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A 14-Decade Numerical Indicator Tube

ZM 1200 numerical indicator tube, about three-quarters actual size.

The ZM1200 cold-cathode indicator tube recently introduced by Philips displays fourteen decades in a space just over 14 cm long. The size and spacing of its characters — 10 mm high by 7 mm wide, on 10 mm pitch — are designed for easiest reading at about arm's length, as in desk-top calculators and similar equipment.

Not only size, but also simplicity give it a distinct advantage over single-decade tubes. The double-ended envelope has only 27 connection pins, as compared with the 168 that would be needed for an equivalent display with conventional indicator tubes. Moreover, for the sake of strength and reliability, the number of welded connections inside the envelope has been kept to a minimum; wherever possible, electrically connected elements have been formed from the same parent material.

For compatibility with the present trend in calculating and display equipment, it is designed for sequential drive, similar cathodes of the fourteen decades being connected in common and each decade having a separate anode. With the anodes and cathodes held at a quiescent bias, digits are selected by applying coincident pulses to the cathode rail of the desired digit and the anode of the desired decade. Brightness can be controlled by changing either the amplitude or duration of the pulses; to illuminate all fourteen decades with an intensity of 600 cd/m² a driving power of less than 2 W is required. A single screen electrode keeps adjoining decades from interfering with each other, and even at a cycling frequency as low as 70 Hz there is no noticeable flicker.

Besides the ten cathodes for delineating the digits 0 to 9, each decade incorporates provision for a decimal point at the lower right and a pointing-off sign at the upper right. For ease of reading, any number can be pointed off in arbitrary groups to the left and right of the decimal.

Reliability of the ZM 1200 Indicator Tube

In response to the item in Vol. 29, No. 1, several readers have made inquiries about the 14-decade numerical indicator tube ZM1200. Besides asking about price and availability, some of them have raised questions about the reliability of the tube. As one reader put it, "... if one cathode fails the whole tube would seem to be crippled, and presumably it isn't a cheap one to replace". The point is well taken and the fact that others have also raised it makes it worth further discussion in these pages. What follows is quoted from a letter written in answer to one inquiry.

Operating limits

Your most important question is, "If one cathode fails, surely the whole tube must be replaced?" That's true, but how likely is such a failure? The life expectancy quoted in the published data is 50 000 operating hours under typical conditions, i.e. within the quoted limit values and assuming no long-term uninterrupted lighting of a single digit. What "long-term" means in this context is 1000 hours or more, which would amount to six weeks, day and night. In the kind of equipment the ZM1200 is meant for — desk calculators, accounting machines, small computers — that sort of usage is very uncommon. Even in the unlikely event that someone *were* to calculate uninterruptedly for six weeks, I think you'll agree that it would have to be a very unusual calculation indeed to keep any digit unchanged in the input or output register for that long! (Of course, there might be persistent zeros in one or more of the left-hand decades, but if the equipment were designed for suppression of insignificant zeros — which is the present trend — that wouldn't matter.)

Cathode sputtering

The reason for the limitation on uninterrupted lighting of a single digit is easy to explain. It's not the lighted digit that's likely to suffer so much as the unlighted ones. A lighted digit is subject to continuous ion bombardment which cleans its surface by sputtering away any impurities that may have collected there. However, the sputtered material has to settle somewhere, and where it settles mostly is on nearby unlighted digits, increasing their work function. If the unlighted digits are brought into service before too long, no harm is done; the material deposited on them is soon sputtered away. But

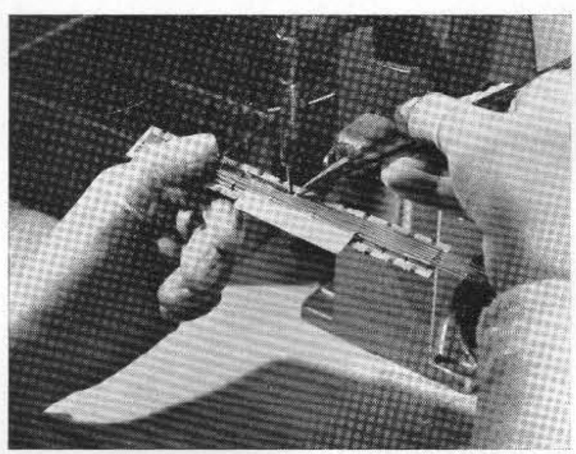

Fig. 1. Separately insulated leads are spot-welded to the anodes that underlie each of the fourteen decades.

if one digit is kept lighted uninterruptedly for, say, three months, some other digit in that decade is likely not to light as well as it should when at last it is wanted.

As for wasting of a continuously lighted digit, that doesn't seem to come into consideration a tall. The rate of sputtering depends, of course, on the peak current and the gas pressure in the tube, but so far we haven't been able to find measurable wasting even of digits that have been operated for several thousands of hours continuously. This correlates well with our experience with conventional

Fig. 2. A Jacob's ladder worked by a foot switch presents numerical cathodes to the assembler in the order in which they are to be fitted over the anodes. Mica insulating frames (alongside the assembly jig) are placed between each pair of electrodes.

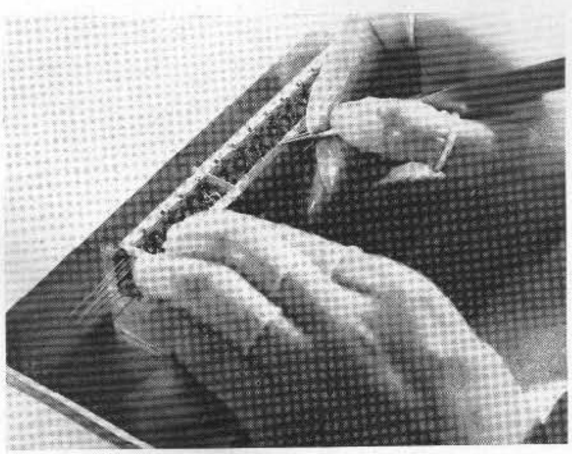

Fig. 3. Mica partitions, inserted after all electrodes are in place, divide the structure into separate cells for each decade; one such partition can be seen above, between the cells of the fourth and fifth decades.

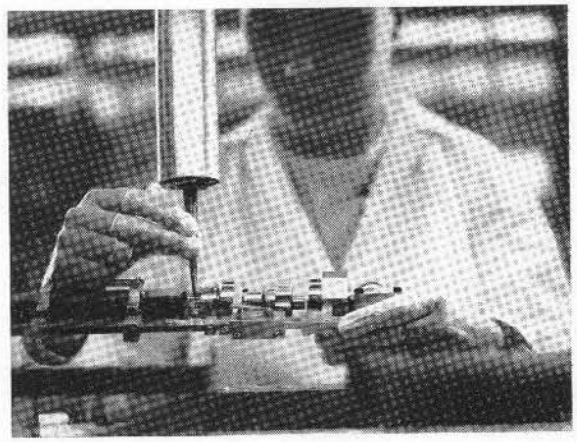

Fig. 4. The completed electrode assembly is spot-welded to the pins of the base. The jig in which the welding operation is carried out ensures concentricity of base and envelope.

Fig. 5. A fixture guides the electrode and base assembly into the glass envelope. Air blown in at the far end of the envelope sweeps detrital flakes of mica towards the entry for extraction by an annular suction nozzle.

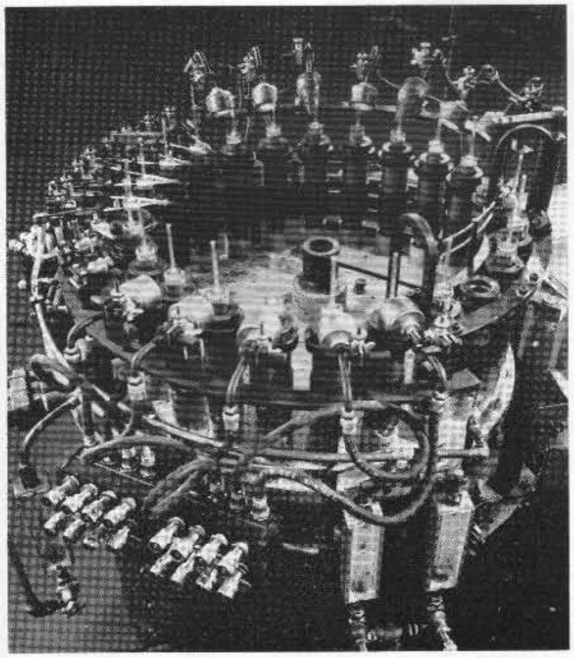

Fig. 6. Fusing the bases to the envelopes; in the machine shown the tubes enter near the three o'clock position and move anti-clockwise through the several steps of the fusing operation.

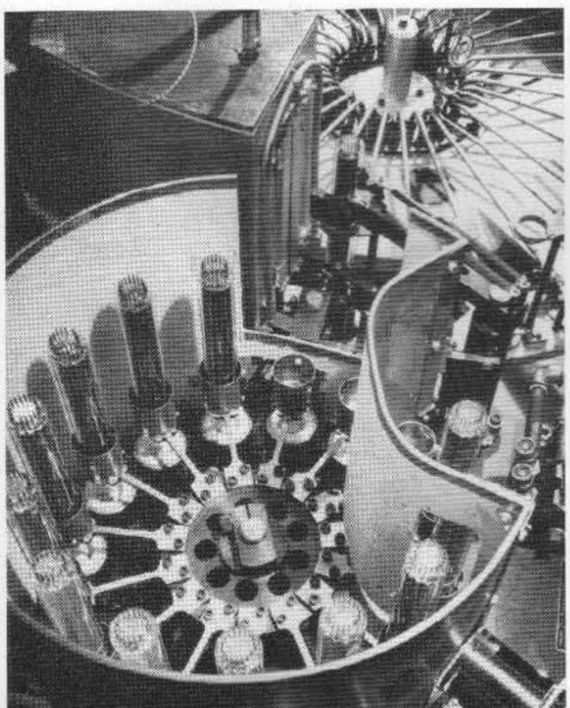

Fig. 7. As the tubes emerge from the outgassing oven (upper left) they are filled with neon-argon and sealed; in the circular structure in the foreground the glass of the base is tempered to develop a favourable stress pattern.

indicator tubes; even in specimens that have operated continuously with one digit lighted for several years, wasting has never been a problem.

What has been a problem with conventional tubes has been darkening of the envelope after they have been operated for several thousand hours under the pulsed conditions that are usual in desk calculators. Conventional tubes can be replaced one at a time when that happens, but if a ZM1200 were to darken, say, in the most used decades, it would seem that the user would either have to put up with it or replace the whole tube. We thought of that and took steps to make sure it wouldn't happen.

In the first place, the gas pressure in the ZM1200 is much higher than in a conventional indicator tube, so the rate of sputtering is proportionately lower. (The high pressure also accounts for the comparatively low operating voltage and the unusual sharpness with which the numerals are defined.)

In the second place, it is designed to operate at

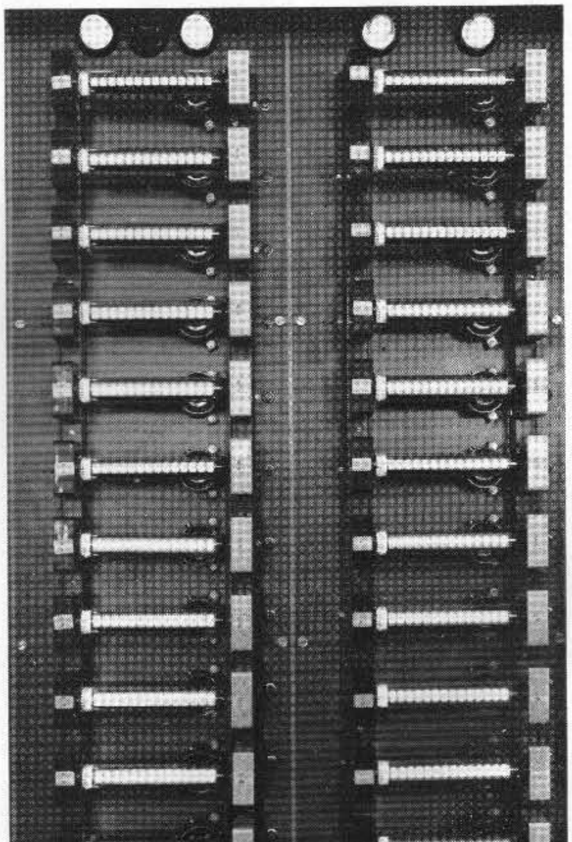

Fig. 8. To clean the cathodes and purge the filling gas of residual impurities the tubes are overdriven until their characteristics are stabilized in the required operating range. In the photo, rapid cycling blurs the individual digits.

much lower peak currents (about 9 mA per decade, or about half as much as a conventional tube), which further reduces the sputtering rate. In the third place, the digits are spaced comparatively far from the glass of the envelope, so the sputtered material has ample opportunity to settle before it gets that far.

And finally, a double mesh screen between the digits and the glass creates a very effective barrier to trap sputtered material before it can reach the glass. In tubes that have been operating continuously at *maximum peak current* for more than eight months in our laboratory there is still no trace of any darkening or deposit on the glass.

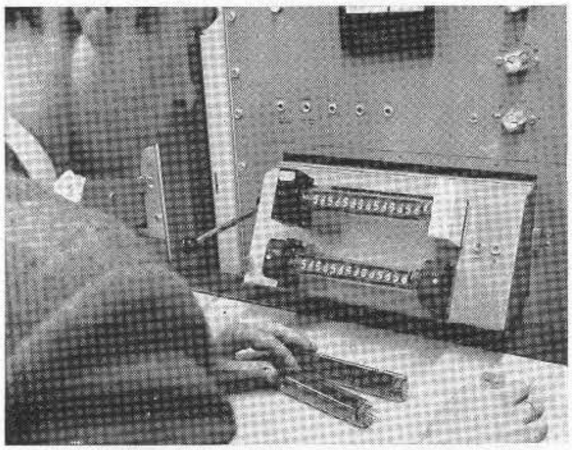

Fig. 9. All tubes are fully inspected and tested before being passed for delivery.

Mechanical reliability

Of course, you may say, there is still the possibility that some little thing will come unstuck inside the tube and it will have to be thrown away. We can't deny that there *is* that possibility, but the probability of its happening is very slight.

Because the tube is designed for sequential drive it has fourteen anodes — one for each decade — but only twelve cathodes, which means that the number of welded joints is kept to an absolute minimum. All the numeral 1 cathodes are formed from a single sheet of metal, all the numeral 2s from another, and so on, through the decimal points and pointing-off signs. Each sheet is strengthened by an integral frame that completely surrounds it, and they are all isolated from each other by intermediate layers of mica. It's a very compact and sturdy construction. Repeated shock tests at 50 g and vibration tests at 50 Hz have never succeeded in shaking anything loose.

Test results

The ZM1200 is still too new for statistically significant conclusions to be inferred from the test results so far available. Judging from our experience with other numerical indicator tubes and from life tests on very early development samples of the ZM1200 we feel quite confident about quoting an expected failure rate of less than 0.2% per 1000 hours. What we can say for certain is that in the more than 25 000 hours of testing to date there has not been a single failure. This covers a total of 11 tubes under test at various currents from 6.5 mA to 11.5 mA, two of them having been in continuous operation for more than 6000 hours each. Regular testing of samples taken from stock has uncovered no evidence of any deterioration in storage, nor have specimens that have been cooked for 24 hours at 200 °C shown any signs of gas contamination or other degradation.

Though the testing to date has not been extensive enough to enable us to calculate a Mean Time Between Failures with a reasonably high confidence level (after all, we haven't had any failures yet), it has at least been convincing enough to give us no hesitation in backing the ZM1200 with a one year guarantee. And we fully expect it to outlive that guarantee by a factor as high as ten, by which time the equipment it is fitted in will very probably have been retired.