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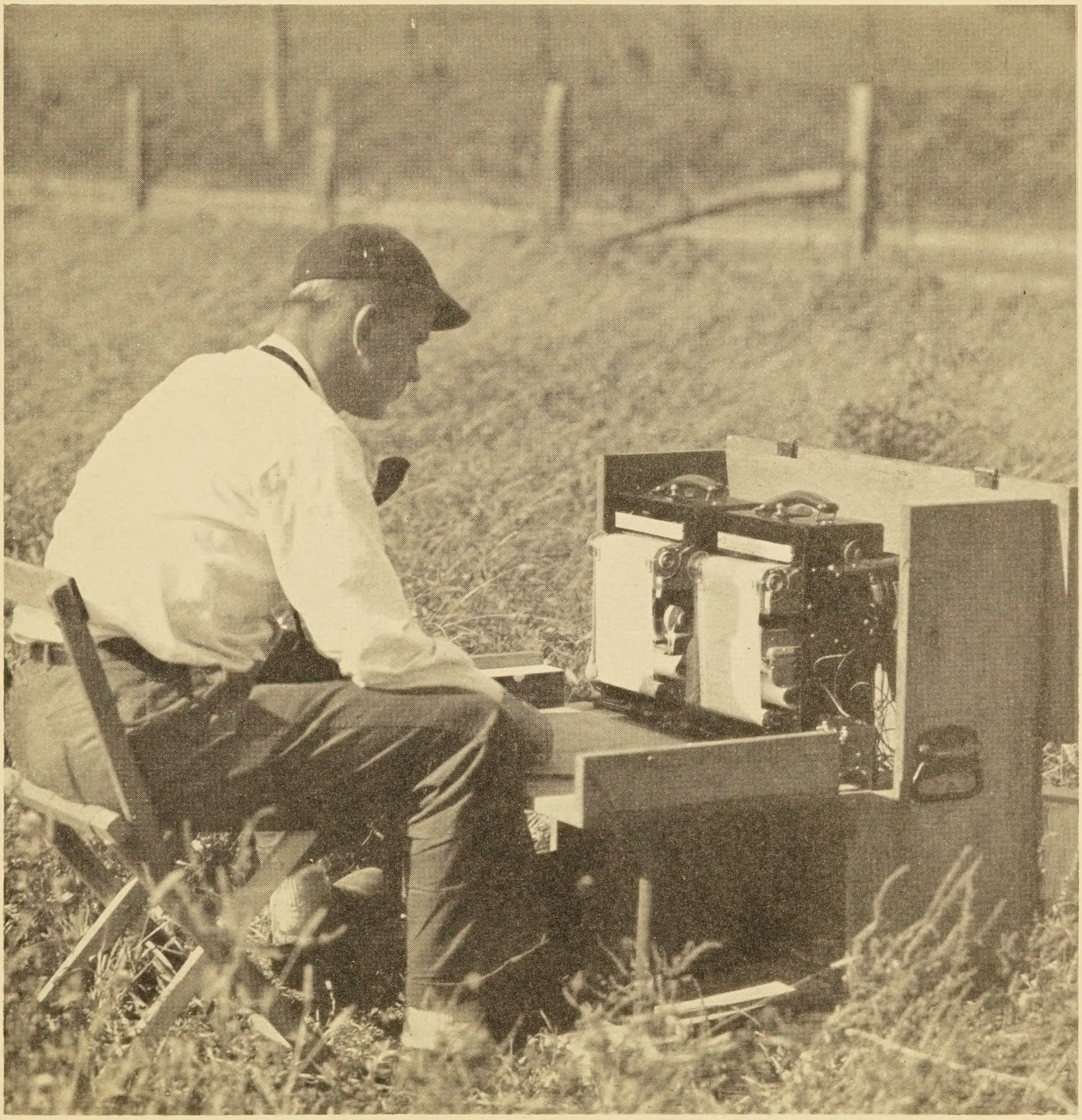

GRAPHIC RECORDERS USED IN FIELD STUDY OF VEHICLE PASSING PRACTICES

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D. M. BEACH, *Editor*

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The reports of research published in this magazine are necessarily qualified by the conditions of the tests from which the data are obtained. Whenever it is deemed possible to do so, generalizations are drawn from the results of the tests; and, unless this is done, the conclusions formulated must be considered as specifically pertinent only to described conditions.

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PROCEDURE EMPLOYED IN ANALYZING PASSING PRACTICES OF MOTOR VEHICLES

Reported by **E. H. HOLMES**, Highway Engineer-Economist, Bureau of Public Roads

THROUGHOUT the entire course of highway development in this country, there has been constant and painstaking research; in fact, it may be said with practical certainty that only by intensive research has such rapid development been possible. The efforts of the many agencies studying their individual problems have been coordinated, and the results of their work integrated, evaluated, and made available to the benefit of all engaged in such activity. But, through force of necessity, the engineers have devoted by far the greater portion of their efforts to the development of a satisfactory structure. First, it was necessary to determine the most suitable combinations of available materials to provide a structure physically capable of supporting the loads imposed by the traffic using it, over a base frequently changing in its supporting power through changes in climatic conditions.

With advances in knowledge of the use of available materials, attention was directed to the refinement of these materials and to the development of others to provide even stronger and more durable surfaces. With the development in the uses of materials came improvement in the processes of their combination, and of their application and manipulation in the field to decrease the cost of those most generally used and to make available for general use those previously impracticable.

During all this development in technique and theory, little attention was given to the alinement of the highway other than to adhere to standards which all too frequently were quite arbitrarily defined. Grades generally were limited to a certain percent and curves to a fixed degree, but too often local conditions were accepted as adequate reasons for disregarding the general limitations. From the beginning, economy of construction was a major factor in the choice of grade and alinement. Calling upon the experience of years of railroad practice, highway engineers balanced cut and fill, and introduced waste and borrow as necessary to provide an alinement cheapest to follow within the limits of the standards adopted.

Consideration of such factors as sight distance and superelevation, for example, was, and generally still is, on the basis of single vehicles. Limits were based on the distance required for a vehicle to stop from a given speed or on the superelevation required for a vehicle to negotiate given curves at given speeds. It is true that vehicles have been studied in quantity, as well as individually, but such studies have been confined to their total number and their classification as a justification for certain types of surfacing, or to their dimensions and weights for information on the required structural strength of the surfaces. Even up to the present time, there has been no concerted, intelligently directed effort to determine the effectiveness of the highway in performing one of its most important functions, that of permitting the safe and expeditious movement of traffic.

Railroad design did not contemplate the promiscuous passing of vehicles moving in the same direction. Fast-moving trains pass slower freights or passenger trains at scheduled times and at predetermined places, not at the particular time chosen as advisable or expedient by the engineer, and passing sidings can be constructed where the topography and other features indicate they are the most economical. But there is no justification for building, for example, a three-lane road, perfectly designed as to economy of construction, if its alinement is such that traffic must be restricted to two lanes on frequently recurring hillcrests or curves. In providing opportunity for passing only where the topography is especially suitable, the road does not fulfill the demands of the traffic which justified it. In short, past research has been largely directed toward the economy of construction, and there is ample evidence that in too many instances concentration on this factor has been at the expense of the economy of alinement, as measured by the effectiveness of the completed highway as a medium of economical transportation.

FIELD STUDY OF PASSING PRACTICES NECESSARY

In the future, research in materials and in the methods of their placement must be continued, but much more emphasis must be placed on this necessary analysis of the effectiveness of the highways built. In fact, it is likely that highway research of the future will be concentrated on the design of alinement, grades, and widths of particular routes, and on the relationship of entire highway systems to the needs of the public, as well as upon the design of the surfaces themselves. In this future analysis work, there must be constant improvement of existing methods of traffic analysis, and the development of entirely new methods for studying the new problems which will be presented.

Coincident with this development of methods, there will be required the design and development of instrumentation to make possible the gathering in the field of the data required by these various analysis methods. In the future, it will not be sufficient to confine the analysis of the movement of traffic to the movement of individual units of the traffic stream. A sufficient analysis must be broad enough in its scope to include all vehicles using the highway. It may be considered a problem of dynamics in which it is necessary not only to study the movement of the individual units of the traffic stream, but also to determine how the movement of these units is affected by the external forces within and without the stream itself.

Of course, in the actual analysis of this whole problem, the approach must be by small, independent, yet related investigations. Two separate studies bearing on the problem are now being conducted by the Bureau of Public Roads.[1] A study of the speed and spacing of vehicles has enabled conclusions to be drawn as to the normal habits of drivers under various traffic conditions and to develop indices to measure when, in

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[1] Preliminary reports of these studies will be published in the February 1939 issue of PUBLIC ROADS.

their normal driving over present highways, drivers become aware of traffic congestion.

In another study, analysis is being made of the performance of motortrucks. Since trucks constitute a known portion of highway traffic, results of this study can be utilized in conjunction with the findings of studies of the normal habits of all drivers. It will be possible to determine not only reasonable performance factors for these vehicles, but also the effect slow-moving vehicles have when they are found in varying percentages in the traffic stream. Still another study deals with the transverse placement of vehicles on the highway. By means of electrical instruments the position of each vehicle is automatically recorded as it passes a given point, while speed meters, now in the process of development, will simultaneously record the speeds. Only by a coordination of such studies can standards be evolved that will result in the greatest latitude in the design of the highway and of the vehicle consistent with the free movement of traffic.

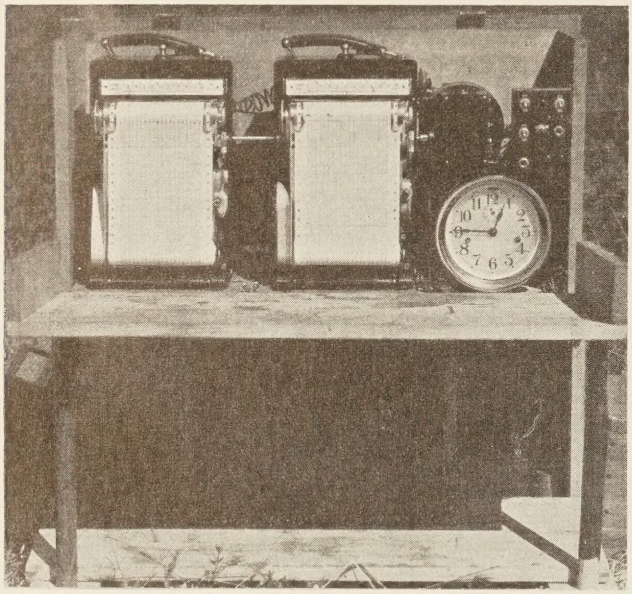


Figure 1.—One Set of Graphic Recorders, and Master Clock Used to Synchronize all Six Recorders.

Still another study in this series of closely related investigations is an analysis of passing practices. Studies of passing distances, both by analytical and experimental methods, have frequently been undertaken, and their results have been useful. Yet it is believed that none of these studies, generally confined to the mechanics of passings, has been sufficiently exhaustive in its nature to answer all the questions the highway designer should ask. It is not difficult to determine the distance required for one vehicle to pass another under various conditions of speeds of the two vehicles, but the results are of little value unless the frequency of concurrence of passings at various speeds is also known. Similarly, it is of little value to know the frequency with which such simple passings occur, if the majority of passings are accomplished not singly, but in groups. A comprehensive analysis of passing practices must, therefore, be built around the following specifications as an absolute minimum:

1. The study must be conducted in the field.
2. The study must include only the normal traffic. Test drivers or test vehicles cannot be employed in determining normal passing practices.
3. All the units of the traffic stream must be observed, and their progress recorded continuously.
4. The section over which the study is conducted must be of sufficient length to permit the completion of any normal passing maneuver.
5. Since observation of normal driving practice is required, the work must be so distributed geographically that all differences in driving habits are included.

In the development of a method satisfying these requirements, a half-mile section of roadway was decided upon as a suitable length to comply with requirement 4. Whether it was too short or whether it involved unnecessary work in being too long can only be determined by analysis of the field data. Indications are, however, that this length was ample. It then became necessary to find a means of recording the progress of all vehicles as they traversed the section. Many methods were considered and discarded without trial in the field. Others, including various photographic means, were investigated in the field, and of these the method chosen involved an adaption of a type of equipment previously employed for highway-capacity and other studies.

DETECTORS SPACED AT 50-FOOT INTERVALS ALONG HALF-MILE SECTION OF HIGHWAY

The method required that detectors be placed in each traffic lane at 50-foot intervals. Each detector was connected by a cable to an individual pen of a graphic time recorder, which recorded on a strip-chart the time at which each passing vehicle actuated successive detectors in the particular lane in which it was traveling. Since this strip-chart moves at a constant speed, to determine the speed of any vehicle over any 50-foot section required only that the distance on the chart between the marks made by successive pens be scaled, and that this measurement be converted to speed. The precision of measurement of vehicle speed thus is a function of the chart speed. In these studies, a chart speed of 45 inches per minute permitted the determination of the vehicle speed to within 2 miles per hour at 60-mile-per-hour speeds and with correspondingly greater precision at slower speeds. Over 100-foot sections, of course, the possible error is but half as great.

Observation over a half-mile section required 108 detectors, 54 for each lane of the two-lane roads, and, correspondingly, time recording apparatus with a similar number of pens. Fortunately, recording equipment ideally adapted to this purpose was available commercially, and experience with these particular instruments in previous studies by the Bureau indicated that they would dependably and accurately record all the movements required. The recording apparatus, as it was assembled in this study, consisted of a number of 20-pen time recorders, normally driven by clockwork but which could be coupled together in pairs to form 40-pen units, the entire units being driven by external electric motors to provide the fast chart feed required for the work. A complete recording unit is shown in figure 1.

The entire half-mile of highway was divided into three independent sections. Within each section, the detectors were connected to a single 40-pen recording unit, thus making it desirable that the recording units be located at three separate points. While the two charts in a single unit were constantly synchronized by the mechanical coupling between the two recorders, it was necessary to synchronize the three units by means of a single master clock in series with a pen in each of the six recorders. This clock automatically closed a circuit and actuated the six pens at 10-second intervals, while the time of day was recorded in code, by means of a telegraph key in the same circuit, at intervals of 2 or 3 minutes.

Figure 2.—Detector Tube Being Installed. The Tube is Centered and the Ends Fastened by Spikes.

The most difficult feature of the instrumentation was the provision of satisfactory detectors. An exhaustive study of available detectors revealed that none could be relied upon even for counting traffic, to say nothing of satisfying the more rigid requirements of this particular study. Cheapness in original cost, inasmuch as over 100 were required, was an important item, but ease of handling, both in installation and in transit, was equally essential.

As a result of concentrated efforts in the development of such a detector, a design employing an air switch and a rubber tube was finally adopted. The air switch itself was constructed from an automobile oil pressure unit by removing the original metal diaphragm and inserting in its place a sensitive diaphragm of rubber. To this revamped air switch was connected a rubber tube about three-eighths of an inch in external diameter to be laid across the pavement. Even the selection of a suitable tube involved considerable research since durability under traffic, resiliency, and a certain wall stiffness proved to be essential factors. Finally a tube composed of 95 percent pure gum rubber, liberally treated inside with talc, was adopted. As a vehicle passed over this tube, the air displaced by the wheels actuated the diaphragm and closed a circuit leading to the time recorders. The design of the complete detecting unit is described in detail on pages 214–216.

As the detector was adapted to use in the passing studies, two air switches were attached to each tube, one at each end, and holes were punched through the walls of the tube at its midpoint. These holes effectively prevented the air impulses from passing across the midpoint and each air switch could, therefore, be actuated only by the vehicles in the traffic lane nearest the switch. Thus a single tube and two air switches served as two detectors, and permitted positive identification of the lateral position of all vehicles with respect to the lane in which they traveled. Figure 2 shows the rubber tube being centered on the road during installation.

An interesting feature of the detector was the means by which the electrical circuits were conducted from the air switches to the recorders. There were, of course, two leads from each air switch. The negative leads from the switches on the side of the road opposite the recording equipment were connected to a single wire running the length of the section and serving as a common return. The positive lead from each of these switches was returned by a wire installed inside the tube to the side of the road near the recording equipment, and was there incorporated in the cable leading to the time recorders. The entire unit, including the tube and the two air switches enclosed in ordinary tin cans for protection from the weather, cost less than $4, and could be wound into a small coil when not in use. When installed at 50-foot intervals on a concrete road the tubes resembled expansion joints, and were barely visible on bituminous surfaces.

POSITION AND SPEED OF EACH VEHICLE RECORDED

Finally, to connect the road switches to the time recorders, some 50,000 feet of wire was made up into six cables, one cable to run in each direction from each recording unit. To the detectors at the ends of the section ran three wires, two for the positive leads and a common return for the negative lead to the switch on the near side of the road. While the common return was tapped at each detector, two wires for the positive leads were added to the cable at 50-foot intervals until it consisted of 19 wires for the road switch circuits as it reached the recording equipment. The recording units were connected by four more wires that were incorporated in the cable. Two of these wires were for the circuits for the synchronizing clock, and two were for the telephones used in communication between the three units. The common returns on the two sides of the road were connected by a wire laid across the pavement. The single return wire mentioned previously, with the leads accurately spaced at 50-foot intervals, was normally laid first, pulled taut and spiked at both ends. By using these leads in spacing the detectors, it was not necessary to measure the sections before or during installation.

The installation of the equipment is the most laborious feature of the field work, a minimum of 4 hours being required for six men to install all the equipment and prepare the recording units for operation. Once the installation is complete, the operation of the apparatus is a simple matter. With an attendant at each recording unit, all six recorders are started simultaneously. The charts, supplied in 100-foot rolls, last about 25 minutes at the chart speed utilized in this study. After one set of charts is exhausted, new ones are inserted in all the recorders and again the units are started simultaneously, the change-over normally requiring about 3 minutes.

During the time the charts are running through the recorders, the attendants record, by means of a telegraph key in circuit with a special pen, the passage of trucks or busses. By thus classifying passing vehicles, it will be possible to determine whether the type of vehicle is in itself a factor in passing practice.

During the preliminary work conducted during the fall months of 1938, it was customary to install the equipment on Saturday morning, and to operate it that afternoon and most of the daylight hours on Sunday. The equipment, with the exception of the detectors, was left in place over Saturday night. By conducting the studies in this way, at four different locations in the vicinity of Washington, D. C., one of which is shown in figure 3, information has been accumulated on approximately 2,000 passings. These data are now being analyzed in the office. It is expected that analysis of a major part of the field data already

FIGURE 3.—DETECTORS IN PLACE ON A SECTION OF ROAD ON WHICH PASSING PRACTICES WERE OBSERVED.

collected will be completed before field work is resumed in the summer months of 1939.

The records of simple passings as they appear on the charts are not difficult to interpret, although passings involving several vehicles are naturally more complicated. The pens in the two recorders of each unit were so connected with the road switches that, as a vehicle travels in its own lane through the section, its progress is recorded on successive pens on one machine. As a vehicle traverses the section in the opposite direction in its own lane, it actuates successive pens in the other of the two recorders. If, however, a vehicle moves in the left lane, it actuates the pens in the recorder connected to the switches in that lane, but in the reverse order, while if it straddles the center line it actuates similarly numbered pens in the two recorders simultaneously.

Thus in a simple passing the two vehicles engaged in the maneuver are first recorded on the chart for the right lane. As the second vehicle draws left to begin passing, its progress is charted on both recorders while it straddles the center line. Soon it moves completely into the left lane and its progress is noted only on the recorder for that lane, where the pens are actuated in reverse order. After having passed the first vehicle, the passing vehicle is recorded again as it straddles the center line in returning to its own lane; and finally, as it draws away from the vehicle just passed, it again is recorded only in the right lane. Meantime, the passed vehicle has been maintaining its course along the right lane, and the effect of the passing on this vehicle may readily be observed by determining whether it accelerated, decelerated, or continued at the same speed while the other vehicle passed and drew away.

STUDY DETERMINES ACTUAL DRIVING PRACTICES

Although interpretation of the field data is not difficult, its transcription and summarization is extremely laborious. Analysis of two or three passings per clerk per day is all that is possible in view of the completeness of the information obtained. The figures in table 1 were summarized from the transcribed data from two simple passings.

Although some of these data will not be required in the immediate analysis, summarizing and tabulating the material in detail is essential to permit any future analyses that may be required. It is obvious that in each simple passing there are four major variables. Three of them—the speed of the passed vehicle, the speed of the passing vehicle, and the speed of the approaching vehicle, if any,—are independent variables while the fourth, the dependent variable, is, of course, the distance required for the completion of the maneuver. In addition to these major variables, there are, particularly in multiple passings, a large number of minor variables, many of which will be significant in an analysis of the entire problem.

TABLE 1.—*Sample data for two simple vehicle passings*

Item	Passing	
	No. 1	No. 2
Speed of passed vehicle before the passing.........miles per hour..	26.2	26.2
Speed of passing vehicle before the passing.........do....	32.0	31.0
Maximum speed of passed vehicle during the passing.........do....	29.1	27.3
Maximum speed of passing vehicle during the passing.........do....	37.9	37.9
Speed maintained by passed vehicle after the passing.........do....	29.6	23.5
Speed maintained by passing vehicle after the passing.........do....	42.6	37.9
Speed difference before the passing.........do....	5.8	4.8
Maximum speed difference during the passing.........do....	8.8	10.6
Speed difference after the passing.........do....	13.0	14.4
Distance passing vehicle straddled center line in beginning passing feet..	100	50
Distance passing vehicle traveled entirely in left lane.........do....	400	200
Distance passing vehicle straddled center line in completing passing feet..	350	100
Distance passing vehicle encroached in left lane.........do....	850	350
Time passing vehicle encroached in left lane.........seconds..	15.4	7.0
Speed of approaching vehicle.........miles per hour..	(1)	34.1
Distance between passing vehicle and vehicle approaching from the other direction immediately before passing.........feet..	(1)	792
Distance approaching vehicle traveled during passing.........do....	(1)	349
Clearance between passing and approaching vehicles at completion of passing.........feet..	(1)	93

[1] None involved.

With respect to the relative importance of the various phases of the analysis, it should be apparent that the times and distances involved in individual passings are of minor importance. It is true that in the design of highways, distances required to pass under the various conditions normally encountered must be known in order to provide the required sight distances. These distances are, again, those needed in the design of the structure and add but little to our knowledge of the effectiveness of the highway in providing for the free movement of traffic.

Toward the end of interpreting the effectiveness of the highways as a medium of transportation, however, it is likely that information on the time required to pass, rather than the distance in which the passing is completed, will be of major significance, for it becomes increasingly evident that the time spacing of vehicles may follow some rather definite laws. Accordingly, a correlation between the time required to pass and the time spaces normally available in the opposing traffic lane will yield almost positive information with respect to highway capacity.

But it is of far greater importance, in the analysis of the entire problem of vehicular movement, to understand, rather than the elements of time and space involved in these individual or multiple passings, the actual behavior of the driving public. It is necessary to examine closely how passings are accomplished and in what number they may be expected, whether there is a preponderance of single passings, as mentioned before, or whether the majority of passings are accomplished by groups of vehicles passing other groups, and whether the alinement of the highway itself perhaps has a greater influence on the passing practices than do the psychology and desires of the individual drivers found in normal highway traffic. Studies that have already been completed along these and other lines have indicated that this driver psychology plays an important part in our traffic problem.

(Continued on page 221)

A SIMPLE PORTABLE AUTOMATIC TRAFFIC COUNTER

Reported by R. E. CRAIG, Junior Highway Engineer, and S. E. REYMER, Chief Scientific Aide, Bureau of Public Roads

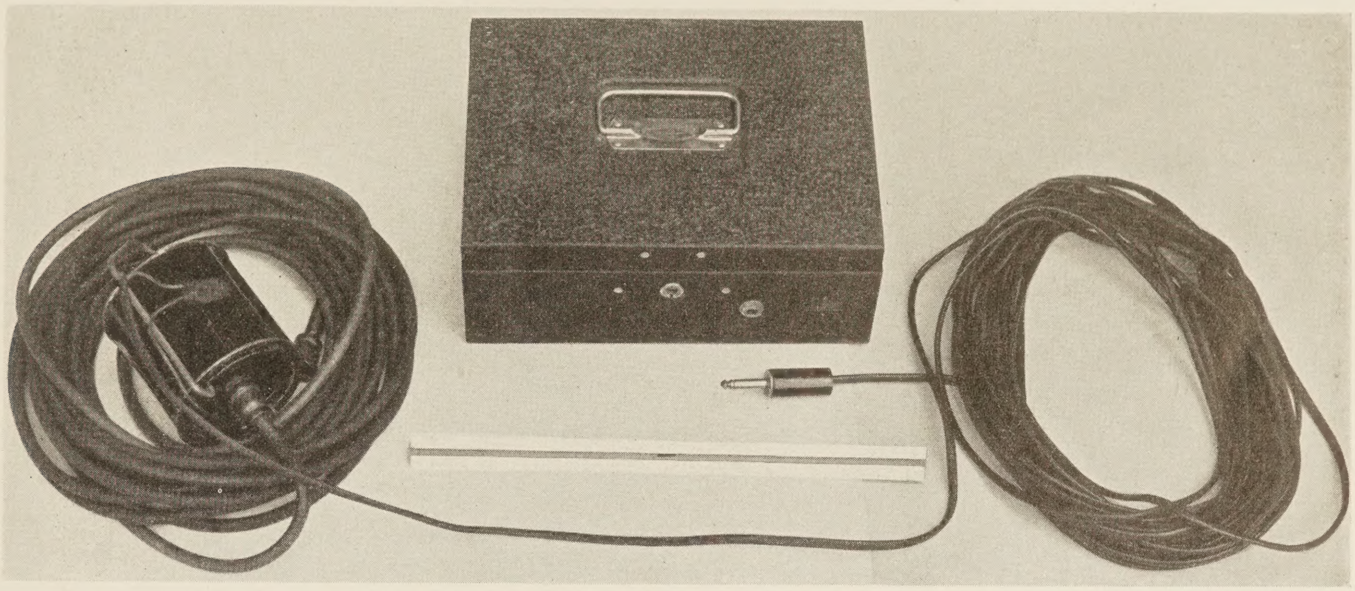


FIGURE 1.—PORTABLE AUTOMATIC TRAFFIC COUNTER, CONSISTING OF: LEFT, ROAD SWITCH AND RUBBER TUBE; MIDDLE, BOX HOUSING COUNTING UNIT AND BATTERIES; AND RIGHT, CABLE CONNECTING PNEUMATIC DETECTOR TO COUNTER.

MOST of the States now engaged in the highway planning surveys have completed the major part of the field work in connection with the traffic surveys. These traffic surveys have necessarily been extremely detailed in their nature. Not only has the geographical coverage been extensive but at many key points the traffic patterns have been intensively studied using data obtained by regularly repeated manual counts and by permanently installed automatic traffic recorders. Traffic has been classified by vehicle types on practically all roads throughout the various States and, on the more important highways, volume and classification counts have been supplemented by studies of commodity movements, of the origin and destination of both passenger and commercial traffic, of the weights and dimensions of commercial vehicles, and many other special localized studies.

This information, now in the process of tabulation and analysis will provide knowledge necessary to a determination of present traffic requirements. Since appreciable increases in traffic volumes are a future probability, it is essential that traffic counts be continued as a measure of future traffic requirements. It is believed that, with the exception of the material changes either in the volume or classification of the traffic in small areas because of extensive construction projects or significant economic changes, the general trends of traffic flow will remain rather uniform throughout a given area. Therefore, it should be possible to measure the increases or decreases of the total traffic volume by means of a relatively few counts properly distributed as to time and location.

Since in a determination of changes in the general level of traffic flow, vehicle classification and other detailed information become relatively less important, it should be possible to collect all the necessary information readily and cheaply by means of automatic traffic counters, should such machines be inexpensive and easily portable. The idea of employing portable counters, either of the recording or nonrecording type, is not new. The need for such counters has long been felt, and a number of agencies have experimented, some at the expense of considerable time and money, with the object of producing a suitable portable counter.

Simple accumulating type counter.—When equipment was first being developed by the Bureau of Public Roads for use in the study of motor-vehicle passing practices, discussed in the preceding report, no satisfactory portable traffic counters were available, principally because a suitable means of detecting the passing vehicles had not yet been developed. The success with which the pneumatic detector, used in these passing studies, actuated the recording elements in the time recorders, led the Bureau to believe that these same or similar detectors might be adapted to a properly designed counting mechanism to permit the construction of a low-priced, self-contained traffic counter. Some experimenting was necessary in order to determine the proper electrical constants to be included in a satisfactory counting circuit but, in the end, very few changes in the detector were required.

Throughout the development work, the primary requirements were simplicity, ruggedness, portability, low cost, ease of installation, and ability to make an accurate count of vehicles traveling at high speeds.

The traffic counter as now developed, shown in figure 1, consists of an electrically operated counting unit connected by a cable to a pneumatically operated detector.

The counting unit is comprised of an electromagnetic counter of the type employed as telephone call registers, an intermediate relay, the necessary batteries for operating the counter and relay, and other circuit compo-

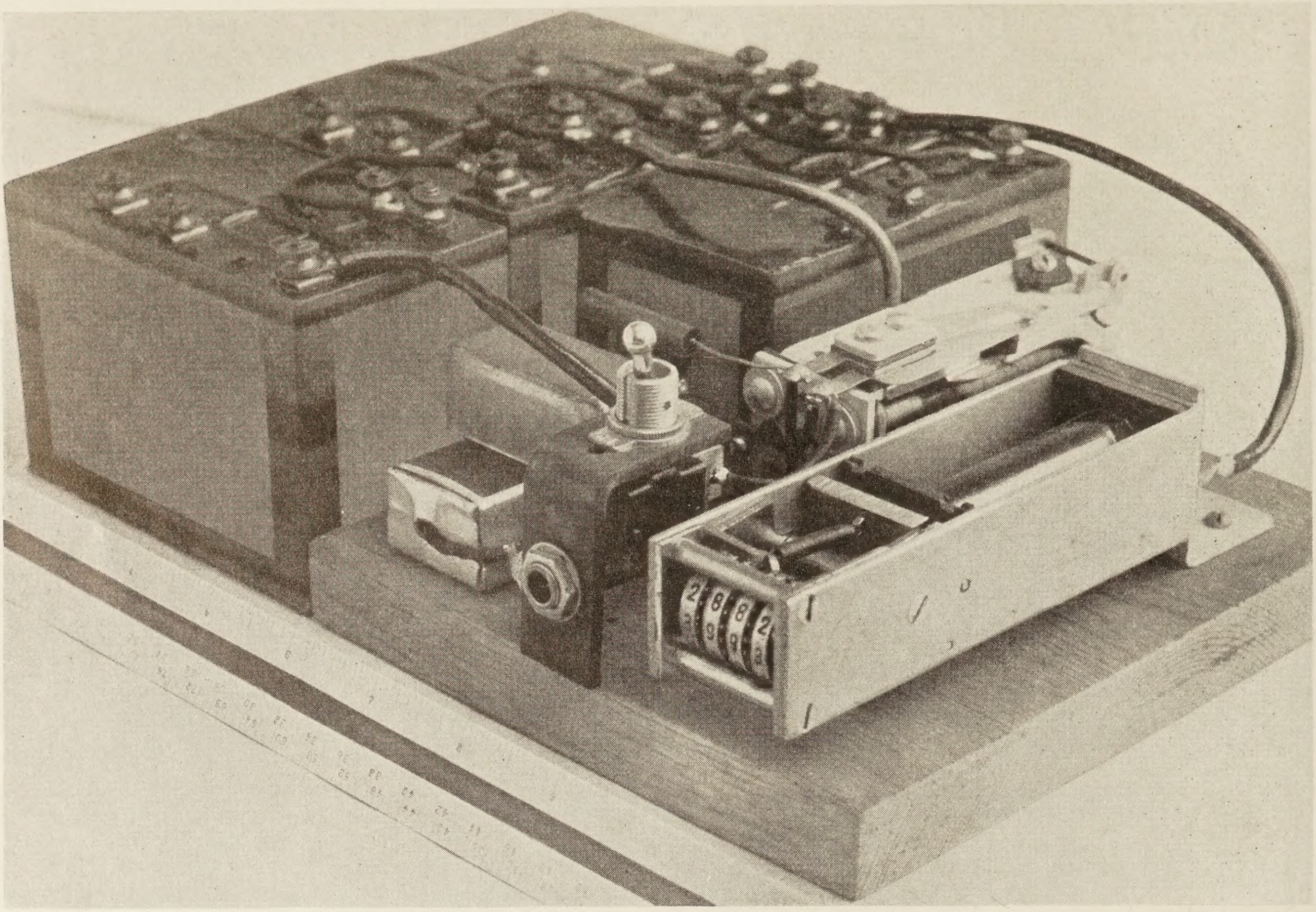


Figure 2.—The Counting Unit, Which Consists of an Electromagnetic Counter, an Intermediate Relay, Batteries for Operating the Counter and Relay, and Other Circuit Components.

nents. This apparatus is housed in a metal box provided with a hinged lid, lock, and carrying handle. The counter is mounted adjacent to a small window in the front side of the box, permitting it to be read from the exterior.

Figure 2 is an interior view of the counting unit, showing the arrangement of its component parts.

OPERATION OF ROAD SWITCH DESCRIBED IN DETAIL

Figure 3, top, shows the assembled pneumatic detector. The assembly consists of the road switch mounted on the inside of the lid of an ordinary tin container. As shown in the figure, the lid is held securely in place by a wire clamp that rides in a metallic guide fastened to the bottom of the tin container with a single brass screw that is also used to hold a spring clip. One terminal of the cable connecting the counting unit to the detector is connected to the spring clip, the other terminal of the cable is fastened, by means of a solderless connector, to a short length of insulated wire brought through a hole provided in the lid. Additional insulation is used where the wire goes through the lid. A one-fourth-inch iron washer and lock-nut are used to mount the road switch on the lid. Rubber tubing of the desired length is connected to the road switch by means of a one-eighth-inch brass nipple and reducer. The rubber tubing is cemented to the brass nipple with rubber cement.

Figure 3, bottom, shows the component parts of the road switch, which is a modified automobile oil pressure gage. In order to render the road switch sufficiently sensitive, a thin rubber diaphragm was substituted for the copper diaphragm with which it was originally equipped. The cover A is removed from the unit by turning off the crimped edge in a lathe. Only sufficient metal is cut away to permit the cover to be removed. The cover can be made to snap back onto the base D by slightly crimping opposite places on the rim of the cover A. Frame B, which carries the contacting elements, is removed from the base D by opening the three small ears. A seven-eighths-inch diameter hole is cut in the metallic diaphragm of the base D. The diaphragm C consists of a piece of thin sheet rubber sandwiched between and cemented to two paper disks. Diaphragm C is then cemented to base D with a rubber cement used for metallic surfaces. The one-eighth-inch brass reducer and nipple are marked E and F, respectively. The contacting elements on frame B were originally flexibly mounted with respect to their actuating elements. It was found necessary to secure them rigidly to the actuating elements as shown in figure 4 in order to eliminate vibration and consequent erroneous counts.

A wiring diagram of the traffic counter is shown in figure 5, the operation being as follows: With plug P inserted in the jack J, and battery switch SW in the "On" position, vehicles passing over the pneumatic detector cause contacts K_2 to close momentarily. Relay L_1 is then operated by the battery B closing contacts K_1 which in turn operate the counter L_2 from a higher voltage tap on battery B. Upon the closure of contacts K_2, the condenser C_1 is charged substantially

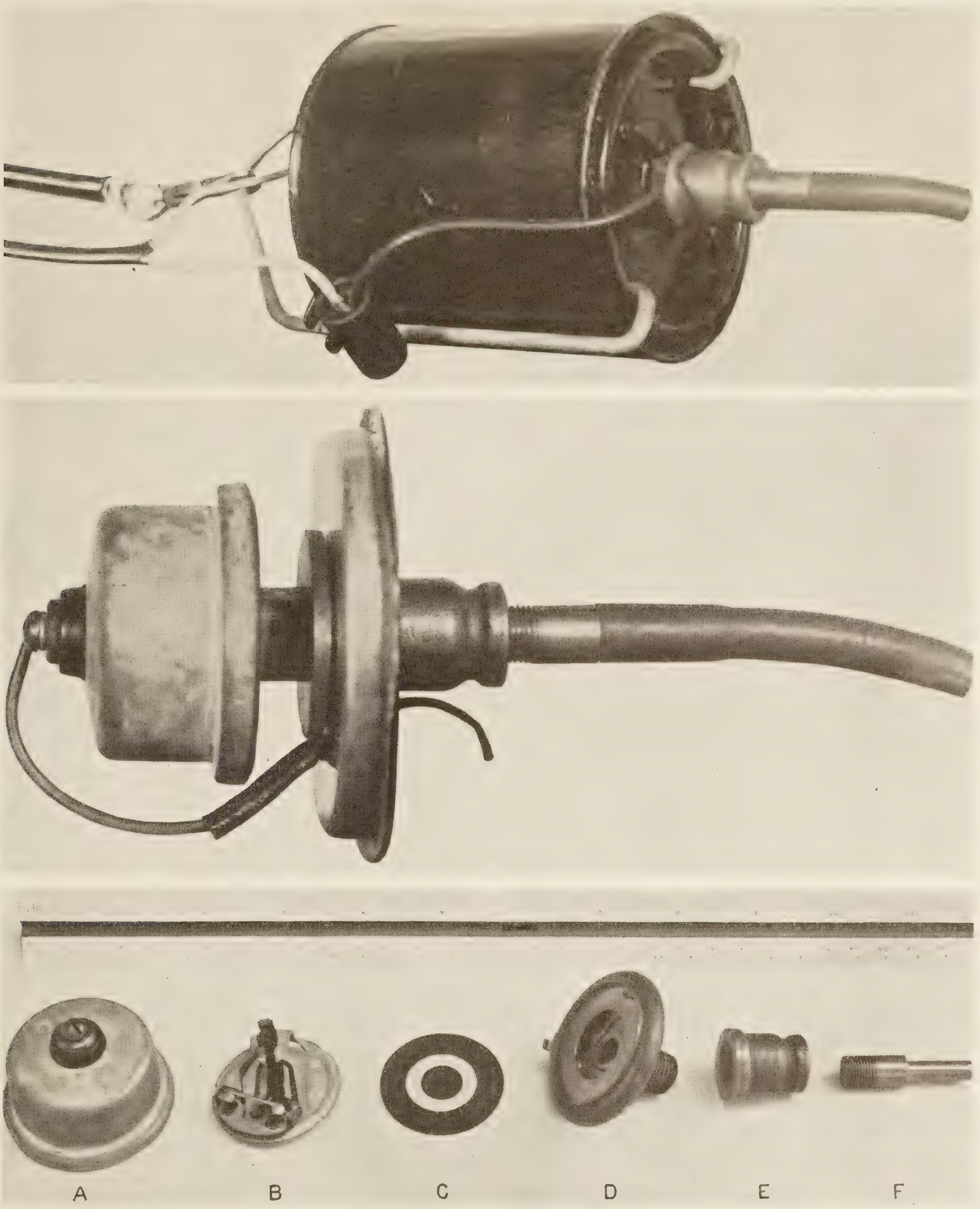


FIGURE 3.—TOP, THE ASSEMBLED ROAD SWITCH. CENTER, ROAD SWITCH WITH CAN AND FASTENINGS REMOVED. BOTTOM, THE COMPONENT PARTS OF THE ROAD SWITCH.

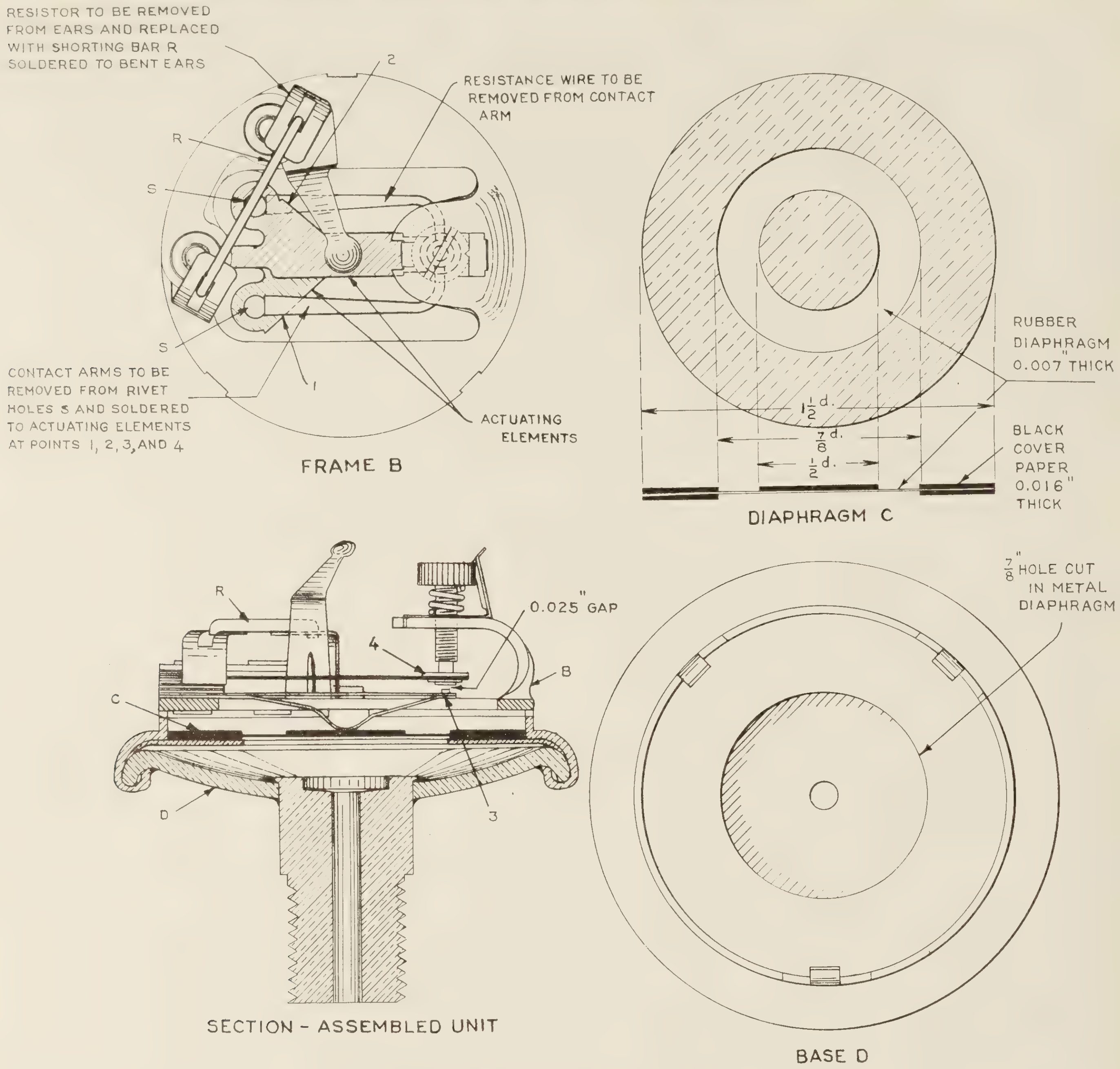
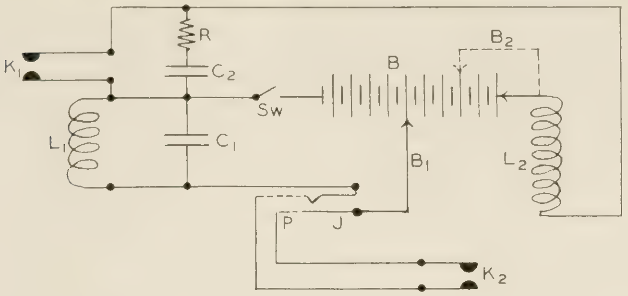


Figure 4.—Details of the Road Switch.

to battery potential, and its discharge through the coil of relay L_1 upon the opening of contacts K_2 serves to increase the holding time of contacts K_1 as well as to insure operation of relay L_1 in the event of the very brief closures of contacts K_2 which result from vehicles traveling at very high speeds. Condenser C_1 also serves to suppress sparking at contacts K_2 thus helping to increase their life. Condenser C_2 in conjunction with resistor R serves as a spark suppressor for contacts K_1.

The operation of the pneumatic detector is as follows: Each pair of wheels of a vehicle in passing over the rubber tubing stretched across the highway causes an air pressure impulse that moves the rubber diaphragm in the road switch which, in turn, actuates the contacting elements, closing the battery circuit and energizing the relay in the counting unit. The end of the rubber tubing remote from the diaphragm is left open because it has been found that this permits equalization of air pressures inside and outside the rubber tubing to be quickly established after passage of the wheels over the tubing, eliminating erroneous counts resulting from air surges, as well as preventing false operation from changes in temperature.

Laboratory tests have shown that the counter will respond to impulses spaced 0.072 second apart. This speed of operation enables the counter to register both axles of a vehicle of 114-inch wheelbase traveling at speeds up to 90 miles per hour, or of a vehicle of 154-inch wheelbase traveling at speeds up to 122 miles per hour. The wheelbase of 114 inches is the average for 15 of the most popular makes of cars having wheelbases of less than 120 inches. The 154-inch wheelbase is the maximum for domestic makes of passenger cars. Al-



L_1 =D.C. RELAY, 200 OHM COIL.
L_2 =D.C. ELECTROMAGNETIC COUNTER, 1,300 OHM COIL.
C_1 =CONDENSER, 4 MFD. 450 VOLT D.C.
C_2 =CONDENSER, .25 MFD. 250 VOLT D.C.
R =RESISTOR, 500 OHM, 1 WATT.
B = B BATTERIES, 90 VOLTS D.C. (4 - 22½ VOLT.)
B_1 = 45 VOLT LEAD. B_2=67½ TO 90 VOLT LEAD.
Sw= SWITCH, SINGLE POLE, SINGLE THROW.
J =TELEPHONE JACK.
P =TELEPHONE PLUG.
K_1 =RELAY CONTACTS.
K_2 =ROAD SWITCH CONTACTS

FIGURE 5.—WIRING DIAGRAM FOR PORTABLE AUTOMATIC TRAFFIC COUNTER.

though the counter, in most instances, will not be called upon to register vehicles traveling at such high speeds, the rapid response enables the counter to register practically all axles of passing vehicles.

The complete counter, including batteries, pneumatic detector, and connecting cable, weighs 16 pounds. The counting unit alone weighs 12 pounds. The counter was assembled from commercially available parts at a net cost of approximately $13 excluding labor.

TESTS SHOW PORTABLE COUNTER TO BE REMARKABLY ACCURATE

Once the problem of providing a properly balanced circuit for the operation of a counting unit by the road switch for a range of vehicle speeds was solved, the counter was taken into the field for testing under actual operating conditions. The first tests were made on paved roads, and the accuracy of the machine counts was entirely satisfactory. Table 1 shows the results of a typical count made on a paved road. The over-all error for the period of the count was −1.7 percent or less than the usual error for a photoelectric counter operating under the same conditions.

Table 2 gives the results of a test made to compare the accuracy of the portable counter with that of the fixed type photoelectric recorder under identical conditions. The over-all error of the portable machine was +0.3 percent, while that of the fixed type was +1.1 percent.

As a test of the sensitivity of the device, a tube 50 feet long was attached to the road switch and was installed on a 22-foot roadway so that the switch was 28 feet from the edge of the pavement. Enough tension was applied to the tube to stretch it to 52 feet. The results of this test are shown in table 3. The over-all error for the period of the count was −1.8 percent and the nearest wheel of approximately half of the vehicles counted was roughly 40 feet from the diaphragm. While an accurate check by lanes was not made, the machine appeared to count as accurately in the far lane as in the near one.

TABLE 1.—*Comparison of machine counts and manual counts of axles to check the accuracy of the portable counter*

Time (p. m.)	Axles counted— Manually	Axles counted— By machine	Error
	Number	*Number*	*Percent*
2:07–2:12	100	100	0
2:12–2:19	137	139	+1.5
2:19–2:25	225	220	−2.2
2:25–2:38	344	338	−1.7
2:38–2:49	254	243	−4.3
2:49–2:59	281	273	−2.8
2:59–3:10	306	302	−1.3
3:10–3:24	379	374	−1.3
3:24–3:33	266	261	−1.9
3:33–3:36	126	126	0
3:36–3:40	124	122	−1.6
3:40–3:45	176	175	−0.6
2:07–3:45	2,718	2,673	−1.7

TABLE 2.—*Comparison of counts made by both the fixed and portable traffic counters with manual counts of traffic made to check their accuracy*

Time (p. m.)	Manual count			Portable counter			Photoelectric counter	
	Tractor-truck semi-trailers and other 3-axle vehicles	Total number of axles	Total number of vehicles	Number of axles counted	Number of vehicles indicated [1]	Percentage of error [2]	Number of vehicles counted	Percentage of error
2:45–3:05	0	178	89	178	89	0	89	0
3:05–3:15	1	95	47	90	45	−4.3	47	0
3:15–3:30	1	133	66	133	66	0	67	+1.5
3:30–3:45	2	166	82	166	83	+1.2	82	0
3:45–4:00	3	167	82	167	83	+1.2	85	+3.7
2:45–4:00	7	739	366	734	367	+0.3	370	+1.

[1] Assuming each vehicle has 2 axles.
[2] On the basis of vehicles indicated.

TABLE 3.—*Comparison of machine counts and manual counts of traffic, made to check the accuracy of the portable counter when the air switch was installed 28 feet from the edge of the pavement*

Time (p. m.)	Axles counted— Manually	Axles counted— By machine	Error
	Number	*Number*	*Percent*
2:25–2:35	303	305	+0.7
2:35–2:45	256	253	−1.2
2:45–3:00	449	440	−2.0
3:00–3:10	411	409	−0.5
3:10–3:20	339	330	−2.7
3:20–3:30	246	232	−5.7
3:30–3:40	381	373	−2.1
3:40–3:50	431	424	−1.6
3:50–3:57	431	423	−1.9
2:25–3:57	3,247	3,189	−1.8

The counter was also tested for accuracy in counting vehicles traveling at various speeds, and was found to record axles satisfactorily at speeds from 5 to 70 miles per hour. No attempt was made to test the equipment on the road beyond this range of speed, although laboratory tests indicate that the average car will be recorded properly at speeds as high as 90 miles per hour.

The first manual check made on the pneumatic detector and counter installed on a gravel road in the same manner as previously used on paved roads showed it to be in error by −21.2 percent. General observations at first indicated that the inaccuracy resulted from the wheels of vehicles passing over the tube at points where it was raised above the roadway because of an uneven cross section. However, when a test vehicle was driven so that the wheels passed over the tube at points where it rested on the surface and then over points where the tube was raised above the surface, the results showed that the entire error was not attributable to this single cause. Although the error was less when the test vehicle passed over the tube at points where it rested on the road, the error was still much greater than had been obtained on paved roads.

Considerable experimenting with different methods of installing the tube on roads having different cross sections and profiles led to the discovery that, where the tube was installed very loosely so that it would conform almost exactly to the cross section of the road, the accuracy of the counts obtained was satisfactory. It was also noted that the longitudinal profile of the road appeared to have more to do with the accuracy of the count than had the cross section. Counts made on roads having uneven longitudinal profiles showed larger percentages of error than counts made on roads with smooth profiles and very irregular cross sections. For example, counts made on a gravel road having a fairly well-shaped cross section but with a slight washboard shape along the longitudinal axis showed an error of −22.7 percent, whereas counts made on a gravel road with a grass-grown strip between the wheel tracks which kept the tube 3 or 4 inches above the tracks showed an error of −2.8 percent. These results were obtained with considerable tension in the tube. With the tube installed as recommended, the error was −7.2 and 0 percent, respectively. The practice since these tests has been to install the tube loosely, taking care not to install it so loosely that traffic will whip it out of line sufficiently to produce extra counts by the wheels on one axle passing over the tube at different times.

The number of vehicles that may be counted with one set of batteries is not definitely known, but it appears that they can be depended upon to count at least 100,000 vehicles when used where the traffic is of such volume that the batteries lose their charge through use rather than deterioration. In one test, the batteries counted approximately 120,000 vehicles over a period of 5 weeks before it was necessary to replace one of them.

PORTABLE COUNTER EASILY AND QUICKLY INSTALLED

Tests of the wearing qualities of tubing installed on paved roads indicate that the different commercial tubings that will operate the counter have a wide range of life. The poorest tubing withstood the passage of approximately 18,000 vehicles, while from accelerated tests it was calculated that the best grade of tubing tested would count three or four hundred thousand vehicles before wearing out. Thus far, in actual road tests the tubes generally have been cut by traffic rather than worn out. Under average conditions, a good grade of windshield wiper tubing has been found to count between one and two hundred thousand vehicles before failing. These failures did not result from frictional wear or the effects of repeated impacts, but rather from the tube being cut or pierced by small stones held in the tread of tires, or from some other unusual circumstance.

It is desirable to obtain as dependable a tube as possible and replace it whenever there is any reason to believe it may fail in the near future, because failure of the counter to operate for the full period will render the count up to the time of failure valueless, thus disrupting the counting schedule as well as requiring at least one extra trip to the location to obtain the desired information. This is not the case, of course, should such a detector be used with a counter that is supplemented with apparatus for periodically recording the counts, since the record would reveal the period of satisfactory operation and the data for this period would be useful.

The counter has operated satisfactorily under all of the weather conditions to which it has been exposed. It is, however, necessary to protect the open end of the tube from rain, because the suction resulting from the displacement of air by passing vehicles may draw water through the entire tube into the road switch and cause faulty counting. Water thus sucked through the tube has also caused the cement holding the diaphragm to fail. This difficulty can be overcome by placing the open end of the tube in a can similar to that used for housing the road switch. It is necessary to leave a small hole in the can so that the effect of having the end of the tube open will not be lost. Other means could also be readily devised.

The installation of the pneumatic detector and counter is very simple and can be accomplished by one man in less than 10 minutes. For best results, the most uniform cross section and profile in the section of highway for which the count is desired should be selected, and the counter placed at a point suitable for locking it to a telephone pole, tree, or other fixed object to prevent theft of the equipment. It is also advisable to select as inconspicuous a place as possible to avoid attracting attention and to reduce the possibility of tampering.

The tube is placed across the road, anchored at each end, and proper connections are made to the cable connecting the road switch and counter. As no tests have as yet been made on the equipment installed on appreciable grades, it is considered advisable to install the equipment on fairly level sections of road.

While this counter and pneumatic detector have proved satisfactory under the limited tests to which they have been subjected, the counter as now developed is not suitable for all types of traffic counting work. In fact, the device does not provide for the printing of subtotals in any way, and therefore its use must be limited to those locations where only the total volume for a given period is desired. Moreover, the detecting unit, as previously mentioned, was adapted from the means successfully used in recording vehicle passing movements. In these passing studies, the detectors were in place only while the studies were in progress and, therefore, were constantly attended and their operation could be continually checked. Any failures in their operation were immediately discovered and the detectors repaired or replaced as necessary. Although failures were infrequent, and not once during the passing studies did a vehicle cut one of the tubes, the thin tubes are believed to be particularly vulnerable to steel-tired vehicles, which will be found in greater proportion on secondary roads than on main highways.

USE OF OTHER TYPES OF DETECTOR BEING CONSIDERED

Consideration has been given to the substitution of a different type of detector even though such a change would require modifications in the electrical constants of the counting circuit. Another type of detector, employed by the Bureau in studies of the lateral placement of vehicles on the pavement, has been considered as a substitute for the pneumatic detector, although its construction is more expensive. This detector is a so-called positive-contact type in which steel strips, placed at the top and bottom of a rubber arch, are held apart by the resiliency of the rubber. The rubber arch is encased in a rubber housing for protection from the weather. As the wheels of the passing vehicles depress the arch and bring the steel strips into contact with one another, an electrical circuit is closed and, in turn, a counter is actuated.

Although this detector might not be any more durable than a rubber tube, its construction makes it less susceptible to failure resulting from cutting or abrasion. Even though a vehicle should cut through the rubber housing, it is unlikely that the steel strips would be harmed. Although a cut or fracture might permit the entrance of water which eventually would short-circuit the detector, it is probable that the trouble would be discovered in the course of regular inspections before the apparatus ceased to function. The rubber tube, on the other hand, would fail to function immediately on being cut or punctured.

Periodic recording type counter.—While the development work completed thus far has included only the simple accumulating type of counter, other agencies have been working on the design and construction of portable counters and have concentrated on the development of devices of the periodic recording type. One of these counters has been tested by the Bureau of Public Roads and at one location was found to have an error of −0.8 percent in counting 858 vehicles. The detector used for this machine consists of two strips of spring steel enclosed in a rubber casing. These strips are forced together by the wheels of passing vehicles, thus closing the electrical circuit operating the counter. The machine is timed by an 8-day spring clock which advances the record tape and closes electrical contacts, causing the machine to print the cumulative counter reading on the tape once each hour.

The Texas State Highway Department has developed a portable periodic recording counter in which the detecting is accomplished by photoelectric means. Since power is derived from batteries, the counter is readily portable. To provide for recording the counts, a cheap miniature camera using 35 mm film has been employed. An 8-day clock, suitably geared to the winding spool, moves the film ahead slowly, and by closing an electric circuit each hour, lights a small bulb thus photographing the counter at regular intervals for periods up to a week.[1]

The Bureau has also been experimenting with photographic means of recording the counts as obtained by the simple accumulating counter just described. The apparatus used also appears to offer good possibilities of recording the counter readings cheaply and accurately. It is believed that periodic recording counters, particularly when used in conjunction with a number of counters of the simple accumulating type, would be quite valuable in the continuing planning surveys for determining the general trends of traffic flow, and for further study of traffic patterns, particularly on the more lightly traveled roads.

At this early stage in the development and use of automatic traffic counters, it is felt that present knowledge is insufficient to justify a definite statement of the requirements in the field of portable automatic traffic counters. It is, however, generally agreed that there is a need for both the periodic recording and simple accumulating types of machines. Past experience indicates that the following characteristics are essential to a satisfactory periodic recording type counter provided, of course, that they all are obtainable without prohibitive initial cost or equipment too delicate for dependable field operation:

1. Continuous operation for 8 days without attention.
2. Reliable timing with error no greater than 5 minutes in 24 hours.
3. Accurate counting on both paved and unpaved roads.
4. Recording of the cumulative traffic total once each hour on the hour.
5. Installation to be accomplished by one man in about 15 minutes.

PRACTICABILITY OF USING SIMPLE ACCUMULATING MACHINES DISCUSSED

With periodic recording machines meeting these requirements operating at key locations a number of simple accumulating counters could be placed at selected locations in the area under study, noting the time and counter reading when each machine was placed in operation and the time and reading after the desired counting period. These short counts could be expanded by comparison with the continuous hourly records obtained by the periodic recording machines. This method of expanding short counts, in addition to being much easier than methods previously used, would give more reliable results. The machines might be moved every day, and they could be used to obtain week-end counts at more important stations. Another plan would be to assign one man to operate three groups of machines so that he could move each group after a week's record had been obtained. Under this schedule he would remove machines in a single group one day and reinstall them at new locations the next day.

For purposes of determining the hourly fluctuations in traffic volume, the simple accumulating type of machine is, of course, not practicable. However, the daily traffic patterns can be determined with these machines if the accumulated totals on the counters are read at 24-hour intervals. Under certain circumstances such a procedure would be entirely practicable, but if it becomes necessary in conducting any series of counts to locate the machines at some distance from one another, it may be difficult to arrange an observer's schedule so that he can read each counter within a few minutes of the specified time each day. All these difficulties are, of course, eliminated with the use of the periodic recording counter since hourly readings of the counter will be recorded from the time the counting unit is installed. But if only the total volume figures for relatively long periods, such as a full week, are required, the simple accumulating counter would be quite satisfactory.

The most appropriate type of machine to use for a particular purpose depends on the type of information required and on the relative cost of the different types of machines under the particular circumstances involved. Although the periodic recording type of machine may have a considerably higher initial cost and perhaps even a higher operating cost, these items may be more than offset by the expense involved in reading the simple accumulating counters at the required intervals. Only by experience in the field with the two

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[1] The November 1938 issue of Roads and Streets carries a description of this machine. The Texas State-wide Highway Planning Survey has also published a pamphlet describing the machine in detail.

types and thorough tests to determine the length of life over which each may be expected to operate effectively can reasonable unit cost be determined. Preliminary estimates, using assumed unit costs, indicate that to meet the most probable requirements of the continuing phases of the highway planning surveys, the periodic recording type machine may be cheaper to operate even at a considerable differential in original cost over that of the simple accumulating counter. The factor of mileage traveled in the use of the two types will probably be the most significant factor in the total cost of operation and, therefore, it is likely that the relative economies will differ in the various States with the wide differences in average distance between station locations which local conditions will require.

MODIFICATIONS OF SIMPLE ACCUMULATING TYPE COUNTER SUGGESTED

Modified simple accumulating type counter.—Thus far, consideration has been given to but two types of counters and to their relative merits for use in the continuation of the highway planning surveys. However, the estimated high initial cost of an hourly recording counter has led to the consideration of special-purpose machines of simpler design. Preliminary work already begun on these counters indicates that they may be, under many circumstances, more efficient than either of the other types. An intermediate type between the periodic recording and the simple accumulating types is a counter that may be started and stopped at predetermined times. A device to obtain this type of count can readily be attached to the simple accumulating counter by inserting, in the detector circuit, a clock mechanism wired to make and break the circuit.

The Bureau is now investigating available devices, to determine whether any will satisfactorily fulfill this purpose, and is considering experimenting in the development of such a device in its own shop. With an attachment of this sort, it would be possible to install a counter, for example, in the afternoon, have the count begin at midnight, and continue for a given number of hours or days depending upon the design of the mechanism and the requirements of the count. Such an attachment should be reasonable in price and so designed that it can be employed, if desired, with any simple accumulating counter. By designing the counters and the time-control mechanisms as independent units, the use of several counters with a smaller number of timing devices would permit the adoption of extremely flexible counting schedules, and reduce to a minimum the cost of travel and labor in collecting large amounts of usable data.

The simple accumulating type of portable counter could be modified by the use in a single counter of not one but several of the electromagnetic counting devices. By attaching the time-control mechanism, modified somewhat in its operation, to this counting unit the volumes for successive periods would be registered on successive counters. Instead of stopping the count after 24 hours, the time-control device would simply shift the circuit from one counting device to the next, and so on, until the cycle was completed. Use of eight counting devices in one counter would be advantageous in that an 8-day spring-clock mechanism could be employed in conjunction with them to provide an effective complete unit.

At least two variations in the use of this 8-bank counter and time-control combination are possible. First, the time interval may be varied by certain modifications of the timing mechanism circuits to permit the accumulation of volumes during periods other than of 24 hours. Twelve-hour or 6-hour periods can be readily obtained in this way, and by a somewhat greater modification of the device, 1-hour periods might also be separately registered. Eight counters would thus permit records by 12-hour periods for 4 days, by 6-hour periods for 2 days, or 1-hour periods for 8 hours (the present generally used counting period for manual counts).

The second modification of this combination would permit the accumulating, on individual counting devices, of the total volume during corresponding periods on successive days. In this manner, the volume count would be accumulated for the desired periods for any number of days up to 8, assuming an 8-day spring clock is used. Such volume figures have not been generally utilized, but their value for control purposes is obvious.

With all the counters thus far described, it has been possible to count or to record only the total traffic using the roadway. Furthermore, these machines, as well as the photoelectric type now in general use, are poorly adapted to counting traffic on roads greater than two lanes in width. Although, with the pneumatic detector, vehicles in two lanes moving in the same direction have been counted with reasonable accuracy in light traffic, there is reason to believe that considerable error may be introduced by vehicles crossing the tube simultaneously under heavy traffic conditions on multilane roads.

This source of error may be eliminated by utilizing the positive-contact detector previously mentioned. For this purpose, however, but one of the steel strips would be continuous over the entire length of the detector. The other would be broken into sections and leads from each section taken to an individual counter, using one section and, correspondingly, one counter for each lane of traffic. A combination of this type, therefore, suggests a further use for a counting unit containing a bank of counters.

Although lane counts have not generally been made in conjunction with the highway planning surveys, it is considered desirable, particularly in the determination of proper widths of multilane highways, to have an accurate knowledge of the direction of traffic flow as well as of its total volume. This detecting and counting unit would also be ideally adapted to city traffic survey work where directional flow and the volume per lane are essential in the design of traffic control methods and in general traffic regulation.

The need for portable automatic traffic counters has long been felt, not only by State and Federal highway officials, but also by city traffic officials and by various commercial agencies to whom a knowledge of traffic volume is essential. In practically all instances the demand has been evidenced by attempts to design equipment capable of performing the types of traffic counts now generally conducted by manual methods. However, a factor which should always be kept in mind in considering the design of traffic counters is that it is entirely possible that many types of counts, previously impossible or impractical by manual methods, may be quite readily accomplished by properly designed automatic counters. It is, therefore, essential in the design of counting mechanisms that the instrument designer work in close coordination with the traffic engineer in order that equipment developed will possess the greatest possible flexibility. Similarly, the traffic engineer is remiss if, in his design of counting schedules, he fails to avail himself of the possible advantages of flexibly designed automatic devices.

In describing the development work to date, it is desired only to present a progress report and to make suggestions that may assist in continuing development work to provide devices most suitable to their individual requirements.

(Continued from page 212)

It is only by analysis of the normal driving practices, as they are recorded for a wide variety of driving conditions, that it will be possible to determine whether the problem is one presented by the average driver, or whether present highway design practices are creating entirely unnecessary problems, either impossible or extremely difficult of solution. It is this phase of the problem to which the greatest attention must be directed. Determination of the distances involved in passing maneuvers is a simple, even though laborious, matter. The determination of the effect of highway alinement and of driver psychology upon future design requirements is a matter requiring far more comprehensive research.

Although this report has been devoted to the methods employed in the analysis of passing practices, it will be evident that the data collected in these field studies will permit of a variety of analyses quite distinct from this one, rather narrow, use. The advantage of this procedure, particularly with respect to the field work, is that the actual occurrences on the entire section under observation have been recorded completely and continuously throughout the study periods in a permanent and easily interpreted form. Further analysis can be conducted simply by referring to the original field charts, or to the transcribed records.

BIBLIOGRAPHY ON HIGHWAY FINANCE NOW AVAILABLE

A bibliography on highway finance has recently been prepared by the Bureau of Public Roads of the United States Department of Agriculture and mimeographed copies are now available for free distribution.

The bibliography is selective in character and includes references to books, articles printed in technical and other periodicals, and publications of societies. It covers chiefly the period from 1928 to date, but includes references to earlier material published by the Bureau of Public Roads.

Librarians, students, and research workers will find the bibliography a valuable aid in locating published material on highway finance.

Single copies of the bibliography can be obtained, without charge, from the Bureau of Public Roads, United States Department of Agriculture, Washington, D. C.

STATUS OF FEDERAL-AID HIGHWAY PROJECTS

AS OF DECEMBER 31, 1938

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 3,558,906	$ 1,685,635	112.4	$ 8,857,711	$ 4,417,375	367.8	$ 1,323,380	$ 660,385	54.2	$ 1,988,046
Arizona	1,931,132	1,474,674	107.4	876,305	563,704	24.9	437,725	194,213	30.6	1,072,275
Arkansas	1,036,098	1,028,697	73.7	3,056,895	3,053,158	191.1	915,470	914,409	53.1	231,186
California	7,660,168	4,213,500	181.4	6,634,208	3,507,830	94.2	1,850,283	983,669	50.2	1,145,410
Colorado	2,272,872	1,229,934	84.3	3,030,903	1,592,037	100.0	751,260	417,710	13.0	1,491,940
Connecticut	934,030	455,835	8.9	684,518	337,455	7.9				1,525,005
Delaware	481,532	237,550	14.1	712,036	353,260	9.9	259,491	125,600	6.6	1,137,707
Florida	1,729,200	864,600	39.8	3,106,238	1,553,119	57.1	277,000	138,500	3.9	2,812,495
Georgia	4,297,272	2,104,079	216.2	4,905,350	2,452,675	232.7	1,036,020	518,010	71.2	5,262,724
Idaho	2,068,519	1,222,347	200.7	1,189,537	710,407	39.0	301,398	179,452	10.9	925,222
Illinois	10,102,553	5,047,048	263.1	7,594,236	3,793,494	166.1	3,530,611	1,765,260	84.7	977,887
Indiana	4,446,630	2,181,093	127.3	3,836,570	1,918,285	70.8	1,574,584	787,212	37.7	2,168,782
Iowa	7,171,962	3,344,519	234.0	5,121,839	2,165,983	161.9	540,887	126,000	34.8	56,547
Kansas	4,302,078	2,149,829	673.6	4,362,243	2,181,121	211.1	3,386,922	1,686,436	150.2	2,273,945
Kentucky	5,584,169	2,775,513	199.3	2,680,426	1,340,213	57.7	1,306,746	653,373	39.1	1,996,080
Louisiana	1,294,187	646,891	38.2	11,742,753	2,516,164	30.3	1,761,038	775,592	28.6	1,782,072
Maine	2,715,195	1,353,191	62.6	1,590,201	795,100	35.2	227,424	113,711	1.9	146,583
Maryland	1,085,456	542,728	17.1	2,094,767	1,031,621	40.6	1,148,781	564,730	10.4	1,540,916
Massachusetts	1,863,674	931,834	9.0	2,984,200	1,491,641	19.4	649,117	322,815	8.4	2,198,362
Michigan	7,424,383	3,599,839	156.2	3,982,708	1,990,702	117.9	1,638,625	817,580	39.5	808,471
Minnesota	4,780,350	2,314,905	289.3	6,086,875	3,023,245	279.3	1,153,760	575,975	61.2	1,904,038
Mississippi	1,802,608	874,442	71.2	10,282,812	3,919,027	447.0	1,610,990	622,220	68.3	1,827,603
Missouri	4,213,623	1,971,236	118.8	2,565,848	1,272,436	58.1	5,754,788	2,742,950	222.8	2,222,644
Montana	1,666,619	936,796	83.6	756,924	425,407	17.6	1,012,152	569,320	69.9	3,882,156
Nebraska	3,204,113	1,565,053	309.3	5,278,728	2,662,277	400.2	5,226,354	1,981,124	390.2	894,856
Nevada	1,447,314	1,241,763	168.8	1,085,933	935,776	38.5	257,545	223,292	12.6	697,909
New Hampshire	881,761	437,187	21.5	437,424	217,752	3.3	93,802	46,900	1.4	1,145,923
New Jersey	1,132,455	557,970	10.8	2,824,716	1,409,248	18.9	1,097,710	548,255	9.8	1,965,117
New Mexico	2,054,234	1,252,372	237.1	2,132,020	1,400,484	74.8	204,244	91,230	33.4	344,832
New York	12,919,513	6,358,010	233.9	10,361,696	5,135,842	170.0	3,822,030	1,600,760	63.6	194,598
North Carolina	6,082,253	2,917,224	248.9	5,036,079	2,516,882	323.1	875,580	425,400	44.8	1,585,065
North Dakota	3,319,408	3,186,988	254.8	500,901	290,805	57.5	69,522	37,236	6.8	3,557,402
Ohio	7,108,523	3,513,044	86.4	8,056,842	4,018,822	78.2	1,978,040	985,864	18.7	5,415,111
Oklahoma	4,852,873	2,562,706	206.1	3,489,873	1,803,756	97.5	1,894,300	999,863	52.0	2,167,924
Oregon	3,131,747	1,849,730	110.7	1,337,972	816,987	83.2	610,573	372,460	26.6	1,382,171
Pennsylvania	7,869,759	3,908,555	132.6	6,937,785	3,466,314	72.1	3,584,605	1,737,299	32.7	1,829,173
Rhode Island	1,179,290	589,645	16.4	372,212	186,106	3.5	307,320	153,660	3.2	907,105
South Carolina	3,807,183	1,671,548	230.6	3,808,045	1,712,476	92.6	580,751	264,800	29.5	1,160,855
South Dakota	1,883,737	1,040,551	228.5	4,675,086	2,585,440	446.3	495,660	274,080	45.4	2,515,736
Tennessee	4,216,795	2,107,676	147.0	3,108,609	1,555,026	56.4	1,564,340	781,670	30.6	3,546,575
Texas	10,739,595	5,309,928	720.6	11,224,350	5,537,497	472.2	4,965,291	2,413,406	293.9	3,530,777
Utah	1,023,819	723,724	112.0	2,000,988	1,418,640	68.2	207,275	147,580	9.9	528,029
Vermont	1,283,285	582,204	34.9	722,784	343,793	17.7	196,970	98,295	4.3	169,425
Virginia	5,915,394	2,955,516	204.9	2,861,368	1,428,849	88.0	903,848	449,619	10.9	362,304
Washington	3,989,159	2,083,068	99.5	2,600,727	1,364,359	25.9	416,525	216,200	10.2	570,311
West Virginia	1,646,147	1,183,551	61.6	1,333,822	703,786	26.9	911,370	451,835	27.2	1,947,582
Wisconsin	3,999,467	1,955,828	134.0	6,744,767	3,186,680	188.6	951,427	435,400	7.7	1,002,426
Wyoming	2,420,989	1,488,150	279.2	313,782	188,371	38.1	339,430	209,730	38.2	496,062
District of Columbia										
Hawaii	824,027	408,939	17.7	826,430	405,695	9.5	28,750	11,410		1,205,177
Puerto Rico	53,980	26,990	2.1	1,139,989	567,815	22.6	598,946	297,050	12.1	342,520
TOTALS	181,410,036	94,664,635	7,692.1	187,949,031	92,264,937	5,811.4	64,630,660	31,509,540	2,366.9	80,843,061

STATUS OF FEDERAL-AID SECONDARY OR FEEDER ROAD PROJECTS

AS OF DECEMBER 31, 1938

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 197,900	$ 98,950	11.9	$ 533,605	$ 265,150	37.3	$ 314,700	$ 156,800	7.9	$ 532,072
Arizona	281,361	187,459	18.6	176,900	115,539	17.5	7,440	5,357		348,127
Arkansas				124,036	116,677	12.1	269,518	267,911	28.4	479,520
California	1,032,491	587,924	78.6	950,335	522,097	50.1	499,627	265,530	19.0	472,285
Colorado	650,358	358,164	41.0	555,510	288,585	29.4	38,040	15,000		259,819
Connecticut	48,450	24,205	1.0	62,584	31,132	.5	73,100	17,455	1.1	245,486
Delaware	18,950	9,475	4.1	53,394	26,697	8.8	47,240	23,135	9.9	187,568
Florida				254,204	127,061	1.5	153,500	76,750	4.4	471,041
Georgia	225,939	109,021	29.4	610,586	305,293	76.2	186,360	93,180	26.4	751,228
Idaho	451,521	204,347	46.9	64,986	27,513	10.3	128,534	76,572	2.6	165,939
Illinois	1,257,586	628,025	112.7	1,661,092	776,546	93.5	377,700	180,350	30.5	443,904
Indiana	599,857	255,400	64.8	679,900	322,150	62.0	703,248	341,752	62.8	323,136
Iowa										1,298,449
Kansas	53,582	26,791	8.6	206,472	103,235	13.3	100,686	50,343	34.6	1,138,602
Kentucky	706,675	209,989	93.3	785,052	216,671	35.8	779,443	229,948	88.6	162,187
Louisiana	64,068	31,900	6.9	505,518	224,125	38.6	567,914	252,510	48.2	215,601
Maine	362,500	181,250	23.3	262,662	126,214	12.5	18,700	9,350	1.2	11,759
Maryland				45,164	15,787	5.8	292,800	110,355	18.4	286,334
Massachusetts				134,123	66,945	2.4	222,970	110,905	4.9	468,550
Michigan	349,961	173,481	32.0	638,804	319,402	41.1	483,200	240,850	23.8	801,806
Minnesota	283,896	131,799	42.2	452,110	224,011	38.6	374,824	187,412	23.9	836,358
Mississippi				299,000	149,500	23.8				739,427
Missouri	320,119	153,359	43.1	147,040	73,130	11.5	895,460	386,430	115.7	452,753
Montana				13,983	7,865					1,027,170
Nebraska	435,709	215,851	79.8	391,214	193,127	59.7	558,656	272,107	100.8	316,731
Nevada	424,798	354,271	68.8	109,464	91,876	15.0	34,544	29,956	2.0	19,752
New Hampshire	241,175	119,755	6.0	64,509	31,583	2.3				95,537
New Jersey	123,040	61,520	2.4	199,860	91,195	2.7				520,058
New Mexico	563,070	343,413	36.9	538,095	328,178	30.9	104,104	63,490	10.1	71,691
New York	2,245,354	1,117,525	159.8	1,782,800	891,400	94.7	178,400	89,200	11.4	264,369
North Carolina	606,848	303,424	72.3	867,284	433,620	66.6	117,630	54,580	13.7	290,231
North Dakota	52,020	27,860	9.0	101,510	54,367	25.8	115,886	62,065	8.5	642,960
Ohio	156,560	78,280	3.8	52,490	32,470	.9	497,100	248,550	24.3	1,472,341
Oklahoma	31,300	16,652	2.1	399,018	211,194	36.2	617,940	305,608	37.0	651,461
Oregon	453,626	266,110	58.5	59,454	36,322	5.0				452,701
Pennsylvania	1,611,605	782,562	115.6	1,795,779	880,108	97.6	549,232	274,616	31.1	179,398
Rhode Island	66,840	33,420	3.5	162,675	81,314	4.8	74,070	37,035	.9	36,122
South Carolina	359,615	161,872	38.3	789,615	325,779	86.4	303,400	118,500	23.6	72,529
South Dakota				11,300	6,250					816,436
Tennessee	120,720	60,360	2.9	656,244	255,222	36.9	174,320	80,690	5.5	663,218
Texas	2,109,627	987,459	306.8	1,847,614	794,250	183.7	726,281	344,323	109.0	998,738
Utah	402,522	222,870	40.1	222,529	118,625	15.2	208,420	91,460	20.5	117,415
Vermont	240,777	108,150	13.8	90,306	45,153	4.0	43,300	20,500	.5	35,793
Virginia	436,847	216,208	57.0	787,620	343,870	47.2	126,162	63,081	18.8	269,226
Washington	561,569	293,796	63.8	388,264	204,178	20.1	349,621	184,100	20.1	48,482
West Virginia	124,300	62,150	9.5	236,846	118,423	18.1				369,101
Wisconsin	373,781	173,542	12.7	815,142	399,890	42.0	23,126	11,450	.8	627,765
Wyoming	416,146	254,582	59.0	285,102	176,169	11.9	121,478	75,041	10.4	79,401
District of Columbia										
Hawaii				56,250	28,125	2.4				218,750
Puerto Rico	74,740	37,370	3.9	243,162	120,595	13.9	31,422	15,425	2.3	73,485
TOTALS	19,137,803	9,670,541	1,884.7	22,171,206	10,744,608	1,546.6	11,490,096	5,539,672	1,003.6	21,522,812

PUBLICATIONS of the BUREAU OF PUBLIC ROADS

Any of the following publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. As his office is not connected with the Department and as the Department does not sell publications, please send no remittance to the United States Department of Agriculture.

ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1931. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1933. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1934. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1935. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1936. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1937. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1938. 10 cents.

HOUSE DOCUMENT NO. 462

Part 1 . . . Nonuniformity of State Motor-Vehicle Traffic Laws. 15 cents.

Part 2 . . . Skilled Investigation at the Scene of the Accident Needed to Develop Causes. 10 cents.

Part 3 . . . Inadequacy of State Motor-Vehicle Accident Reporting. 10 cents.

Part 4 . . . Official Inspection of Vehicles. 10 cents.

Part 5 . . . Case Histories of Fatal Highway Accidents. 10 cents.

Part 6 . . . The Accident-Prone Driver. 10 cents.

MISCELLANEOUS PUBLICATIONS

No. 76MP. . The Results of Physical Tests of Road-Building Rock. 10 cents.

No. 191MP . . Roadside Improvement. 10 cents.

No. 272MP . . Construction of Private Driveways. 10 cents.

No. 279MP . . Bibliography on Highway Lighting. 5 cents.

Highway Accidents. 10 cents.

The Taxation of Motor Vehicles in 1932. 35 cents.

Guides to Traffic Safety. 10 cents.

Federal Legislation and Rules and Regulations Relating to Highway Construction. 15 cents.

An Economic and Statistical Analysis of Highway-Construction Expenditures. 15 cents.

Highway Bond Calculations. 10 cents.

DEPARTMENT BULLETINS

No. 1279D. . Rural Highway Mileage, Income, and Expenditures, 1921 and 1922. 15 cents.

No. 1486D. . Highway Bridge Location. 15 cents.

TECHNICAL BULLETINS

No. 55T. . . Highway Bridge Surveys. 20 cents.

No. 265T. . . Electrical Equipment on Movable Bridges. 35 cents.

Single copies of the following publications may be obtained from the Bureau of Public Roads upon request. They cannot be purchased from the Superintendent of Documents.

MISCELLANEOUS PUBLICATIONS

No. 296MP. . . . Bibliography on Highway Safety.

SEPARATE REPRINT FROM THE YEARBOOK

No. 1036Y. . Road Work on Farm Outlets Needs Skill and Right Equipment.

TRANSPORTATION SURVEY REPORTS

Report of a Survey of Transportation on the State Highway System of Ohio (1927).

Report of a Survey of Transportation on the State Highways of Vermont (1927).

Report of a Survey of Transportation on the State Highways of New Hampshire (1927).

Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio (1928).

Report of a Survey of Transportation on the State Highways of Pennsylvania (1928).

Report of a Survey of Traffic on the Federal-Aid Highway Systems of Eleven Western States (1930).

UNIFORM VEHICLE CODE

Act I.—Uniform Motor Vehicle Administration, Registration, Certificate of Title, and Antitheft Act.

Act II.—Uniform Motor Vehicle Operators' and Chauffeurs' License Act.

Act III.—Uniform Motor Vehicle Civil Liability Act.

Act IV.—Uniform Motor Vehicle Safety Responsibility Act.

Act V.—Uniform Act Regulating Traffic on Highways.

Model Traffic Ordinances.

A complete list of the publications of the Bureau of Public Roads, classified according to subject and including the more important articles in PUBLIC ROADS, may be obtained upon request addressed to the U. S. Bureau of Public Roads, Willard Building, Washington, D. C.

STATUS OF FEDERAL-AID GRADE CROSSING PROJECTS

AS OF DECEMBER 31, 1938

STATE	COMPLETED DURING CURRENT FISCAL YEAR					UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
			NUMBER					NUMBER					NUMBER			
	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	
Alabama	$ 243,609	$ 243,410	6		4	$ 947,379	$ 945,524	9	1		$ 57,400	$ 57,400	2		3	$ 739,185
Arizona						9,452	9,452									620,761
Arkansas	82,511	81,574	4			461,497	461,106	8			278,920	278,811	5			937,278
California	669,417	669,417	2	2		1,147,259	1,146,684	7	2		667,526	667,046	2			1,217,062
Colorado	30,569	27,337	1		1	131,999	131,999	2		1	517,478	509,348	4		17	619,628
Connecticut						18,930	12,665									831,825
Delaware	24,500	24,500			7						61,920	61,920	2		16	407,330
Florida						435,116	435,116	3								970,681
Georgia						202,880	202,880	4			183,050	183,050	2		1	2,031,457
Idaho	174,973	174,800	4			263,415	249,386	4			131,898	120,500	1			278,184
Illinois	286,500	286,500	2		1	1,950,825	1,950,825	12	2	9	870,690	870,690	6		66	2,096,925
Indiana	688,715	599,689	3	5		754,680	727,780	2	1	89	271,000	271,000	1	1		815,680
Iowa	1,027,480	972,694	10	1	19	203,820	191,700	2	1	1	140,097	130,308	7		1	1,272,859
Kansas	455,031	455,022	8		4	671,850	671,850	10			478,465	478,465	4		6	969,171
Kentucky	145,000	145,000	1			344,297	344,297	4	1	31	441,642	441,642	6	1		883,106
Louisiana						233,219	226,478	3			476,771	473,090	10			877,503
Maine	48,590	48,590	2			332,396	332,396	3	2		69,830	69,830	1		1	240,387
Maryland						64,586	64,586	1								962,247
Massachusetts	54,710	54,710		1		220,486	220,290	1	1		223,815	223,705		3		1,414,583
Michigan	893,783	887,372	8	1	16	690,796	690,796	6	2	29	114,000	114,000				1,593,017
Minnesota	39,556	39,556		1	1	760,185	759,864	3	5		18,297	18,297			3	1,628,254
Mississippi						465,800	465,800	6			250,000	250,000	1			868,351
Missouri	184,074	182,952	3	1		223,970	223,970	2			397,960	397,960	1	1		2,220,371
Montana	355,586	350,704	4			534,647	534,647	5			323,913	323,913	4			115,207
Nebraska	150,374	150,374	4			729,314	729,314	15			757,668	757,668	18		33	127,054
Nevada	149,761	149,761		3	2	203,311	203,311	2			11,280	11,280			4	94,289
New Hampshire	63,852	63,545		1	1	94,076	94,017	5		2						336,188
New Jersey	116,891	111,665	1	1		223,914	223,914	1	1	2						1,634,678
New Mexico	168,984	168,984	4	1		118,994	118,994	3								563,513
New York	992,501	991,800	4	3	2	1,720,351	1,712,101	5	7		231,660	136,520		2	1	3,929,508
North Carolina	81,950	81,950		1	1	917,500	884,800	7	5		276,760	276,760	1	1	10	1,200,884
North Dakota	184,700	184,700		1		637,438	637,438	4	1							757,083
Ohio						437,870	437,870	5			329,990	329,990	4			3,461,308
Oklahoma						17,343	17,343				359,305	325,305	2		55	1,938,861
Oregon	308,391	307,742	1	2		58,634	58,634				129,997	129,997	2			481,611
Pennsylvania	138,043	122,837	1			304,601	299,694	2			1,421,663	1,210,027	3			4,099,977
Rhode Island						335,019	335,019	1	2		103,772	103,772		1		54,959
South Carolina	20,930	20,930				164,359	109,393	3	2		335,820	335,820	12		40	1,022,959
South Dakota	119,383	119,383	2		8	286,368	286,368	3	2	1	19,820	19,820	2		2	894,529
Tennessee						44,830	44,830		1		310,680	310,680	1	1	7	1,536,523
Texas	34,033	33,377	2			1,306,764	1,305,352	12	6		566,572	508,765	7			3,495,622
Utah	101,648	101,648	2		4	47,359	47,359	2								424,056
Vermont	208,512	203,155	6	1	3	36,504	36,504		1	3	18,330	18,330			6	222,463
Virginia	248,306	248,306	12	1		290,418	290,418	4	1		348,843	348,843	5	1	13	908,463
Washington	179,118	177,018	1	3	2	747,122	747,122	9	1		111,006	109,595	1		12	351,875
West Virginia	216,320	215,300	1			200,861	200,861	1		2	147,750	131,990	4		4	775,947
Wisconsin	221,661	221,493	3			1,187,718	1,101,026	11			4,917	4,917			1	1,146,073
Wyoming	156,370	156,370		2	1	15,180	15,180			2	19,810	19,810			8	485,370
District of Columbia						34,262	34,262		1							291,169
Hawaii						193,200	193,200	3	1							300,550
Puerto Rico						214,569	213,370	4								516,930
TOTALS	9,266,332	9,074,165	102	32	77	21,637,363	21,377,785	199	50	172	11,480,315	11,030,864	121	12	310	55,663,494

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