

MICHIGAN  
STATE HIGHWAY DEPARTMENT  
Charles M. Ziegler  
State Highway Commissioner

TRAFFIC PAINTS AND THEIR USE IN PAVEMENT MARKING

C. C. Rhodes

An article for publication in  
"Organic Finishing", February, 1956

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Highway Research Project 47 G-36

Research Laboratory  
Testing and Research Division  
Report No. 245  
December 13, 1955

## TRAFFIC PAINTS AND THEIR USE IN PAVEMENT MARKING

With traffic congestion of the nation's streets and highways growing at an alarming rate, the role of pavement marking paints in promoting safe, quick and orderly flow of traffic is one of steadily increasing importance. Unlike most other products of the coatings industry, traffic paint is not intended primarily to beautify or protect, but to serve as both a guide and warning to the motoring public. Millions of dollars are spent annually for pavement marking by the various state, county and city agencies responsible for street and highway maintenance. In 1954 the 48 states alone consumed approximately 3 million gallons of white and yellow traffic paint at an estimated cost of more than 6 million dollars. Adding city and county requirements just about doubles these amounts. According to current usage, approximately two-thirds of this paint, or 4 million gallons, would ordinarily have been reflectorized with glass beads at an average rate of 5 lb. per gal. of paint requiring a total of some 10,000 tons at a cost of more than 1-1/2 million dollars.

The above figures are for material only and give some idea of the importance of traffic paint to both producer and consumer from an economic standpoint. To the paint industry, the total annual output of these products represents a sizeable segment of commercial sales; to the purchaser it means bearing the responsibility for securing the best possible product with regard to service per dollar expended.

For the purchaser, however, responsibility extends beyond economic considerations only. Lives and public safety as well as money are at stake, and the continued presence of visible painted lines through seasons of dangerous driving has a value that cannot be calculated in dollars. In many instances, the judicious use of traffic paint has unsnarled chronic traffic jams and resulted in a marked reduction in accident rate at critical locations.

All of the above considerations amply demonstrate the importance of traffic paint to the producer, the consumer or purchaser, and the driving public. It is the purpose of this article, therefore, to state what the essential requirements for good traffic paint are, how they are tested and purchased, and what methods and equipment are used in their application. It will be interesting also to look briefly on current traffic paint research and analyze present trends in paint formulation and reflectorizing methods.

Since glass bead reflectorization has become a prime requisite in most present day uses of traffic paint, the inter-relation of beads and paint is an important factor in the evaluation of these products. It seems appropriate, therefore, to discuss this phase of traffic paint performance and describe current methods of pavement marking before giving the qualities to be sought in a good traffic paint.

## PRINCIPLES OF GLASS BEAD REFLECTORIZATION

Probably few motorists realize the extent of the improvement in night visibility of traffic stripes accomplished by glass bead reflectorization. The photograph in Figure 1 shows the difference in visibility of two lane lines, both of which are reflectorized but made with different paint and beads. Illumination for this photograph was furnished solely by the headlamps of an automobile in the center lane. The lines were both put down on the same day, but the beads in the one on the left are almost completely drowned in the paint. This line was very durable and showed up well several months later after the beads became exposed through weathering and abrasion of the paint binder, but a comparison of the two lines at the time of this photograph gives some idea of the effectiveness of good glass bead reflectorization. White paint with no beads at all is an almost invisible dull gray when viewed under these conditions.

Glass beads belong to a general class of optical mirrors known as "reflex reflectors". This class of reflectors is characterized by the ability to return incident light into the immediate neighborhood of its source, regardless of the position of the source. Reflex reflectors are of two general types, employing entirely different optical principles. In the first, or lens-mirror type, reflex reflection is achieved by the symmetrical refraction and reflection of parallel light rays about the axis of the incident beam, which sends these rays back in the general direction of the source. This is the older of the two types and is sometimes called "cat's eye" because the idea for this type of reflector probably originated with the observation of the luminous intensity of the eyes of animals at night when seen by the light of a campfire. The second, or cube corner type, operates on the principle of the parallel return of reflected rays from three mutually perpendicular plane surfaces. Reflectors of the cube corner type have a wide use in traffic control, for example in the delineators which show up as a series of bright spots on both sides of the road in Figure 1. In general, however, they are not applicable to the reflectorization of traffic paints.

There are a few fundamental principles of glass bead reflectorization which should be understood and kept in mind in order to develop maximum effectiveness and night visibility of painted stripes. First, the refractive index of the glass is probably the most important single property of the bead, since it chiefly controls the distribution of the reflected light. Long range intensity is achieved through the concentration of the returned light flux in a relatively narrow cone about the axis of the incident beam. To accomplish this, the rays of the incident beam must be focused at the reflecting surface, which in this case is the bead-paint interface. It can be shown both mathematically and experimentally that the optimum refractive index for maximum intensity of reflected light is about 1.90. Values greater or less than this will bring the beam out of focus at the reflecting surface with a resultant increase in the dispersion of the returned light.

While the optical properties of the glass strongly influence the distribution of reflected light, it is the paint which largely determines the amount of light returned. The proportion of incident light reflected from the bead-paint interface is a function of the difference in refractive index of the two materials, so that with beads of ordinary low index glass ( $n = 1.50$ ), the higher the hiding power of the paint pigments, the greater the fraction of total light returned.

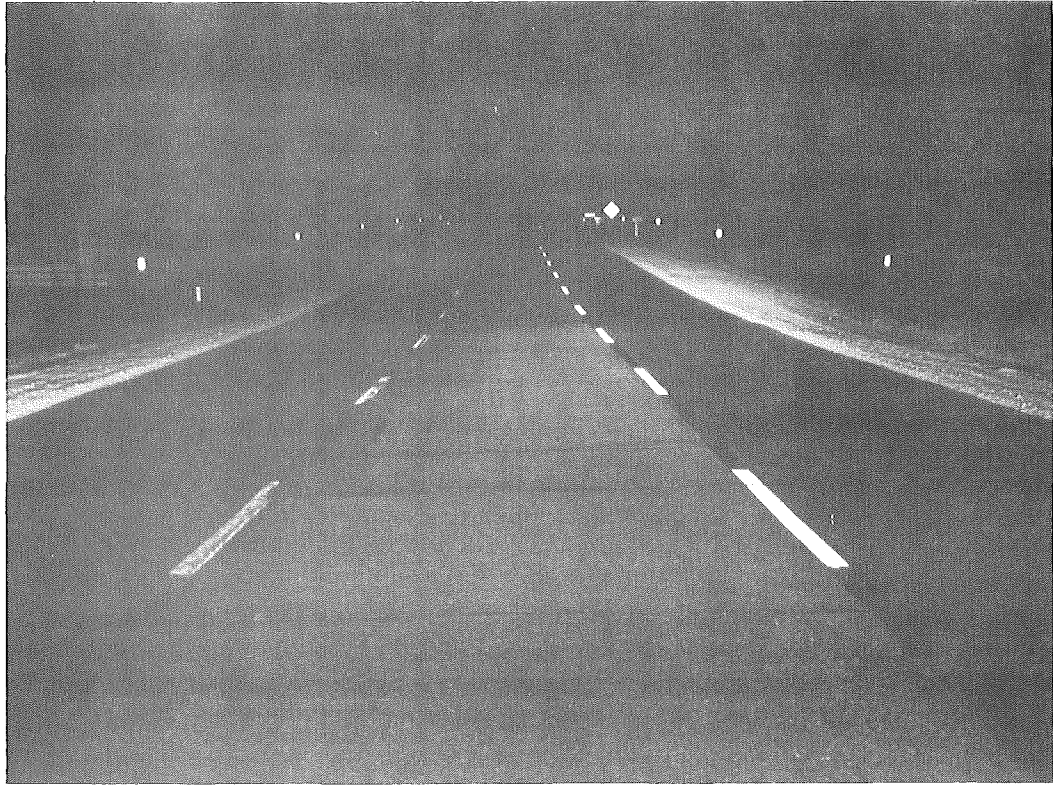


Figure 1. Bead reflectorized traffic stripes at night. Poor visibility of stripe on the left due to drowning of beads in wet paint.



Figure 2. Two-lane bituminous concrete with black-white skip centerline (right) and solid yellow no-passing line (left).

From the above considerations, it is quite evident that beads and paint are intimately related in the reflective process. With a given bead, the amount of reflected light can be influenced considerably by the characteristics of vehicle and pigments in the paint in which it is placed. The converse is also true.

Another phase of the bead-paint relationship is mutual compatibility with respect to interfacial tensions, or wetting of the bead by the paint. It is important that the paint wet the bead sufficiently to form a bond that will resist dislodgement. Too great an attraction will cause the beads to "drown" too easily; too little will result in poor bond and allow the beads to be "kicked out" of the stripe at a relatively early age. Alkyd vehicles generally exhibit excellent bead-holding qualities.

The two aspects of inter-relationship of beads and paint just discussed present a strong argument in favor of treating the reflectorized stripe as an entity rather than as a combination of independent materials. Any evaluation of beads and paint separately which does not take the above mutual effects into account is incomplete and may be misleading.

There are three methods currently in use for incorporating glass beads in the paint for reflectorization. In the first method (drop-in), the beads are dropped in the wet paint film immediately after application. In the second, the beads are premixed with the paint before putting it through the gun. Still a third method, known as overlay, employs a combination of both of the others wherein some of the beads are premixed and some dropped on. Each of these methods has its own characteristic requirements as to bead size distribution or grading as well as certain inherent advantages and disadvantages.

In general, beads are easily dispensed for drop-in application, there are no undue equipment troubles, and immediate reflection is attainable through the choice of a bead grading which provides a portion of beads large enough to insure partial exposure of the reflecting surface above the wet paint film. The chief disadvantage of this method is the possibility of poor bead distribution in and on the stripe. Also, if beads of too large maximum size are used, there is an early loss of reflection due to dislodgement of the large beads by traffic and weather.

In the premix method, uniform distribution of beads in paint is assured, but there is very little initial reflection and the stripes must be exposed on the highway long enough for traffic and weather to uncover the top surfaces of beads before they become really effective. Beads used for premixing are necessarily small, usually finer than a No. 70 sieve, in order to avoid rebound from the pavement, to prevent excessive settling in the paint, and to handle the mixture in the spraying equipment. Once down and beads exposed, this type of stripe gives uniform and long lasting reflection. A serious drawback, however, is the difficulty of maintaining spray guns in working order during application, especially when putting down black-white skip lines where the white paint valve opens and closes once every 50 ft. The fine beads indent the valve seats and score the stems, resulting in frequent interruptions to repair the gun to keep it from leaking over the black setment.

The overlay method combines the advantages of both the other methods as far as reflective efficiency is concerned. The basis premix supplies continuing uniform reflection while the overlay of beads on the premix assures immediate reflection. However, it is subject to the same application troubles as the premix method.

Bead application methods in Michigan have not been finally standardized as yet, pending results of experiments now under way to determine the relative merits of drop-in and overlay application. A 100-percent premix application is never used by the Michigan State Highway Department because of the poor initial reflection obtained by this method. Six pounds of beads per gallon of paint are used for drop-in application, while 4 lb. per gal. are mixed with the paint and an additional 2 lb. per gal. dropped on in the overlay method.

## STRIPING PRACTICE

At present, national standards for pavement marking as set forth in the Manual on Uniform Traffic Control Devices, issued by the Bureau of Public Roads, do not completely prescribe a uniform striping practice. Even though most states conform to this Manual in marking their pavements, the Manual itself permits optional practice in certain respects which, unfortunately, has resulted in a confusing non-uniformity from state to state. Probably the most noticeable variation is in the color of paint used to indicate a barrier or regulatory line not to be crossed by traffic. The Manual specifies the use of a dashed white system for lane lines and continuous or solid lines for barrier lines such as no-passing zones and centerlines on multi-lane pavements. Either white or yellow may be used for solid lines, although yellow is recommended for this purpose since it is associated with a warning or regulatory meaning in highway signs.

Details of the dashed white line are also optional in the Manual, although here again certain recommendations are made as to length of white segments and the blank spaces or black segments between. Nearly all states use a dashed line in some form and the length of segments painted varies from a minimum of 9-ft. dash with 15-ft. gap to a maximum of 70-ft. dash with 70-ft. gap. Almost half of the states have standardized on a 15-ft. dash with a 25-ft. gap.

The Joint Committee which prepared the Manual recognizes the need for a uniform practice and has set up a Subcommittee on Research to keep informed on current developments and to promote the research necessary for standardization of traffic control devices, including striping procedures.

Striping practice in Michigan conforms to both the specifications and recommendations in the Manual. The photographs of Figures 2 through 5 are representative examples of stripe systems on highways of various widths and types of surface. Figure 4 shows also the use of colored concrete (black) on an expressway to channel traffic at an access point. The lane lines are 20 lineal ft. of white to 30 ft. of black, and solid yellow is used for no-passing zones. Double center lines on multi-lane undivided pavements are solid yellow 5-1/2 in. apart with a solid black line between. The black paint used in Michigan is a tar made with a relatively hard pitch base having a softening point of 80 to 99 C. There are no unpainted gaps in dashed lines. The black paint provides a pleasing and effective contrast with both white and yellow, even on bituminous surfaces, as may be seen by referring again to Figures 2 to 5 inclusive. All lines are 4 in. wide and paint is applied at the rate of 16.5 gal. per mi. of continuous stripe, which corresponds to a wet film thickness of 15.0 mils.



Figure 3. Two-lane concrete pavement with black-white centerline. The black segment is effective here.



Figure 4. Six-lane expressway, showing black-white lane lines and the use of black pigmented concrete to channel traffic.



Figure 5. Four-lane undivided concrete pavement at night, showing yellow centerlines and black-white lane lines.



Figure 6. Front quarter view of striping equipment used by Michigan State Highway Department.



Recently, interest in line markings on pavement edges has been aroused again through a widely publicized experiment on the Merritt Parkway in Connecticut initiated by Dr. John V. N. Dorr. On one New York highway where this system was used, the accident rate was reported to have been cut 55 percent. The idea is not new, as evidenced by the fact that specifications for them were included in the 1948 edition of the Manual on Uniform Traffic Control Devices mentioned above. According to the Manual, experience up to that time indicated that edge lines might be easily mistaken for lane lines and drivers would be apt to run off the road in an attempt to keep to the right of the line. Therefore their use was not recommended. Apparently the effectiveness of edge marking depends to some extent on the color and type of shoulder adjacent to the pavement surface. In spite of earlier adverse reaction, however, this type of pavement marking appears promising and is being investigated further by extensive trials in at least 10 other states, including Michigan.

### EQUIPMENT AND APPLICATION

About one-third of the states use pavement-marking equipment designed and built in their own shops, the other two-thirds using commercially produced stripers. These machines vary considerably in weight, size, and type of paint and bead dispensing equipment. Weight for self-propelled units ranges from about 500 lb. to 22,000 lb., and width from 2 ft. 8 in. to 9 ft. 6 in. Most stripers have pressure nozzles although a few states are using the flow type.

Michigan equipment and procedures are the result of years of invention and experiment, and are sufficiently typical of the best modern practice to serve as illustrative examples in explaining painting operations. Figure 6 is a front quarter view of the striper showing the retractable guide wheel and general features of equipment arrangement. In this photograph, the service pickup truck is directly behind the striper while the operators and an equipment inspector examine the work of a new bead dispenser designed and built in their own shop. Figure 7 is a rear view of another similar unit showing the various controls (upper right) used by the operator, and the retractable dolly (lower left) which carries the paint guns and bead dispensers.

The unit can put down three stripes simultaneously and carries three paint tanks, one each for white and yellow of 60-gal. capacity, and one 120-gal. tank for black paint. The tanks for white and yellow paint are equipped with air-operated variable-speed internal agitators to preserve homogeneity, especially when a paint-bead premix is used. Paint is pumped from drums to the tanks on the machine by an air-operated pump. The unit is also equipped with an air-operated portable stirrer which is used when necessary to mix the paint in the drum before transferring to the tank. Air to operate all this equipment is furnished by a compressor of 60cfm. capacity mounted on the truck and driven by a gasoline motor.

Paint guns are of a well known commercial make modified with specially designed parts for internal atomization. The orifice is quite large - the gun is capable of delivering 2.67 gal. per min. at 60 lb. tank pressure - and can handle fairly large pieces of skin or gel without clogging. The guns are triggered by compressed air through automatic controls which can be set to retrace the black-white skips in old stripes. Around each gun is a metal shield designed and made in the equipment shops of the Highway Department for controlling width and cross section of the stripe through the formation of an air curtain created by venturi action.

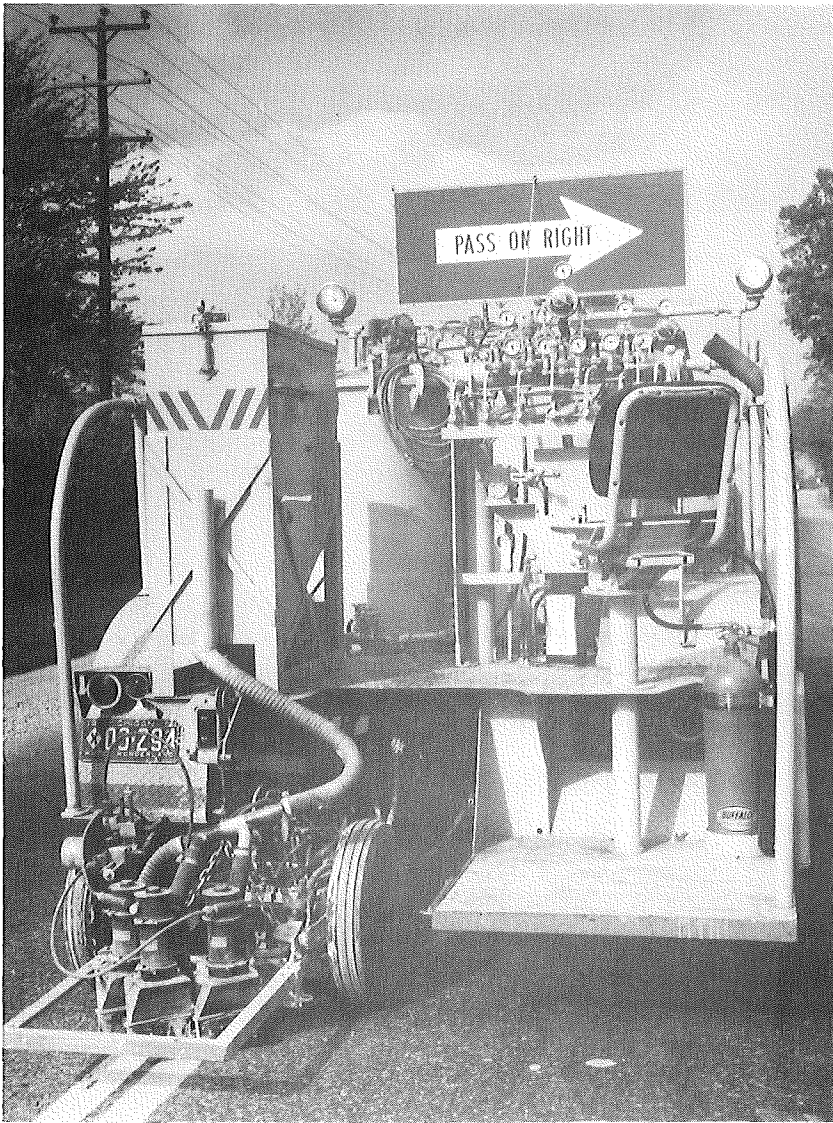


Figure 7. Rear view of striping machine showing controls (upper right) and retractable dolly (lower left).



Figure 8. General view of paint test section.

All but one of the Michigan machines have bead dispensers designed and built in Highway Department shops. Bead flow is controlled by an augur feed to an overflow in the end of the pipe, whence the beads cascade downward over a pair of adjustable combs inside a metal shield. A new type of distributor is being developed now to secure more uniform distribution without the use of combs. On one machine a California type dispenser has been installed, in which the beads drop through horizontally rotating slotted disks. Application by this dispenser is quite uniform, but there is a variable and uncontrollable lag at the cutoff which is objectionable. Both types of dispenser can be adjusted to deliver either 2 or 6 lb. of beads per gal. of paint depending on whether the overlay or drop-in method is used. They are synchronized with spray gun operation for white and yellow paints through adjustable, automatic controls.

### REQUIREMENTS FOR A GOOD TRAFFIC PAINT

Because of essential differences in function and environment, traffic paints are judged on a somewhat different set of qualities than most other organic coatings. In addition to the ordinary qualities of consistency, package stability, hiding power, durability, color, settling tendency, and drying time, there are at least three others which are specifically associated with traffic paint performance. These three qualities are night visibility, resistance to bleeding on tar and asphalt, and bead-holding properties.

Even in the list of common paint qualities first mentioned, there are several which carry considerably more weight in the appraisal of traffic paints than in the evaluation of other types. This is especially true of drying time, color, consistency and durability. The term "durability" as used in this article has a more comprehensive meaning than is ordinarily associated with it and includes adhesion and resistance to weathering, as well as resistance to abrasion and erosion.

In the following discussion, the requirements for a good traffic paint will be separated into two groups: first, those governing physical properties deemed necessary for proper handling and application; and second, those which have to do with performance of the paint in the finished stripe.

#### Handling and Application Characteristics

Regardless of the subsequent performance of a given traffic paint in service, it is obvious that certain primary requirements must be met in order to make sure that the paint can be transported, stored, and put through the spraying equipment to produce a presentable stripe of the required thickness without costly breakdowns or undue hold-up of traffic during application. Tests for settling, package stability, consistency and drying time can be depended on fairly well to control these qualities. Settling and stability requirements are about the same for traffic paint as for other paint products. However, the consistency of traffic paint has added significance because, in addition to its effect on application characteristics, it influences, to a large extent, the way in which the drop-in beads are distributed through the paint film which, in turn, has a marked effect on the durability and reflective life of the stripe. Usually a compromise must be struck between the necessity on the one hand of maintaining sufficient body to hold a clean stripe edge and, on the other, the desirability of keeping the paint thin enough to

allow the smaller beads to descend to the bottom of the wet paint film during application. While the optimum range of consistency has not been determined completely as yet, experience so far suggests lower and upper limits of about 65 and 80 KU respectively for drop-in bead application.

Drying time is an especially critical property of traffic paints. Since spray rigs usually operate at a speed of 6 to 10 or 12 miles per hour, a drying time of only 20 minutes will leave a trail of wet paint at least 2 miles long behind the machine. Excessively long drying time means either costly delays to a crew of four to six men and their equipment, or an unmanageable stream of traffic in the wake of the striping machine. When the drying time is too short, all kinds of spraying troubles develop, application is poor, and there are frequent interruptions to clean the equipment. Besides this, the type of formulation generally required to achieve very short drying time is not conducive to long wear. Considered independently of practical limitations such as the above, the shorter the drying time, the better. In no case should it be longer than 1 hour.

### Performance Characteristics

The physical qualities that are most significant in the performance of reflectorized traffic paints are night visibility, durability, color and brightness, and resistance to bleeding. While there is considerable difference of opinion as to the relative importance of these qualities, it is the consensus of Michigan highway administrators that night visibility takes precedence over all others. Durability is a complementary attribute, of course, since night visibility is impossible without paint on the pavement. It is also true that the paint should have sufficient durability to remain effective through the winter and early spring following application. It does not follow, however, that the most durable paint has the best night visibility or gives the best performance in traffic stripes. As mentioned previously, night visibility of reflectorized traffic paint is produced by the joint action of beads and paint, and the paint factors that make for night visibility are not necessarily related to those required for durability.

Color and brightness are important too since yellow traffic paint must conform to a federal standard shade which has a national significance associated with warning in the control of traffic. The color of white paint is not as important, although a brilliant white color improves both daytime appearance and night visibility. The associated quality of brightness also enhances general appearance and attracts attention. Brightness, or luminous directional reflectivity relative to magnesium oxide, can be determined photometrically by the use of either of two ASTM methods, D 307 or D 771.

Resistance to bleeding is another significant performance quality of traffic paint. A large proportion of traffic paint goes on bituminous surfaces and, even on concrete, the lane line is usually placed directly over a longitudinal joint subject to periodic sealing with bituminous materials. This means that traffic paints should resist the bleeding through of both tar and asphalt substrates which result in unsightly appearance and loss of effectiveness. Reflectorized paints are especially sensitive to bleeding, because the bitumen from the substrate seems to migrate to the underside of the glass beads, thus cutting off re-

flectorization and darkening the general appearance of the paint before actually appearing on the surface. Resistance to bleeding can be determined by ASTM methods D 869-52T and D 868-48. A minimum index of 4 is usually required when the paint is tested by these methods.

## METHODS OF PROCUREMENT

In general, there are two current philosophies upon which the procurement of traffic paint is based. One is the so-called formula method, in which the product is completely specified as to composition and certain physical properties evaluated in the laboratory. Some specifications of this type also prescribed all essential processes in the production of the paint. The other, known as the performance method, is based on specifications requiring a field performance test to determine relative quality of competitive products. In this method there are usually no composition requirements although certain supplementary provisions may be specified to insure proper handling and application characteristics. Sometimes a combination of the two methods is used.

Many users of traffic paint have found that a strictly formula type of specification does not assure a uniformly satisfactory product. It is a common experience that paints made up from the same formula by different producers do not always give the same performance. Also, progress to better products must depend on continuing field performance tests to appraise new formulations or modifications of existing ones. Responsibility for the specification formula rests on the purchaser who is usually not as well equipped as the paint industry to do the necessary development work to produce a superior product.

The performance type of specification has definite advantages over the formula type, but heretofore has been vulnerable in several respects. Two important advantages are that the paint is tested in the same environment and under the same conditions as in actual service, and the development of better formulations is stimulated by skilled competition unhampered by composition requirements. On the other hand, two serious weaknesses have been lack of precise control of film thickness in test stripes and lack of infallible means to make sure that the paint finally purchased was the same as the paint originally tested. Because of these two weaknesses, many agencies have hesitated to adopt performance specifications and tests as a basis for traffic paint procurement.

Recently, equipment and methods for performance tests have been developed in Michigan<sup>1</sup> which have overcome these weaknesses and added refinements of evaluation and purchasing procedures to make the performance method a strong and effective implement of procurement. Rate of paint application in test stripes guaranteed to within  $\pm 5$  percent of the manufacturer's recommendation is made possible by the use of a totally new machine designed and

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<sup>1</sup>C. C. Rhodes, "Procuring Traffic Paint on the Basis of Performance Tests", 35th Annual Meeting of the Highway Research Board, Jan. 17-20, 1956, Washington, D. C.

built for the purpose. Methods of evaluation have been devised which take into account performance at all stages of the test rather than just the terminal condition of the test stripes. And last, but most important, absorption spectroscopy is used to identify the purchased paint with the sample originally furnished for performance tests.

Four test sections are laid out, two on concrete and two on bituminous surfaces. Three stripes of each paint are applied in each test section. The paints are identified only by code number and the locations of the various paints are rotated in the four test sections to compensate for application variables. A general view of operations in one of these sections is shown in Figure 8. Detailed observations are made during the application of the paints, including air temperature and relative humidity, atomization pressures, wet film thickness, drying time, stripe width and Hunter night visibility readings. Pictures of drying time observations, using the standard ASTM wheel, and night visibility measurements with a Hunter meter are shown in Figures 9 and 10 respectively.

A photograph of the machine used to put down the paints is shown in Figure 11. By using a piston geared to an axle of the carriage through a rack and pinion and acting directly against the paint in a cylinder, a metered quantity of paint is delivered to each stripe by direct displacement. In this way, the paint is applied at the prescribed rate irrespective of the travel speed of the machine or consistency of the paint. By means of a four-speed transmission and auxiliary gears, the wet film thickness can be varied from 12 to 25 mils in steps of 1 mil. Although the machine is built to apply paint at the specified rate, the actual quantity delivered is verified in each case by weight checks of test stripes on heavy wrapping paper.

In making the service evaluations, the paints are rated from 0 to 10 on three qualities, namely - night visibility, durability, and general appearance, the latter quality including color fidelity and color retention. The three qualities are not considered of equal importance and the rating for night visibility is weighted 50 percent, that for durability 40 percent, and general appearance 10 percent. The test stripes are evaluated by four independent observers as soon as possible after application and every 3 months for a year. From the five evaluations so obtained, a service factor is derived which represents the area under the curve obtained by plotting weighted rating against time. Thus, this factor gives the integrated performance of each paint from the first day of the test to the last. These service factors then constitute a basis for the selection of bidders and the quantitative evaluation of bids.

After the paint has been purchased and delivered, each batch is tested for identity with the original test sample. In addition to routine tests for pigment and solvent content, weight per gallon, consistency, color, and drying time, an absorption curve for the vehicle is run on the infrared spectrophotometer. It is not necessary to determine the composition of the vehicle; it is only necessary that the curve for the unknown, or batch sample, match that of the reference sample. This technique has filled the gap that formerly existed because of the inadequacy of conventional analytical methods of paint analysis.

Besides the field tests to determine actual performance on the pavement, various other tests to evaluate handling and application characteristics are performed both in the laboratory and on the test stripes as mentioned earlier in this article in connection with the requirements for a good traffic paint. Among these are tests for bleeding, settling, color, consistency, and drying time. All paints must meet the specified requirements for these five qualities before being considered for final evaluation in the field tests.



Figure 9. Drying time tests with standard ASTM wheel.



Figure 10. Taking night visibility readings on test stripes.

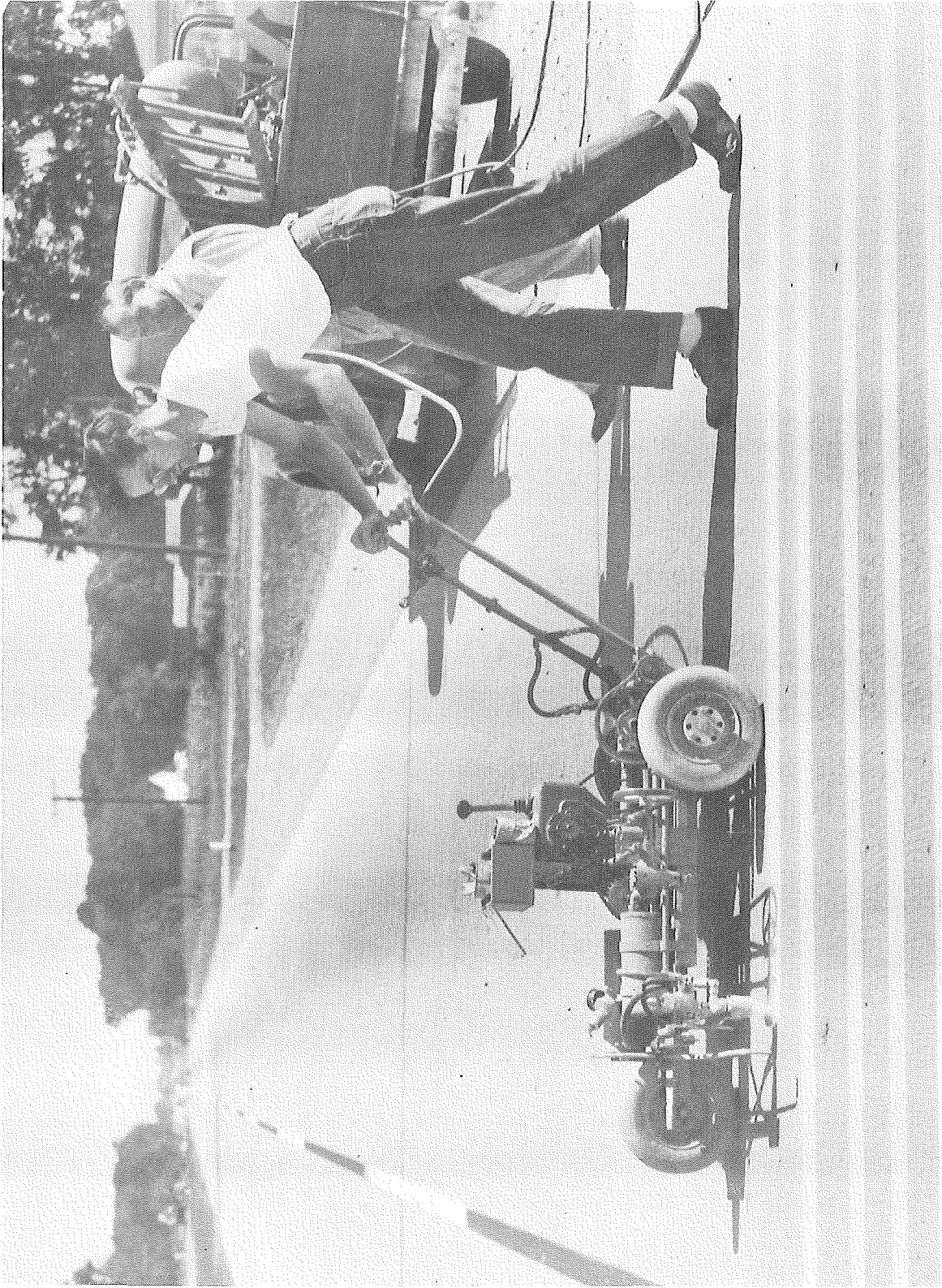


Figure 11. Experimental striping machine in operation.



## CURRENT TRAFFIC PAINT RESEARCH

More than thirty years ago the first traffic stripe was painted in Wayne County, Michigan. In 1925, when the use of traffic paint was well established and production on the increase, the need for research in this specialized branch was recognized and beginning to claim the attention of paint chemists and technologists. Since that time an immense amount of work has been directed toward the improvement of traffic paint and development of significant tests for quality. This research has been carried on by all segments of the traffic paint industry, both producer and consumer. Prominent among these are the National Bureau of Standards, American Society for Testing Materials, American Association of State Highway Officials, U.S. Bureau of Public Roads, the various states through the correlation and encouragement of the Highway Research Board of the National Research Council, and last, but by no means least, the producers of paint and paint-making materials. The work of all of these agencies and the research of private industry is becoming more and more inter-related through common representation on the various committees of national organizations such as the ASTM, AASHO, and Highway Research Board.

Although great strides have been made in the development of better products, there are still many problems to be solved and questions to be answered. Glass bead reflectorization has posed some additional problems also. Better products should be developed and, at the same time, better test methods and equipment should be devised whereby quality can be evaluated more precisely.

The American Association of State Highway Officials has been active in carrying on research needed to relate composition with field performance. The Subcommittee on Paint of the Committee on Materials has just concluded a series of cooperative tests in which seven states participated. In this program both white and yellow unbeaded paints of known composition were subjected to performance tests by the seven cooperators in areas ranging from Pennsylvania to California. The tests yielded a great deal of useful information but interpretation of the results was made difficult by the lack of uniformity in test methods and inadequate equipment for applying test stripes of controlled film thickness. Further cooperative tests are proposed which will include beaded paints and which will be more closely controlled as to test conditions and methods of evaluation.

Individual states are carrying on research both in formulation and test methods. Committee D-2 on Paints and Marking Materials of the Highway Research Board has been instrumental in bringing out and making available the results of much of this research through symposia and papers at the Annual Meeting of the Board. There is a wide variety in these reports and papers, with subjects ranging from fundamental studies of glass bead optics to methods and equipment used in statewide striping operations. The Committee also performs a valuable service through its national surveys of striping practice and equipment of the various states to determine trends in materials and methods.

Besides the continuing search for better materials and test methods, there are other subjects demanding the immediate attention of investigators in this field. Among the more urgent needs are better methods of applying beaded paint and of distributing beads by the drop-in method, a quantitative evaluation of the relative merits of drop-in and overlay methods of bead

application, and a study of the economics of paint film thickness in traffic stripes. A long recognized need, still unfilled, is for an accelerated laboratory test which will definitely predict relative performance in service. Subcommittee IV on Traffic Paints of ASTM Committee D-1 has attempted to supply this need through cooperative research directed toward finding a laboratory test, the results of which could be correlated with field performance. So far, these attempts have been unsuccessful but some progress has been made and the work is still being carried on.

## PRESENT TRENDS IN PAINT FORMULATION

Ever since the need for traffic lane markings was first recognized, many different kinds of materials and methods have been tried for this purpose. Traffic lines of inlaid colored concrete, stone chips on asphalt, metal insets, reflector buttons, and plastic stripe inlaid or cemented to the pavement surface have all been tried but none has proved as satisfactory as the painted stripe. The big disadvantage of painted stripes is their relatively short life. While the first formulations were noticeably lacking in durability, a major portion of research has been devoted to correcting this fault and modern traffic paints have been developed to give a much longer service life under considerably more rigorous conditions than formerly.

The demand for greater durability is the chief factor shaping the current trend in traffic paint formulations, always with the provision, however, that other essential qualities are not sacrificed in the process. To be durable, a traffic paint must possess innate adhesiveness to the substrate, be highly resistant to water and alkali, and also highly resistant to both mechanical abrasion and erosion by weather.

A primary cause of traffic paint failure is chipping or scaling on portland cement concrete surfaces and poor adhesion to the exposed aggregate of bituminous surfaces. Moisture from damp or wet soil underneath the pavement transfuses through the layer of concrete carrying soluble salts and alkalis from the cement with it which, on evaporation of the water, crystallize at the interface or attack the paint film. Thus, more durable paints must be formulated with an eye to both materials and pigment volume ratios - resins which will be adhesive and water and alkali resistant, and pigment volume ratios such that the dried film is vapor permeable without being soft or "short".

Epoxy resins, because of their outstanding adhesiveness and alkali resistance, are beginning to find their way into traffic paint formulations, and show promise of excellent performance and expanding use in this field. Alkyd resins and chlorinated rubber vehicles have also shown considerable merit in traffic paints and their use will undoubtedly be extended still further. Various thermosetting and thermoplastic resins have given superior performance over former standard traffic paints and a practical hot or reaction-type of spraying procedure for compounds of this type on the highway may be a development of the near future. In addition to durability, such compounds would have the important advantage of short setting time to no pick-up, since the material hardens by cooling rather than by solvent evaporation or oxidation.

There is, however, a practical limit set on the durability of traffic paints by the glass beads used in reflectorization. Differential wear of paint and glass is necessary for continued night visibility. Also, alteration or flattening of the spherical surfaces of the beads by abrasion would seriously impair night visibility. When the point is reached where the paint is more durable than the glass, either the increased durability will have to be sacrificed or a new reflectorizing material found.