with this counting solution were not sufficiently stable to be used routinely.

Addition of any of a number of detergents to the toluene-Thixcin counting solution mixture gave stable emulsions. In Table 1 are shown the results when variable amounts of Hyamine 10-X [p-(diisobutylcresoxyethoxyethyl)dimethylbenzylammonium chloride monohydrate], in the form obtained from Rohm and Haas Company, were incorporated by vigorous shaking at room temperature into a mixture of toluene counting solution, Thixcin R, and 1 ml of an aqueous solution of glucose-U-C^{14} or sodium benzoate–C^{14}. The efficiency increased with increasing concentration of Hyamine although, visually, the emulsion appeared to be stable at 0.5 percent Hyamine. The efficiency at 5 percent Hyamine was about 78 percent of that given by dissolving benzoic acid–C^{14} in the toluene counting solution.

The usefulness of the method was explored further by using tritiated water and thymine-H^3 in water. Samples with and without Thixcin, and containing increasing amounts of Hyamine, were prepared and counted repeatedly over a 5-day period. Those samples without the gelling agent invariably showed a progressive decrease in counting rate, while those containing lower concentrations of Hyamine gave very poor efficiencies. When the gelling agent was present, together with sufficient Hyamine to give an emulsion, there seemed to be little difference in stability or efficiency when the emulsion was formed either by vigorous shaking by hand or by subjecting the mixture to ultrasound for 15 minutes. The ultrasound treatment did give higher counting rates than those obtained by shaking when suboptimal amounts of Hyamine were present. As is shown in Table 2, there is a tendency toward a decreased efficiency during the first day of standing. This could be due to settling but might also be due to quenching associated with a resorption of oxygen which had been removed during the ultrasonic treatment. The counting efficiency with 5 percent Hyamine is about the same as that observed when toluene-soluble tritiated compounds are dissolved in the same counting solution without Thixcin and Hyamine. This is not due to solubility in toluene because of the Hyamine, since identical samples without Thixcin present gave considerably lower counting rates (of the order of a few percent), and this rate diminished progressively on standing and breaking of the emulsion.

Table 1. Effect of Hyamine concentration on counting efficiency of C^{14} compounds.

Percent Hyamine	Percent efficiency	
	Glucose-U-C^{14}*	Sodium benzoate-C^{14}†
0	4.2	3.7
0.25	31.3	34.6
0.5	36.1	34.3
1.5	37.5	45.0
2.5	44.3	49.6
5.0	52.2	51.5

* 3 percent Thixcin R gel. † 4 percent Thixcin R gel.

Table 2. Effect of Hyamine concentration on counting efficiency of tritium compounds (water and thymine).

Percent Hyamine	Percent efficiency		
	Days after sample preparation		
	0	1	5
	Water		
0.25	3.49	3.74	3.99
2.5	9.14	8.87	8.69
5.0	9.61	8.64	8.67
	Thymine		
0.25	3.31	3.82	3.74
2.5	8.97	9.00	8.87
5.0	10.53	10.21	10.05

Increasing amounts of an aqueous solution of H^3-thymidine were dispersed in a 3 percent Thixcin–5 percent Hyamine counting solution. Good reproducibility was observed in replicate samples. Visually, there appeared to be large differences in the types of emulsions formed when different amounts of aqueous phase were present. With 0.5 percent water present, a homogeneous solution was obtained at room temperature, but at the freezer temperature these samples were cloudy. Stable emulsions were difficult to obtain in the range of 10 to 20 percent water, but above 20 percent water a thick, stable paste was again obtained. There was almost a linear increase in observed counts with increase in radioactive solution added, up to a concentration of 5 percent, and it is probable that it is in this range that the greatest usefulness of the method resides. However, when greater than 15 percent water is present, a situation similar to an infinitely thick sample in planchet counting prevails and gives counting rates independent of amount of sample added.

At the present time, the general method used is as follows: 1 ml of the sample is dispensed into a counting vial to which is added 19 ml of a warm solution of 0.4 percent 2,5-diphenyloxazole, 0.01 percent 1,4-di-2-(5-phenyloxazolyl)-benzene, 3 percent Thixcin R, and 5 percent Hyamine 10-X in toluene. After brief manual shaking, the sample bottles are subjected to ultrasound for about 15 minutes. After a brief additional shake (to remove gas pockets), the samples are stored in the counter for 24 hours prior to counting. Development of new air pockets during this time does not appear to affect the counting rate. When a large number of identical samples were counted by this method, a standard error of less than 5 percent resulted (*10*).

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Sensitive 4π Detector for Scanning Radiochromatograms

Abstract. In an effort to obtain improved sensitivity in scanning unidimensional radiochromatograms of compounds labeled with weak beta-emitters, a detecting system was devised which simultaneously scans the upper and lower surfaces of the chromatogram. The instrument embodies substantial improvements based on the operation of a prototype.

When radiochromatograms emitting low-level or low-energy radiation are scanned, electronic amplification may be used to increase the height of recorded peaks. However, radioactive zones on a chromatogram can be located with greater reliability when the difference between background rate and rate due to a radioactive spot is as large as possible. Detectors exhibiting high sensitivity and low background can thus be used to advantage when critical conditions are encountered.

The inexpensive and simple instrument described in this report (*1*) was designed for high sensitivity and was found to be useful for scanning radio-

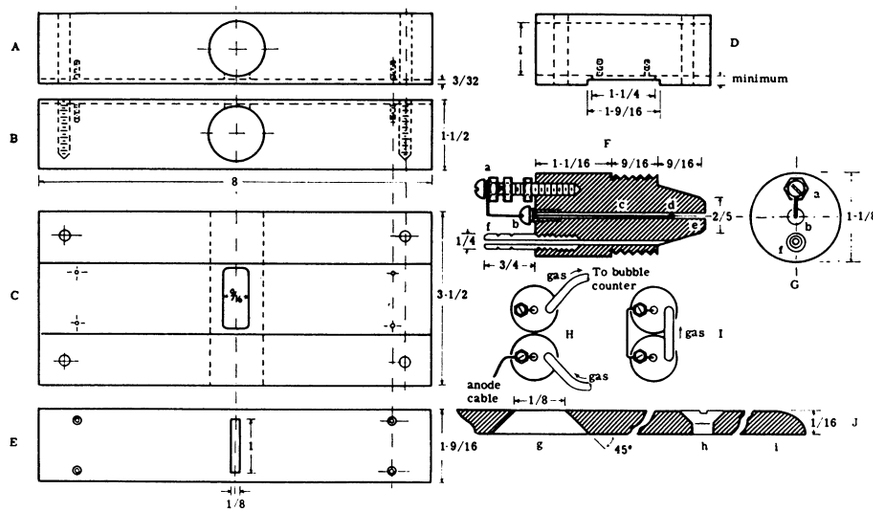

Fig. 1. Structural details of scanner. All dimensions in inches.

chromatograms of weak beta-emitters. Several months of use has shown it to be an eminently satisfactory instrument. It has a low background rate, and its sensitivity is equal to, or better than, that of the single windowless detectors with which it was compared. Since even thinner windows than that used (about 0.85 mg/cm^2) may be installed, still higher sensitivity may be achieved without sacrificing the advantages of closed tubes. However, for detection of very weak beta-emitters, such as tritium, dual windowless detectors should prove particularly useful.

Figure 1 shows structural details of the scanner. *A* and *B* are side views of the upper and lower aluminum blocks. Threads for Teflon plugs are not shown. *C* is a top view (corresponding to *B*), and *D* is a front view (corresponding to *A*). *F* and *G* are sections through the side and front, respectively, of Teflon plugs; *a* is a binding post for copper wire from the anode, *b* is a gas-tight solder joint where copper wire passes through a hollow screw into 0.055-in. hole *c* to solder joint *d* with anode wire *e*. Gas enters or leaves through the stainless-steel gas nipple *f*. The arrangement of the connections to Teflon plugs is shown in *H* and *I* for both sides of the blocks. *E* is a top view of the brass slide, and *J* is an enlarged cross section through the side, showing a beveled slit (*g*, bevel facing away from the chromatogram), a countersunk screw-hole (*h*), and the smoothly-beveled leading edge of the slide (*i*). The bolts, visible in Fig. 2, are not shown.

Additional materials required are four straight copper wires, 5 to 6 in. long, B&S gauge 18, flattened on one end; two anode wires, about 2.5 in. long, of stainless-steel surgical wire suture, 40 gauge; material for windows (such as Du Pont Mylar polyester film, 0.00025 in. thick), 1.25 by 1.55 in. in area; and cement for affixing windows (such as Du Pont Duco cement).

The procedure for assembly is as follows. The flattened portion of a copper wire is folded, the anode wire is inserted, and the folded portion is crimped and soft-soldered. The copper wire is pushed through the center hole of a Teflon plug, the soldered joint being well recessed into the hole. The seal to hollow screw *b* (*F*, Fig. 2) is made with soft solder, and the wire is connected to binding post *a*. After another copper wire has been attached to the anode, it is lowered through the detector hole into a previously inserted second plug. After tightening of the plugs, during which twisting of the anode should be avoided, the copper wire is gently pulled taut and soldered and connected as before. Applying silicone grease to the threads assures a gas-tight seal.

The window is placed on a film of cement and stretched taut; pressure is required to obtain airtight closure. Finally, the brass slide is screwed in place. The steps in the assembly of the second detector are identical.

Because the metallic blocks serve as cathodes, connection is conveniently made to one of the four bolts. Provision for insulating the terminals to prevent shock due to accidental shorting should be made by use of plastic caps or insulating tape. Helium saturated with ethanol at 0°C is satisfactory for flushing the detectors.

The useful plateau for such a system is approximately 150 volts, lying between 1275 and 1425 volts, with a slope of less than 4 percent per 100 volts, with helium-ethanol. Background, measured for 2 hours at an operating potential of 1350 volts with a commercial scaler and detectors shielded with 2-in. lead bricks, was 17.7 count/min.

The performance of the instrument is demonstrated in Fig. 2. Carbon-14 profiles of the radiochromatogram were obtained, in ascending order, with a helium-organic quenched 1.5 mg/cm^2 commercial Geiger-Müller tube, prototype detector (*2*), detector described above, and a commercial windowless flow counter.

Slit width was 1/8 in. in all except the uppermost profile, where sections 1/8 in. long were cut from the strip and counted in a sample changer. Scanning data: time constant, 40 sec.; scanning rate, 6 in./hr; full scale, 1000 count/min. In another experiment, sensitivity to iodine-131 exceeded that of a commercial windowless scanner by approximately 10 percent.

Transport of the paper strip was achieved by taping one end to the recorder chart as shown in Fig. 2. Depending upon the thickness and length of the strip, this will result in a deviation between the length of chart and the chromatogram (*2*). Radioactive markers may be used to correlate chart with radioactive areas, since the deviation is linear. For strips of moderate length

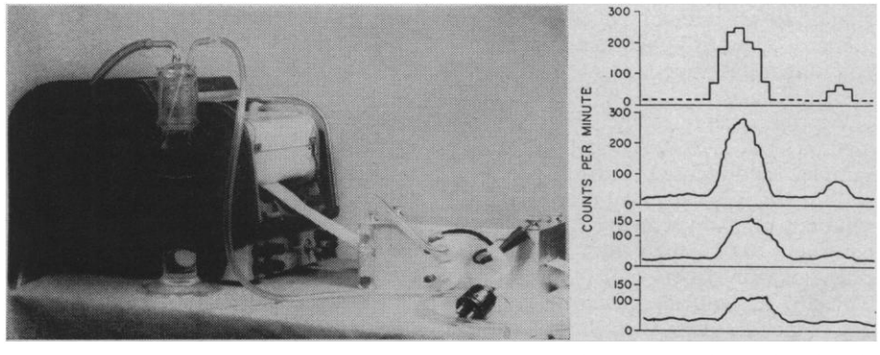

Fig. 2. (Left) Complete assembly of scanner. The lead shield and the insulation for the anode terminals are not shown. (Right) Radiochromatographic profiles; see text.

and thickness, such as 12-in. lengths of Whatman No. 1 paper, the differences are virtually negligible. Furthermore, the deviation is not cumulative, and it is no greater for a single one than for any one of a number of similar strips taped together end to end.

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12 October 1959

Luminosity Losses in Deuteranopes

In 1958 Heath (*1*) published some luminosity curves for normal and dichromatic subjects. The luminosity values are given as the reciprocals of relative energies of different wavelength bands required to provide a critical flicker frequency of 20, 25, 30, or 40 flashes per second.

Heath found the usual luminosity loss for protanopic subjects as contrasted with normal subjects. However, his findings for deuteranopes were unusual. Instead of a luminosity loss in the blue and green regions of the spectrum, he found a luminosity gain for deuteranopes in the spectral region from about 520 mμ into the red beyond 700 mμ.

The results obtained on deuteranopes by Heath with the critical flicker measurements are not in accord with some recent foveal luminosity measures based on foveal threshold determinations (*2*) and on the determination of luminosities for different levels of visual acuity (*3*) [see also the data obtained by Boynton *et al.* (*4*) on single dichromats by a rapid chromatic adaption method].

The fact that Heath's results may not be in accord with those obtained by the other methods may be due to a number of factors, including the possibilities (i) that the method involving equality of flicker may provide conditions that give rise to special wavelength effects, and (ii) that Heath's criteria for the selection of deuteranopes were different from those used by the other investigators. We have found a heightened sensitivity comparable to that reported by Heath for wavelengths longer than about 500 mμ in two subjects, one protanomolous, the other deuteranomolous. Such cases merit further study, and flicker criterion data should be correlated with data obtained by other methods.

Heath's conclusions, taken at face value, seem to bolster a position upheld by Walls (*5*), among others—that is, that luminosity losses do not occur in deuteranopes. The evidence cited here indicates that deuteranopes can, and that many do, lose luminosity in the green and blue regions of the spectrum.

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   We do not say in any of our more complete accounts that her left eye is unqualifiedly deuteranopic; her hue discrimination is, in fact, atypical in the blue and green. [We did refer to her "deuteranopic" eye in two early abstracts: *Science* **120**, 780 (1954) and *J. Opt. Soc. Am.* **45**, 407 (1955).] We do, however, emphasize the fact that her dichromatic eye shows many of the characteristics of deuteranopia (including possible luminosity loss), and we have thought it useful to consider principles based on her case that might apply to this form of color blindness.

24 October 1959

The question of whether deuteranopes show losses or gains in luminosity, quite apart from the two possibilities suggested by Graham and Hsia, may lie in one's definition of "luminosity." Curves of reciprocals of foveal threshold energies—that is, cone sensitivity curves—representing the *envelope* of the individual sensitivity curves of only the most dark-adaptable of the several receptor types, cannot be regarded as "luminosity" curves in the same sense as curves of reciprocals of energies required for a given photopic effect [for example, a constant brightness, or a particular critical frequency of flicker fusion (CFF)] where interaction, summation, inhibition, and adaptive effects may markedly alter the respective contributions of each type of receptor (*1*). The "special wavelength effects" of the tremendous difference in adaptation levels between threshold and photopia are by no means yet fully known, but interpretation of threshold data in terms of luminosity losses or gains would imply that, whatever the adaptive effects, they must be independent of wavelength, so that an observer's threshold sensitivity curve would be identical in shape to his photopic luminosity curve. A mass of evidence to the contrary exists (*2*). Moreover, the threshold method requires the further assumption that the relationship between the thresholds of normal, protanope, and deuteranope subjects is the same as the relationship beween their photopic luminosities—that is, that the rate of increase in subjective brightness with increased stimulus intensity is identical for all observers as well as for all wavelengths. Figure 1 demonstrates the changing relations found among our observers at photopic levels with the CFF method, and the results of such changes if extrapolated to the "cone threshold" level—results which resemble those found by Hecht and Hsia (*3*).

With regard to the selection of sub-

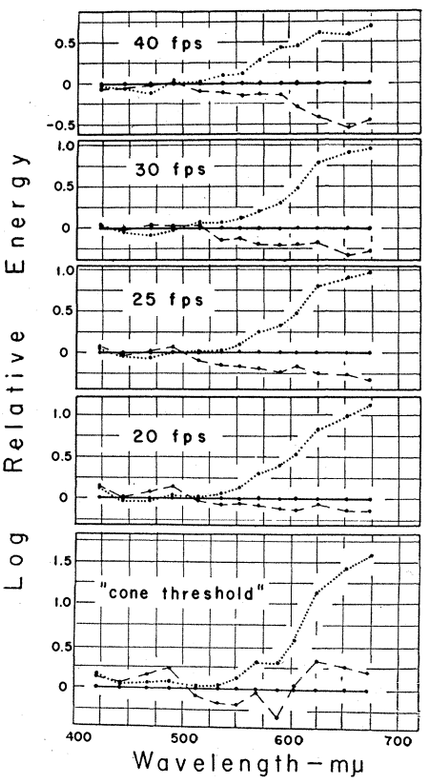

Fig. 1. Logarithms of the ratios of spectral energy requirements of protanopes (dotted lines), normal subjects (solid lines), and deuteranopes (dashed lines), to the normal requirements for four flicker-fusion frequencies. "Cone threshold" data were derived by linear extrapolation to the zero CFF level.