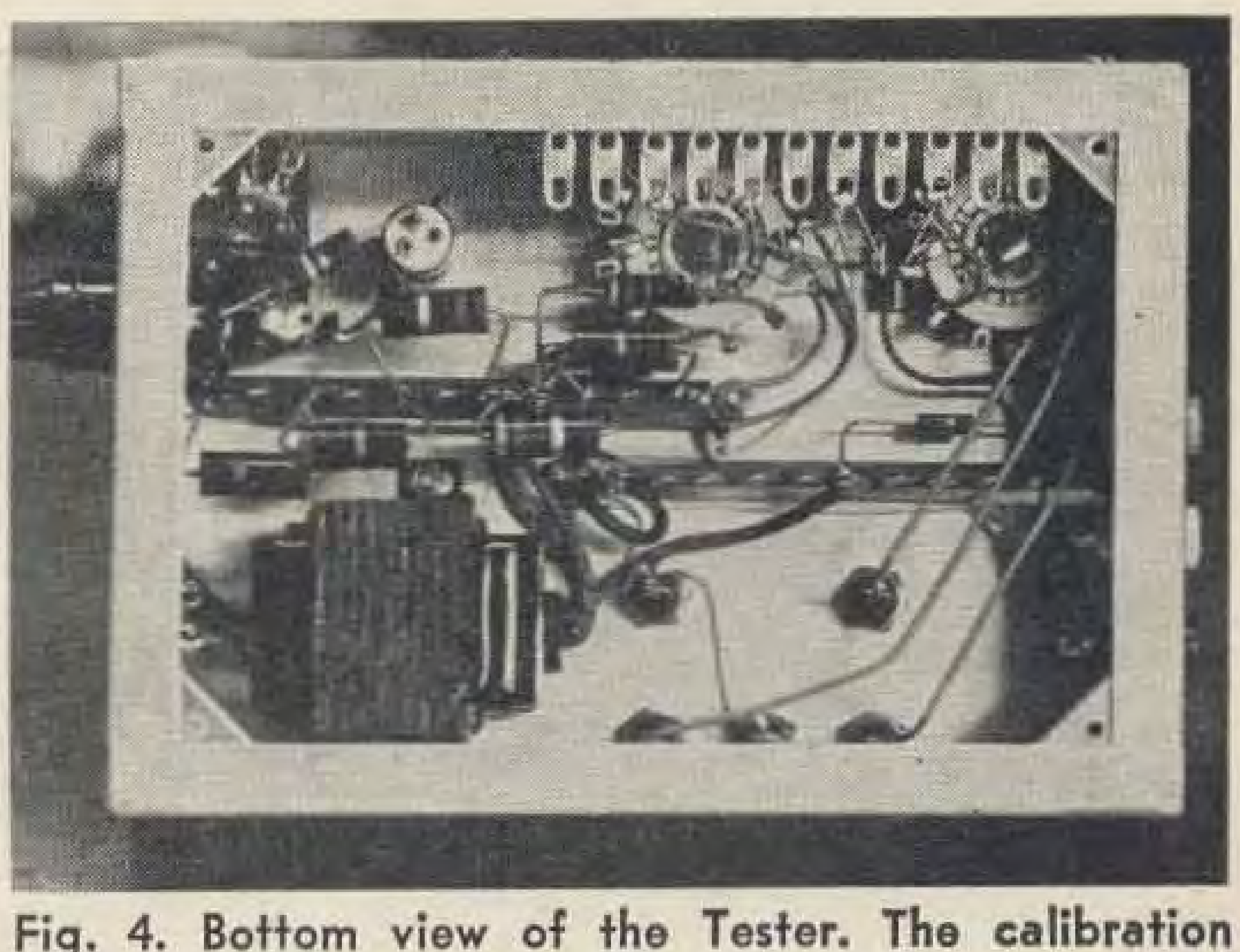

Fig. 4. Bottom view of the Tester. The calibration zeners are on the lug strip at the upper right hand corner of the chassis.

Fig. 5. Top view. I finished the Tester with slow-drying enamel and freehand India ink lettering.

5 mA or so at the price of a slight loss in signal amplitude. A much larger current is available at the diode test terminals, so watch your fingers! Turn the Tester off when changing diodes.

Construction

Fig. 3 shows a complete schematic of the Tester. Those protective resistors and the two-pole power switch might seem a little elaborate to you. But I've been in this field for some time and I think I've blown as big fuses as anybody, and got bit a few times too. The lots of little precautions like these tucked away in everything I build add up to a pretty fair insurance policy for me as well as the gear.

A 5x7x2 chassis serves as case and panel,

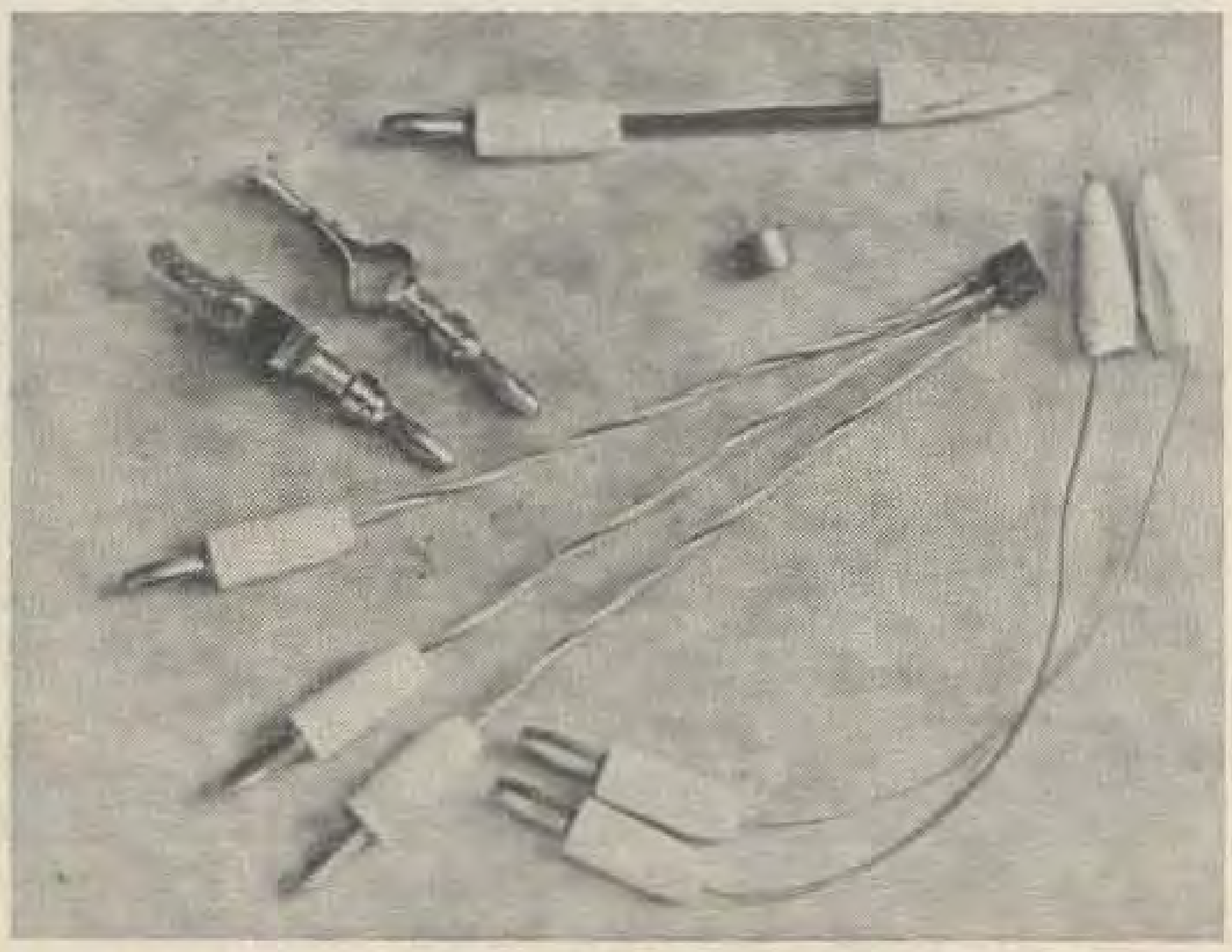

Fig. 6. Assorted leads for the tester. They go well with the Heathkit transistor tester too.

and a bottom plate makes a worthwhile improvement. All wiring is point-to-point, and three 11-lug solder strips provide additional useful tie points. About half the lugs actually got used. Fig. 4 shows a bottom view of the Tester.

You can see the transformer in the lower left hand corner of the chassis. If your transformer won't go in upside down there is lots of room on the back wall. The AC cheater-cord connector goes in the LH side wall beside the transformer, with a half-inch of clearance around its solder lugs. The fuseholder is in the same wall perhaps two inches forward. There wasn't enough room for it on the top, and fuseholders aren't very interesting anyway. I might have used a TV solder-in fuse and saved cutting a hole.

On the top surface, three rotary switches and a neon pilot lamp are mounted on the same line slightly more than one inch from the front wall. See Fig. 5. With the transistor and diode terminals toward the rear, there is a clear area across the inside of the chassis which takes two of the three 11-lug strips.

I used banana jacks for all test and output connections. They seem to be more convenient than anything else. Fig. 6 shows a collection of connecting adapters made up for the Tester. The ones on the left are made up of Grayhill #2-0 breadboarding terminals soldered onto banana plugs, and they are particularly handy when testing diodes. The others are make up of banana plugs and some light and some heavy wire, with Mueller's micro-gator clips. The more common alligator clips just don't get a grip on fine wires and transistors leads. Somewhere in there is a transistor socket with short leads, which I might have color-coded emitter yellow, base green, and collector blue. These assorted adapter leads tend to congregate on my Heathkit transistor tester when I'm not checking diodes.

A rotary switch turns the power on and off. I always use a rotary switch in this critical location. A toggle switch could collapse someday, accidentally turning on the circuit. A rotary switch can't possibly do that, and its general health is immediately apparent just by looking at it. I like that.

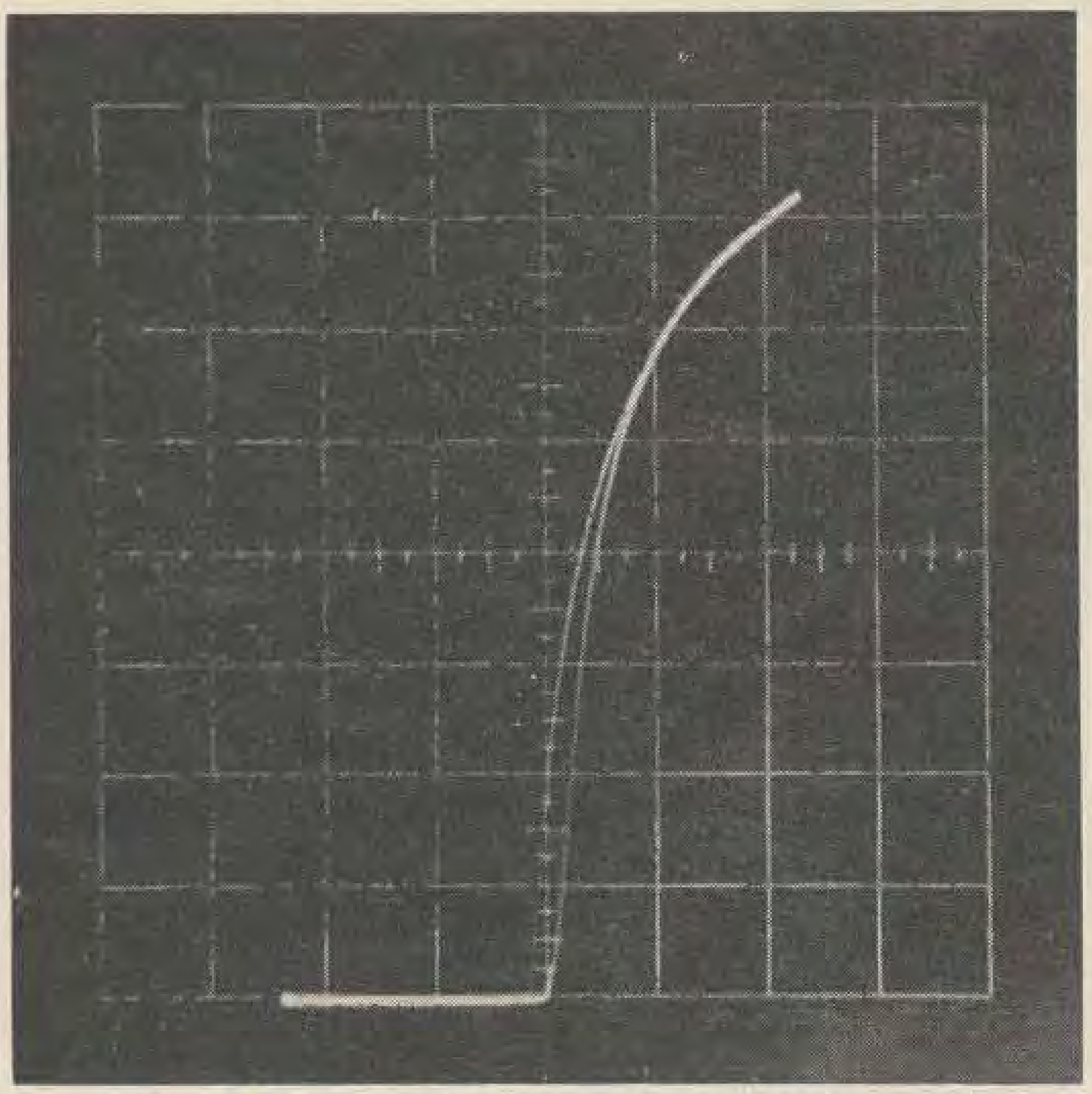

Fig. 7A. Germanium diode characteristics, showing gradual breakdown with increasing reverse voltage, and low forward resistance.

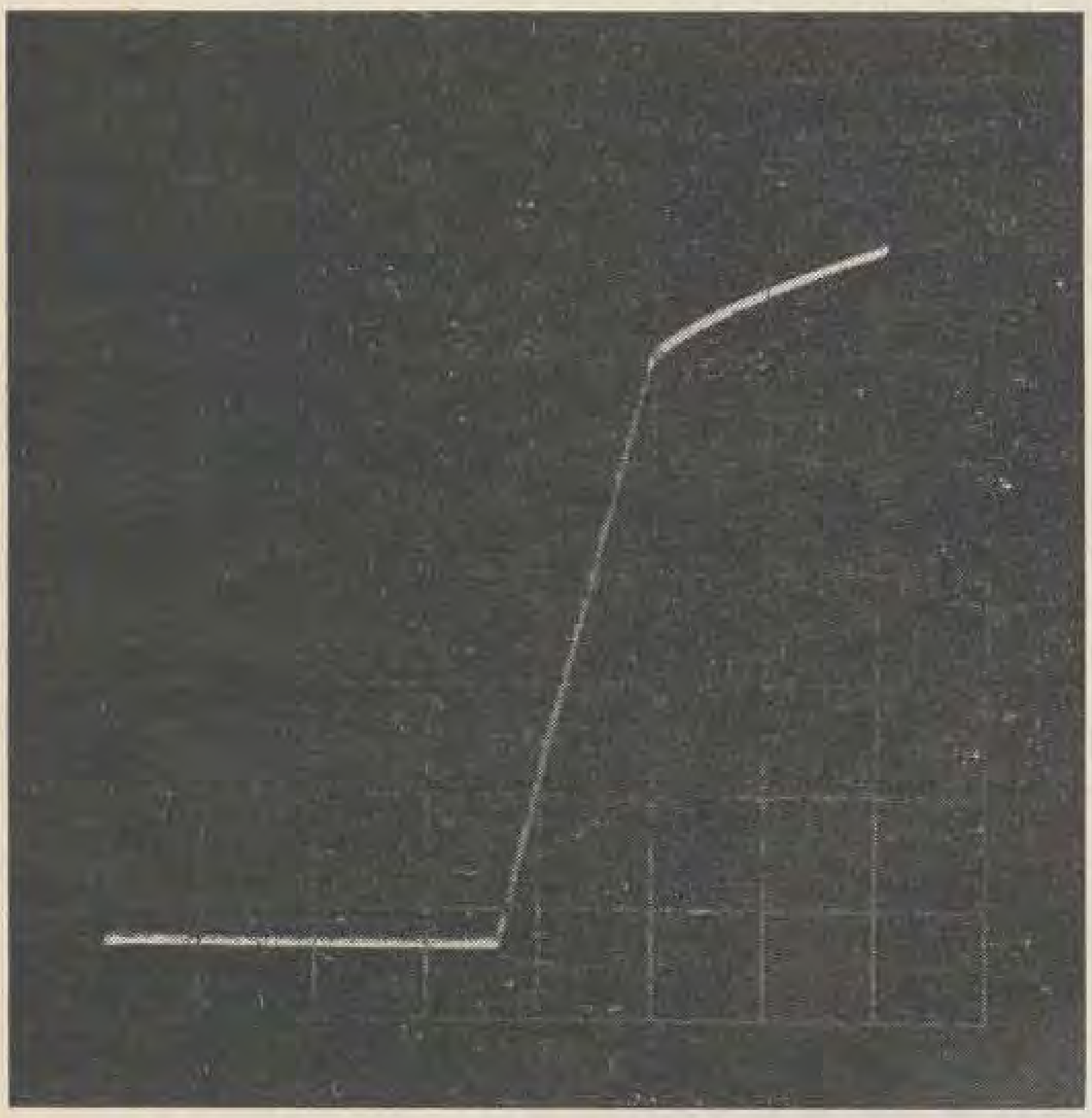

Fig. 7B. Another germanium diode, showing a sharp knee but poor dynamic resistance.

The other two switches are single-pole non-shorting (make after break) rotary switches, and any of several varieties are usable. Mine were assembled from CTS parts, purchased in little boxes and then you assemble what you need. I see some nice switches in Allied's #260B catalog on page 308. They are Mallory's Series 3200J non-shorting single-gang switches, and they come already assembled.

When you are finishing up the circuit, leave the transformer heater leads a little loose. You may want to reverse them. Before you finalize things, hook up the tester to a scope, set the scope to very low vertical sensitivity, and see which way the trace goes. It should be a straight line, rising to the right. That is, if a positive voltage to the scope's vertical input deflects the spot upwards, and to the horizontal input deflects the spot to the right. Otherwise you may have to redraw the curves shown in the illustrations.

The calibrating diodes go in last. Finish up everything else, and use the Tester to choose them. They'll be zeners or other diodes that show good zener characteristics. Details follow shortly.

Component values in this circuit are not critical because I don't expect too much from it. If I need exact measurements I get them somewhere else. I've chosen properly sized resistors so you can leave it on all night without anything roasting. If you want to change those resistors, it's easy. Ohm's Law:

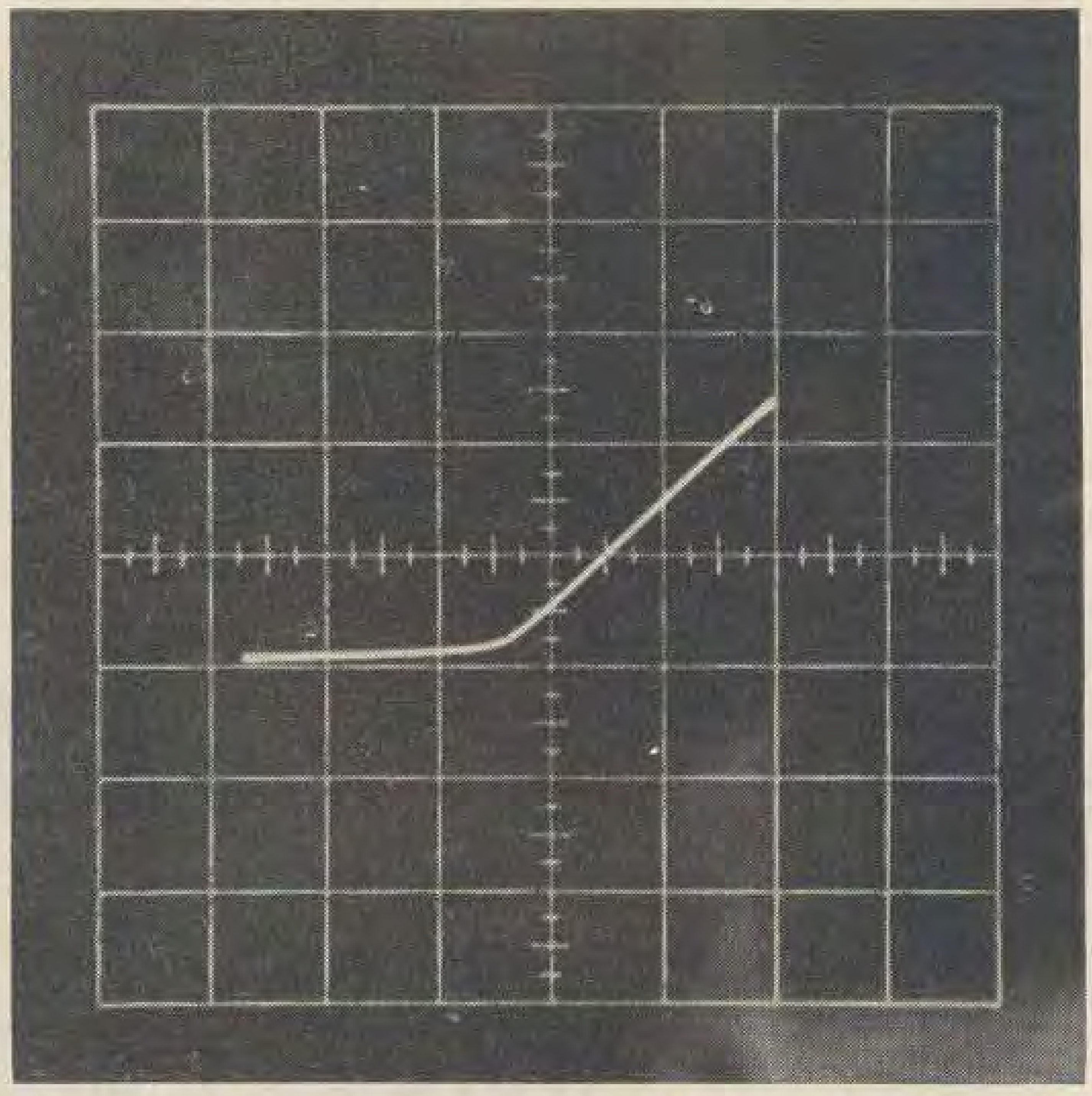

Fig. 7C. A germanium diode after overheating. The scope gain is very high, so we see that its diode characteristics are nearly gone.

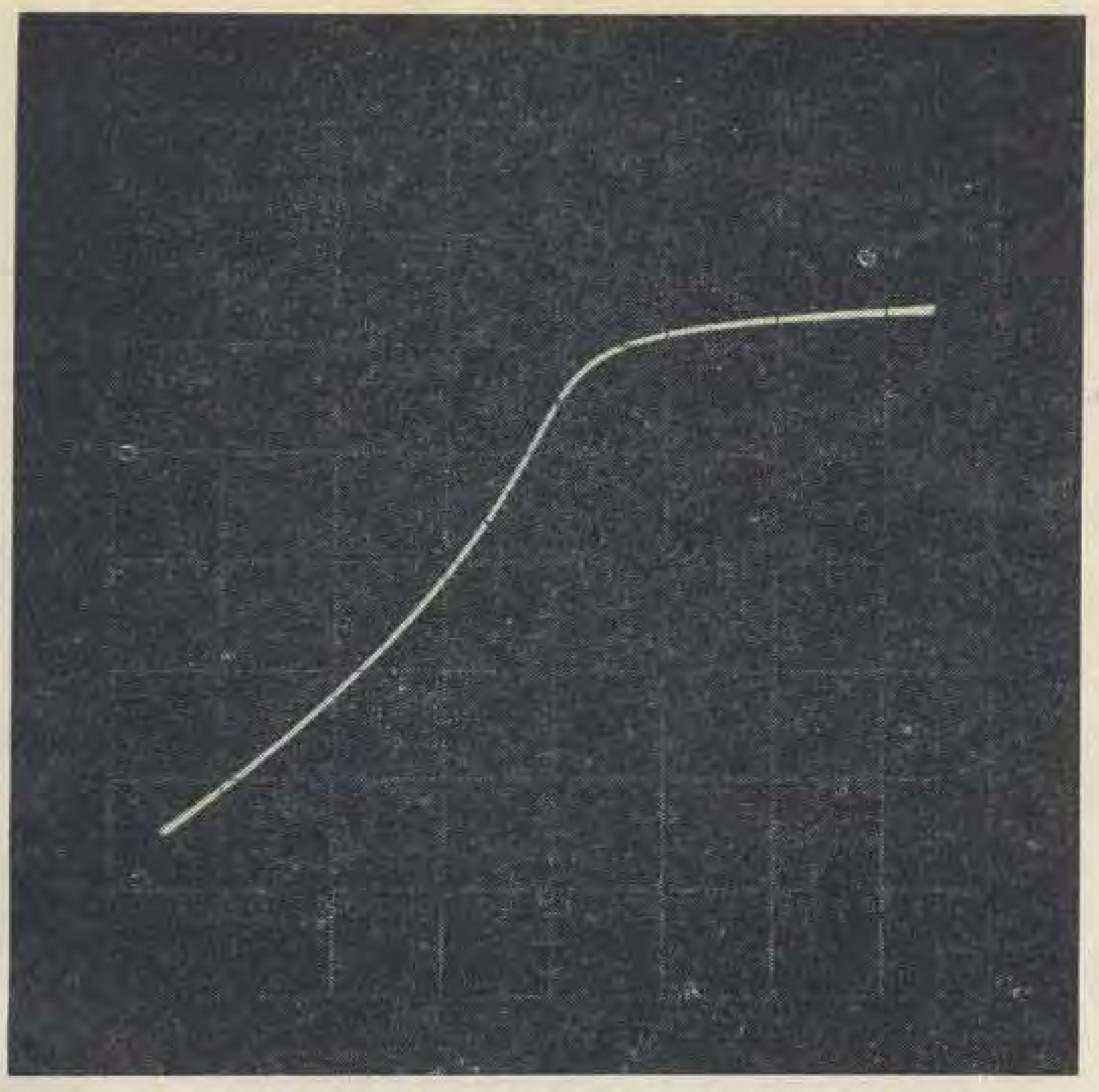

Fig. 8A. BE diode of a germanium transistor. Downward curve indicates a PNP transistor, and rather vague conduction and reverse characteristics suggest high leakage.

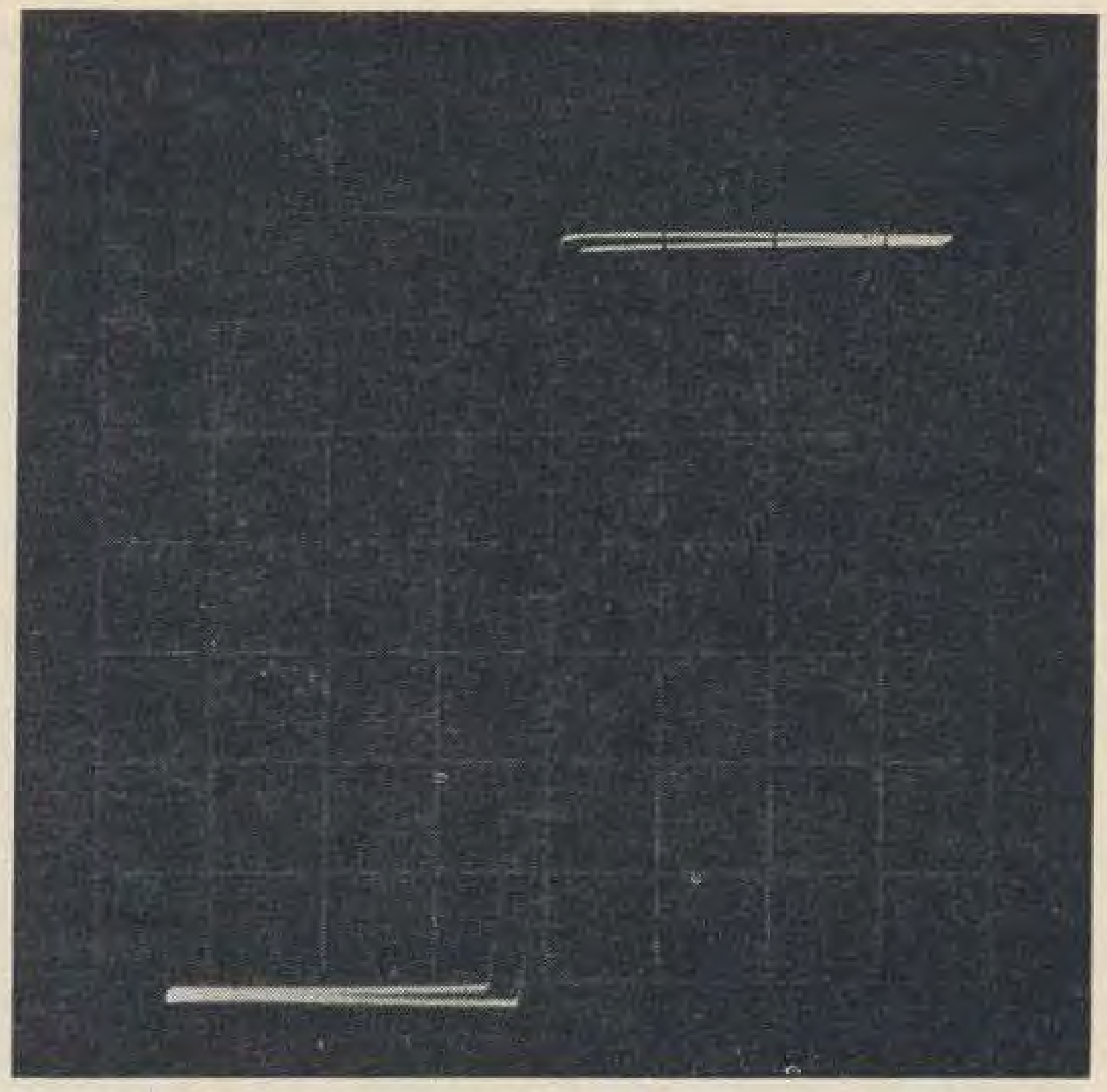

Fig. 8B. BC characteristics of the same transistor. This curve is also downward, and it shows a very sharp conduction and breakdown knee.

RMS voltage over resistance equals RMS current, and you can see in **Fig. 5** which values I chose. If you can't find a 150 volt transformer, compute new resistances for what you have available. I wouldn't use a lower voltage because some transistors and small diodes show breakdown voltages in the 100-volt range.

The case is finished off with good enamel and careful hand lettering. I won't go into detail on that because it's pretty well covered by my article on the subject in the March 1967 73.

The calibrating zeners

If you have a scope with fixed voltage ranges, you probably aren't interested in the calibrating zeners. If not, you need them, but how are you going to find out what their values are?

Perhaps you have some zeners of known characteristics, but the usual 10%, 20% or greater tolerances seem rather excessive. If you're familiar with your VTVM, you may have guessed the answer already: use its ability to indicate peak-to-peak AC voltages.

A review of the meter manual should answer any questions that may arise. So far as I know, all inexpensive VTVM's use a peak-reading circuit, with a meter scale that is labeled for sine-wave readings. We'll just convert those estimated sine-wave figures right back to P-P, by multiplying by 2.82. Or perhaps, like my Paco, P-P scales are included on the meter face.

Set up the Tester and your oscilloscope. Attach your meter ground lead to the Tester ground return, and the meter probe to the scope Vertical Input terminal. Set the VTVM for AC measurements and start testing diodes. When you come to a diode that has nice sharp corners and flat top and bottom, make an RMS reading, convert to P-P, and you have that diode calibrated. I think 3 volts is a little low, because I went through nearly a hundred diodes and transistors before I found one of this value; you might try 5 volts and you'll find one quickly. Three more of them would add up to 15 volts, and these are probably better choices than 3 and 10 volts.

Remember to make your measurements at the same current you will use when calibrating the scope. My zeners give true readings at 1 mA; you'll get sharp corners more easily at a higher current.

Testing diodes

The quickest way to understand the Tester indications is to put a diode in it and then work out the meaning of the different parts of the curve. Repeat with several different diodes. Most everything you need to know is in the theory section, and in several widely distributed handbooks. Just take a little bit at a time and ask, how did it get that way? I've included some illustrative photos and

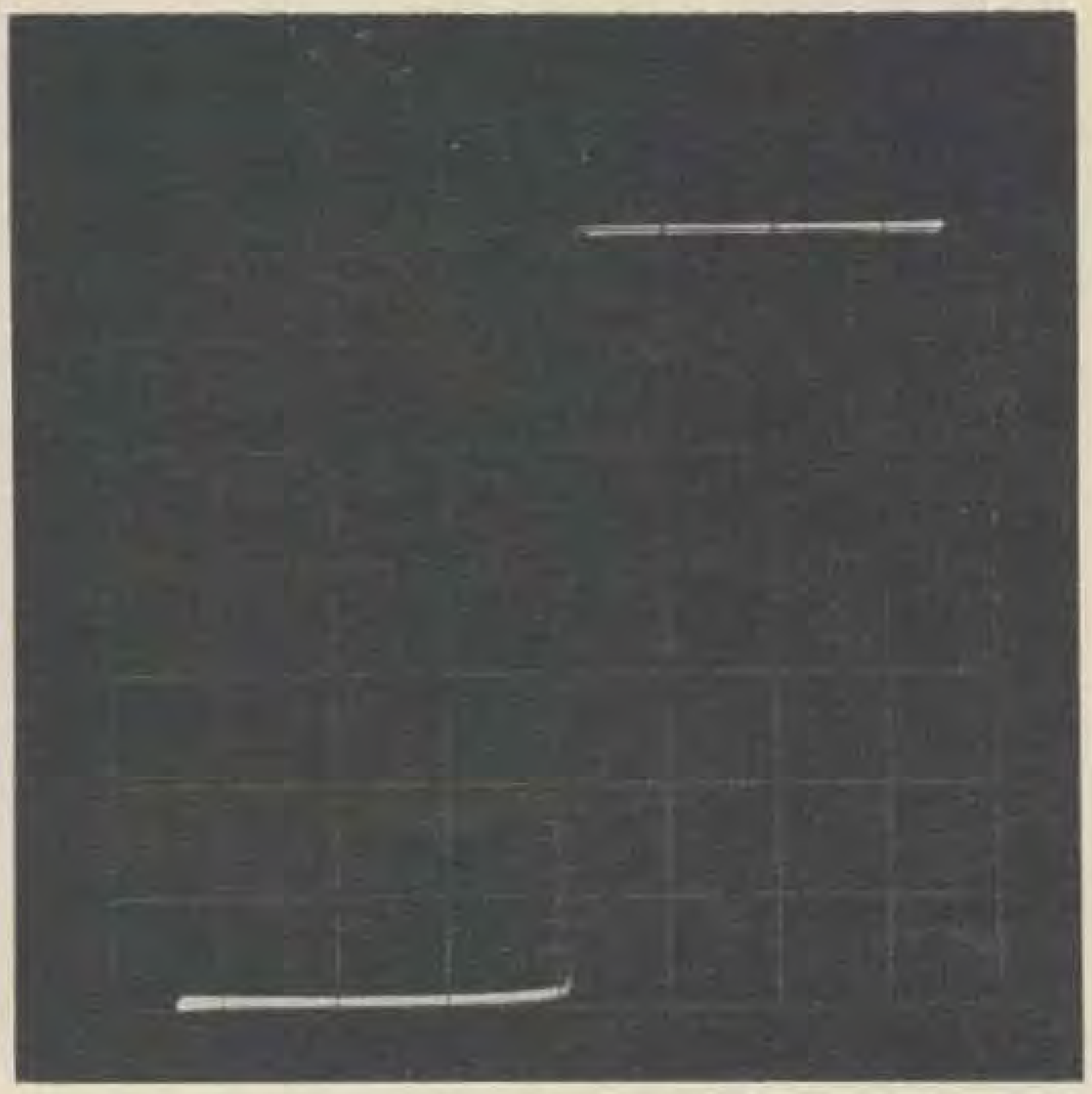

Fig. 9A. It's not obvious here, but this silicon transistor BE diode curve turns upwards.

Fig. 9B. BC characteristics of the same transistor. I don't know what causes the very noticeable phase shift. Can somebody tell me?

brief explanations.

All bipolar transistors have two inherent diodes. One is the base-emitter diode, and the other is the base-collector diode. The Tester checks these diodes one at a time, and it doesn't tell you anything about how the transistor will work. But if one of the diodes is bad, the transistor won't work. And the direction the curve goes indicates whether you have a PNP or an NPN transistor. See **Figs. 8** and **9**.

Why do many diodes show a double line in the vertical parts of the pattern? These lines merge at higher currents but are very distinctly separate for small currents and large diodes. I think this is phase shift of the applied voltage through the RC network of series resistor and reverse-biased diode capacitance before it goes into breakdown. In that case, the LH line would be the rightward-going trace (phase retarded).

Zener regulators

Do you have trouble finding zener regulators? The Tester will find lots of them, and tell you how they'll work in your circuits. It's so handy for checking zeners it belongs in my zeners article (73, October 1966) but when I wrote that I hadn't thought of it yet.

It turns out that not only specially built silicon diodes will serves as zener regulators, but some unspecial diodes and even germanium transistors! The Tester finds the ones that can regulate, and some of you out there working with low-power circuits can now find very low-power zeners to go with them. Wish I'd found out about this sooner! I haven't done any work in the matter, but I expect germanium zeners aren't going to show as good temperature stability as silicon zeners. Well, that is another problem. **Fig. 11** shows the base-emitter breakdown characteristics of an unlabeled germanium computer transistor from somebody's printed circuit board.

Fig. 10. A very close look at a perfectly good GE Z4XL6.2 zener diode. It shows some zener noise under 200 microamps, and low dynamic resistance.