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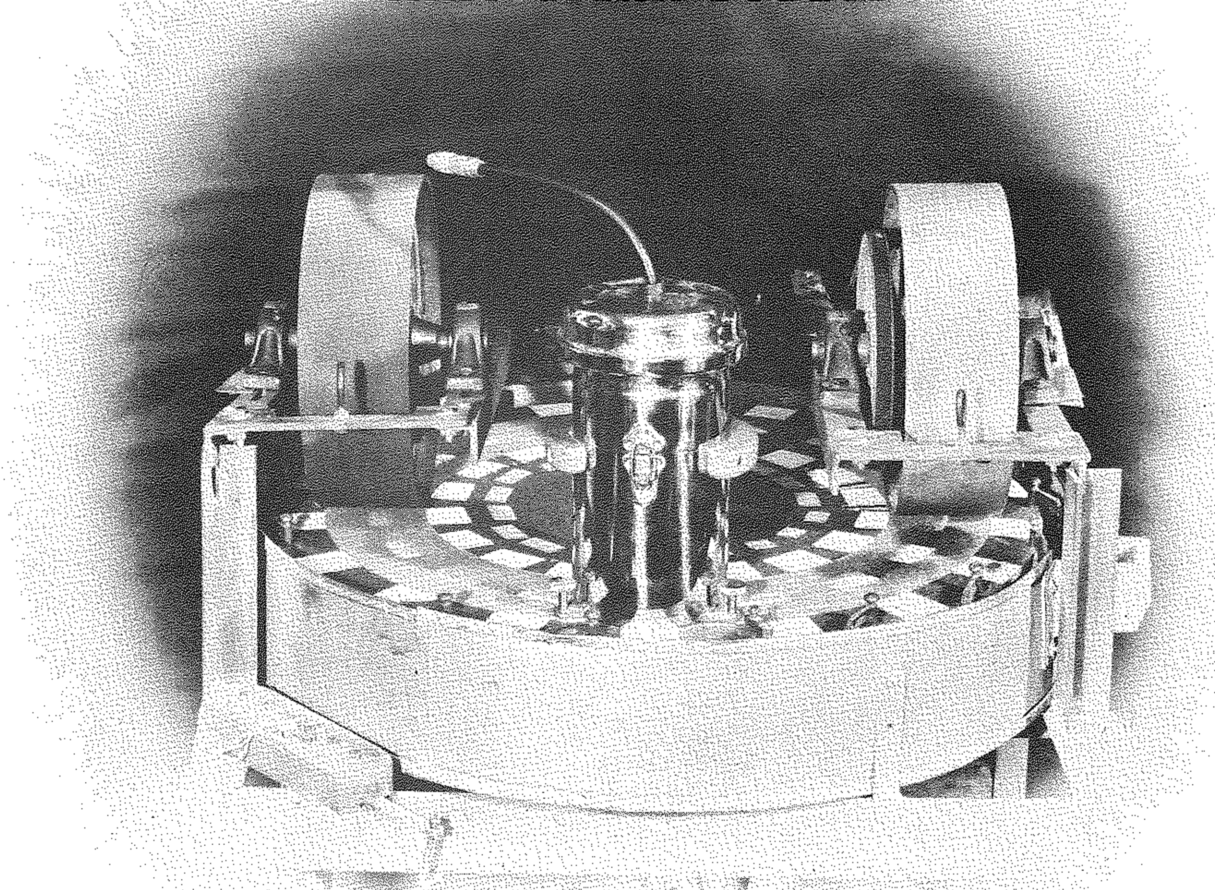

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MICHIGAN STATE HIGHWAY DEPARTMENT

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APPLICATION OF A BETA-RAY BACKSCATTER THICKNESS GAGE TO TRAFFIC PAINT WEAR STUDIES

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APPLICATION OF A BETA-RAY BACKSCATTER THICKNESS GAGE TO TRAFFIC PAINT WEAR STUDIES

by

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Testing and Research Division
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FOREWORD

This paper has been prepared for presentation at the ASTM Committee E-10 Symposium on Radioisotopes in Los Angeles, California, on September 21, 1956. The investigations reported herein represent a phase of one project in the program of research adopted by the isotopes section of the Michigan State Highway Department research laboratory located on the campus of Michigan State University, in cooperation with the University of Michigan-Phoenix Memorial Project staff in Ann Arbor.

ABSTRACT

The proper selection of pavement-marking paints by highway departments must be based on durability as well as on cost. The non-destructive measurement of film thickness must in turn comprise an important factor in the evaluation of traffic paint durability, both in the laboratory and in the field. A means of estimating paint film thickness is provided by the beta-ray backscatter gage. Accuracies to the nearest tenth of a mil are practical.

Construction of a beta-ray backscatter device, its application to the measurement of traffic stripe thicknesses, and its significance in the development of an accelerated laboratory wear test are reported. It was shown impossible to produce uniform wear across a paint stripe on a horizontally rotating turntable by a vertical wear wheel. It was found that the coefficient of thermal expansion of the dry paint film is a factor in the occurrence of chipping or failure in adhesion, that the gage is potentially applicable in the field of chemical analysis and identification, and that it may be useful for the determination of bulk densities.

APPLICATION OF A BETA-RAY BACKSCATTER THICKNESS GAGE TO TRAFFIC PAINT WEAR STUDIES

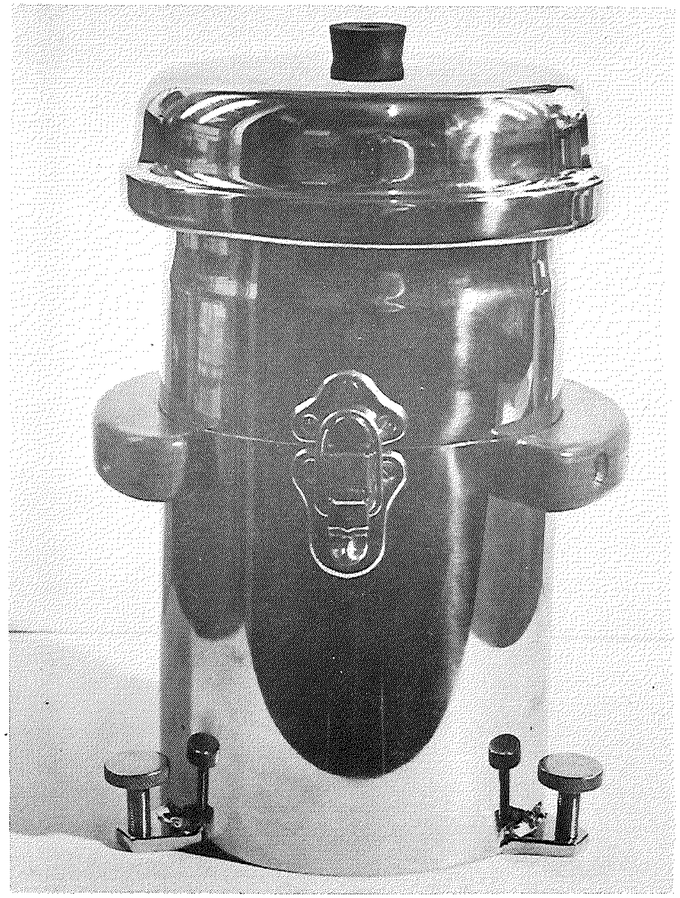
One of the many problems which confront state highway department officials today has to do with the proper selection of traffic paints for their pavement-marking programs. Vast sums are spent annually to provide that additional measure of safety and driver comfort which a well-coordinated system of traffic stripes makes possible and which the American public has come to expect. It is only natural, therefore, that highway departments should be concerned with the economic challenge of getting the most out of their pavement-marking dollars.

That this challenge is a tough one, nobody will dispute. In the absence of an acceptable accelerated laboratory wear test, most highway departments are relying on field performance installations of one sort or another to show up differences in durability among available paints. As shown in the state of Michigan (4) and elsewhere, particularly when used in conjunction with night visibility ratings and certain laboratory identification procedures, these performance tests are capable of providing important information on which a rational system of purchasing may be based. On the other hand, such tests are admittedly slow. They do not of themselves identify paints. They possess the inherent disadvantage that they offer little in the way of fundamental information as to why a given paint may occupy a certain position in the durability rating. From the research standpoint as well as from consideration of the time involved in conducting tests there still exists a need for a valid and reliable accelerated wear test which can be performed in the laboratory in a matter of hours.

One of the difficulties encountered in all attempts to measure paint wear in the laboratory has been that of evaluating the wear produced. The thickness of the paint stripe is the dependent variable, the very function which all wear tests are designed to alter; yet there has never been a satisfactory method of measuring that thickness. It was in the hope of eliminating at least this one difficulty out of the many which are associated with the problem of estimating paint wear in the laboratory, that the Michigan State Highway Department developed a beta ray backscatter gage for measuring the thicknesses of traffic paint stripes.

Although the theory of the beta ray backscatter gage has some rather complex ramifications, the design of the Michigan gage is relatively simple. Approximately a penny's worth of the radioactive isotope strontium 90, amounting to about 10 microcuries in strength, is embedded in the center of a tiny brass cylinder. A small hole leads from the isotope to one end of the cylinder and a thin plastic seal keeps the isotope in place. In use, the cylinder is suspended about one centimeter above the paint film with the hole pointing down. Directly above the cylinder is a Geiger tube. None of the beta rays from the strontium 90 can enter the Geiger tube directly, since they can escape only in a downward direction. However, a certain number are reflected back from the paint film into the Geiger tube, where they are counted. The number which are reflected back, or backscattered, in a given time is a function of the thickness of the paint stripe.

The design of the gage is shown in Figures 1 through 6. Arrangement is made for adjusting the distances from the paint surface to the source of radioactivity and from the source to the Geiger tube to produce maximum efficiency. Since



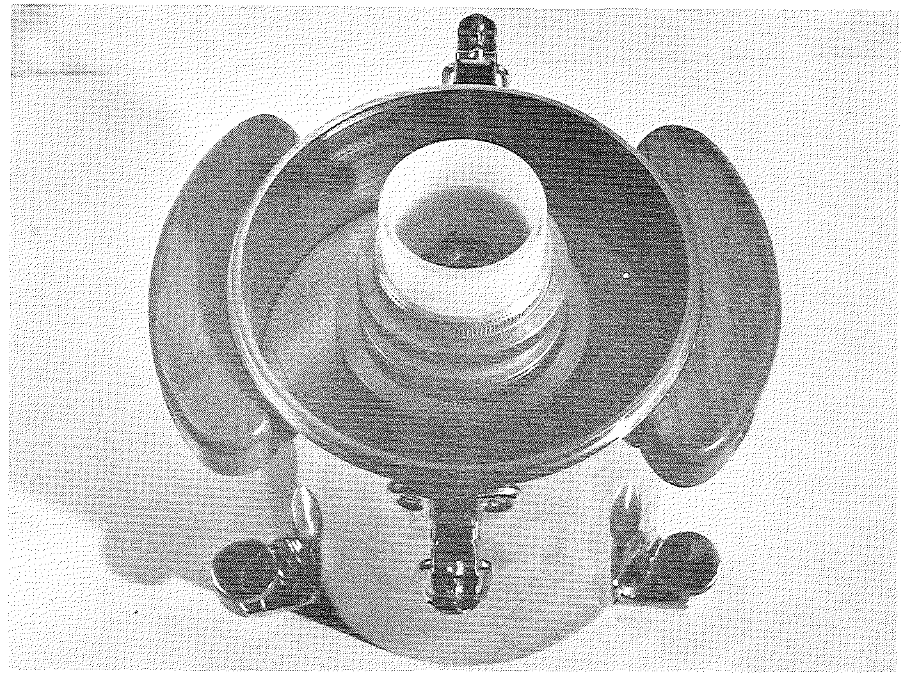


Figure 1 (left). - Beta Gage completely assembled.

Figure 2 (above). - Beta Gage showing view with covered removed.

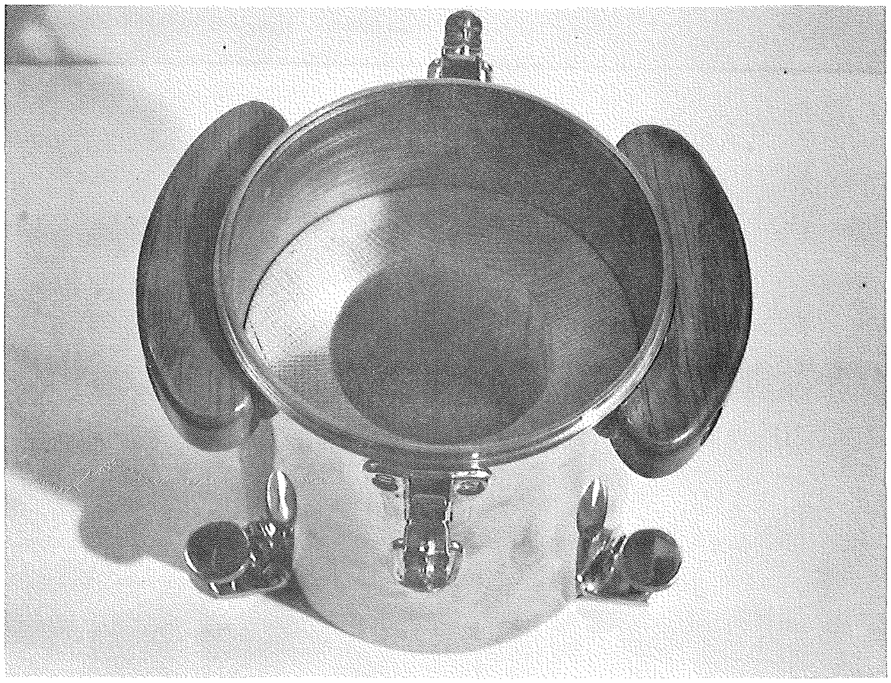


Figure 3. - Beta Gage showing view with counter tube, plastic cylinders and source holder removed.

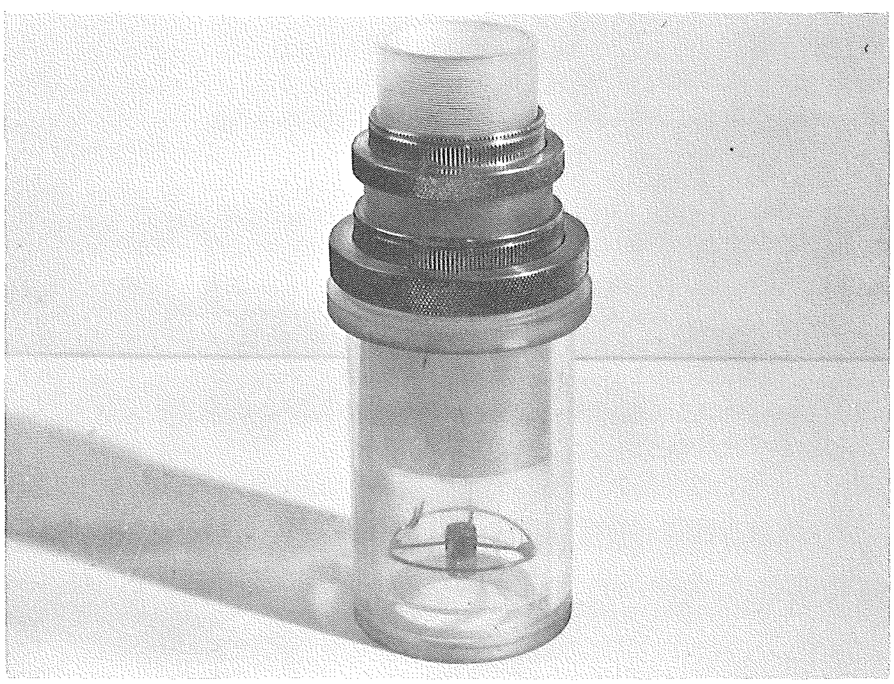


Figure 4. - Beta Gage showing source holder, plastic cylinders and brass friction rings comprising interior - assembled.

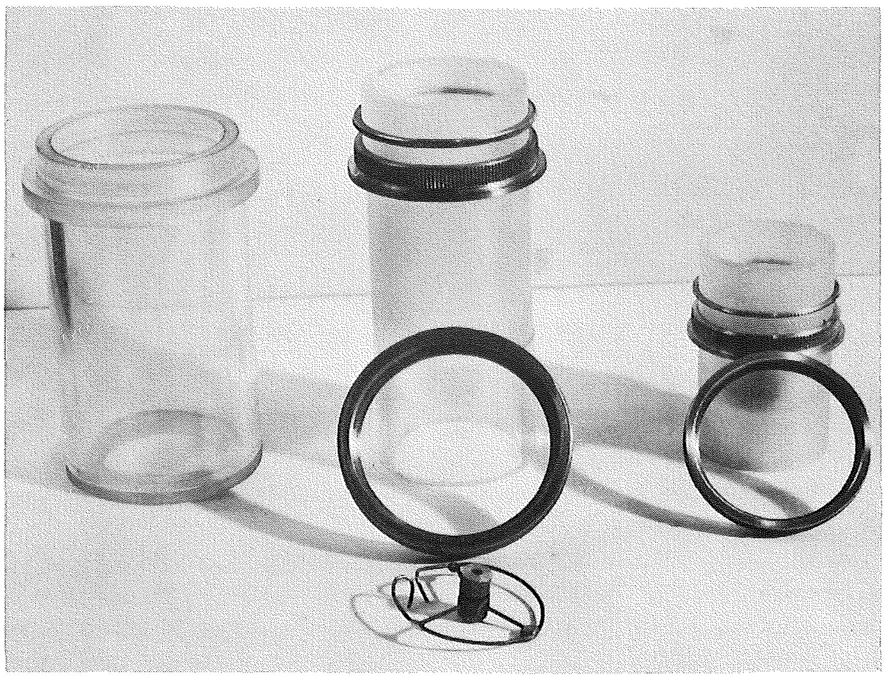


Figure 5. - Beta Gage, (same as Figure 4) unassembled.

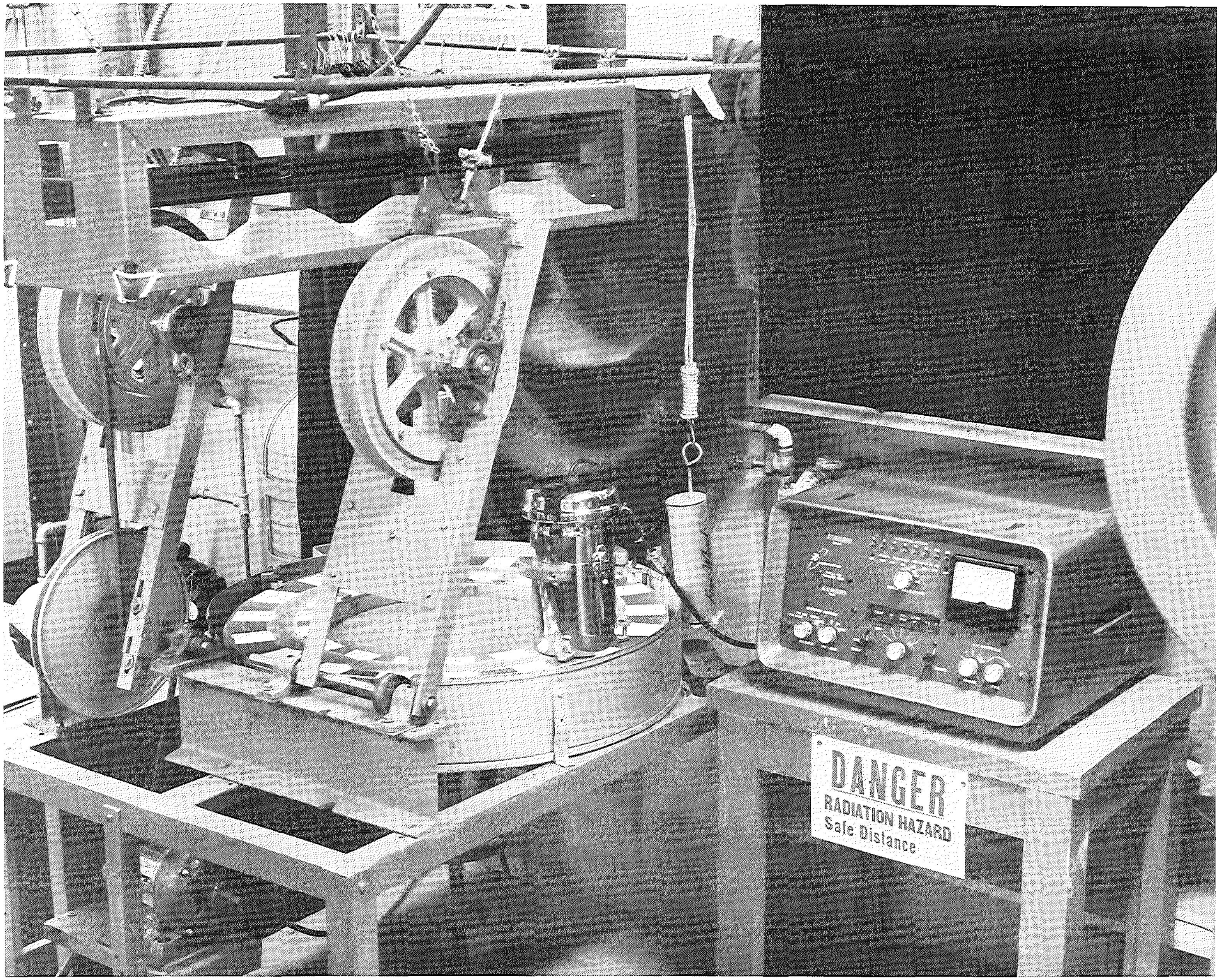


Figure 6. - Beta Gage in use for determination of paint film thickness.

these distances are critical and must be kept constant after adjustment, the holding and adjusting mechanisms are positive and rugged. Recording may be done with a conventional scaler, as in Figure 6, or by means of a portable battery-operated rate meter for field use.

Application of the equipment to laboratory wear tests of traffic paints resulted in a number of discoveries. Results of wear tests indicated that it was possible to follow the reduction in paint film thickness to the nearest tenth of a mil. It was found that the instrument could be calibrated for an unknown paint simply by taking a count at infinite thickness (defined below), since curves of counting rate vs thickness were found to be similar for all paints. This is illustrated in Figure 7. Definite proof was obtained of the difficulty of applying two or more paint stripes at identical thicknesses reliably. Proof was also obtained of the more or less obvious fact that the thicker a paint stripe is, other things being equal, the longer it will withstand abrasion, as shown in Figure 8.

Extremely interesting was the attainment of definite proof of the impossibility of producing uniform wear across a paint stripe on a horizontally rotating turntable subjected to wear by a vertical wear wheel. Results indicated that with such a machine, provided alignment was perfect, symmetrical wear could be expected, but never uniform wear. This discovery was subjected to mathematical analysis and it was shown conclusively that such a result is predictable. With perfect alignment, the point of least wear falls in the center of the wear track, with points of increasing wear to each side of that point along the radius of the turntable. It is at the point of least wear, at the middle of the wear track, that minimum slip occurs between the turntable or paint stripe and the vertical wear wheel. It

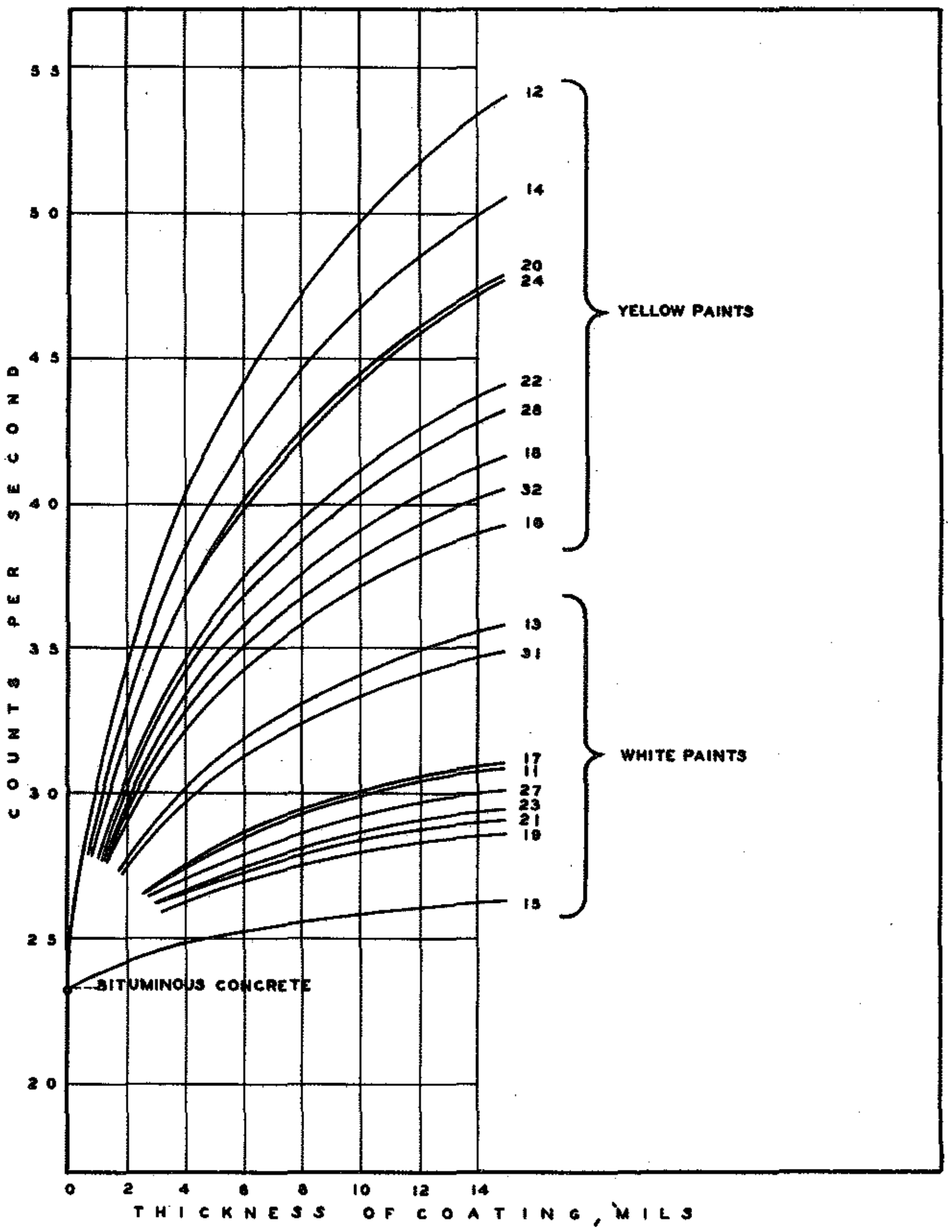


Figure 7. - Backscatter counting rate vs thickness traffic paints over bituminous concrete.

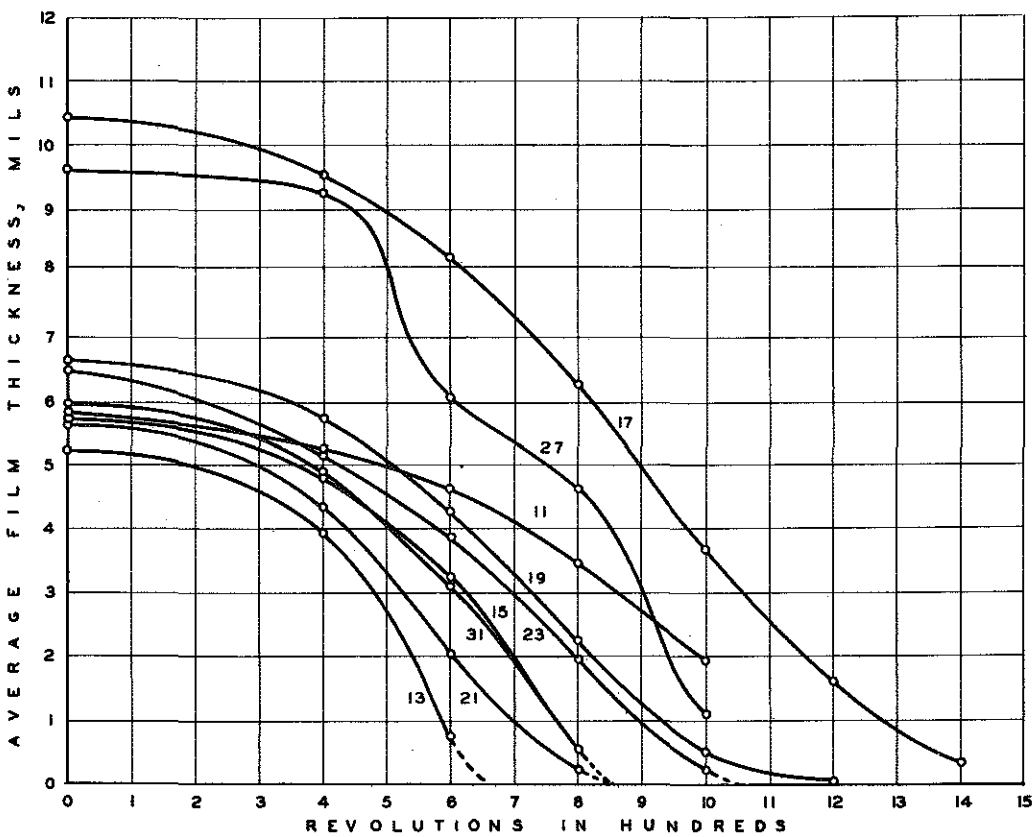


Figure 8. - Abrasion resistances of traffic paints.

can also be shown mathematically that uniform wear can be produced with paints applied to a horizontally rotating turntable provided the wear wheel is in the shape of a section of a cone whose axis prolonged will pass through the center of the turntable.

Investigation disclosed that the average thickness at infinite thickness of nine different white and nine different yellow traffic paints was 26 mils. This means that for the device employed in these measurements the thicknesses must be less than 26 mils in order to be measured. Use of a radioactive isotope producing beta rays having energies different than those of the beta rays associated with strontium 90 decay (0.537 and 2.18 mev peaks) could be expected to alter the minimum thickness at infinite thickness. This thickness is the minimum thickness above which there is no change in the counting rate of backscattered beta particles.

In addition to paint wear which has been produced as a result of abrasion, there occurs in various parts of the country another type of wear which has been variously alluded to as stripping, peeling, scaling, chipping, or failure in adhesion. This type of wear is characterized by the sudden pulling away of sizable portions of the paint film intact, exposing the bare substrate beneath. The beta ray backscatter gage can be applied to the study of this type of paint failure provided one is satisfied with an integrated average of paint remaining within the active circle of contact between the gage and the paint film. This circle is one and three-quarters inches in diameter in the Michigan gage. It can, however, be made larger.

Studies of chipping suggested that the coefficient of thermal expansion of the dry paint film, and particularly its magnitude compared with that for the substrate, might be an important factor in the occurrence of this phenomenon. Preliminary measurements using strain gages have disclosed that of six paints investigated, that which gave the best performance in the field and had the least amount of chipping also possessed a coefficient of thermal expansion which was closest to that of the concrete pavement over which it had been applied. Coefficients for the other five paints were much larger, as can be seen in Table I. Those measured were of the dried and cured paint films.

As indicated in Figure 7, it was found that the backscatter counting rates with yellow paints were considerably higher than those with white paints, although as stated, the calibration curves were similar. This phenomenon is associated with the chemical compositions of the paints and is suggestive of another application of the beta ray gage, an application which lies in the field of chemical analysis and identification. It was found, for example, that entirely different counting rates at infinite thickness were obtained for a variety of materials such as different types of woods, plastics, construction materials, metals, etc. Once the gage has been calibrated, substances can be re-identified by obtaining their counting rates at infinite thickness, or clues to their chemical composition can be obtained.

It was found also that these counting rates are to some extent functions of the bulk densities of materials, which is suggestive of the possibility that the instrument may find application in studies of densities of different materials.

TABLE I

Relation Between Field Performance of Traffic Paints

and the Linear Coefficients of Thermal Expansion

of their Dried Films

Paint No.	Durability Rating*			Linear Coefficient of Thermal Expansion of dried and cured paint film, micro-inches/inch/degree F
	No. of Days			
	15	195	369	
54 PR-162	10.0	9.3	8.3	14.0
54 PR-156	10.0	5.0	3.5	26.7
54 PR-140	10.0	5.5	3.9	30.0
54 PR-146	10.0	5.4	3.2	22.5
54 PR-159	9.0	3.0	2.4	23.5
54 PR-148	10.0	1.7	0.6	23.3
				(Concrete) 5-6

*A rating of 10 signifies 100 percent paint remaining.

In conclusion, it has been found that the beta ray backscatter gage is applicable to studies of traffic paint durability. Its use permits the operator to follow changes in paint film thickness brought about by accelerated laboratory wear tests. Certain results of tests using the gage are here reported, together with possible additional applications.

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