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AUTOMATIC TRAFFIC RECORDER INSTALLED ON U S 240 IN MARYLAND

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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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AN ACTION PROGRAM TO ADVANCE SAFETY ON THE HIGHWAYS[1]

By THOS. H. MacDONALD, Chief, United States Bureau of Public Roads

THE ADVANCEMENT of safety on the streets and highways of the nation requires definite action on many fronts. The desirable objective for the year 1938 is a vigorous, concerted movement to bring into being on an effective scale the measures and methods which the present knowledge of the character and scope of the problems sustains as a sound program. Perhaps the most important single principle developed during the year just closed of extensive study by the Bureau of Public Roads and the Highway Research Board of many phases of this subject is that there is no single cause of accidents. Each accident is the result of causes in combination. There are always present more than a single element and the number of these elements that can and do contribute to accidents is very large.

The possible number of combinations of these elements by mathematical calculation produces a potentiality of accidents of a magnitude beyond conception. Probably the failure of the lawmakers to recognize this characteristic of multiple contributing elements in each accident has acted as a powerful deterrent to more effective programs of accident control. Certainly it has given rise to serious delays in formulating and applying sound preventive measures. For example, the hope that a single panacea exists that will stop accidents, although utterly absurd, results in all sorts of cure-all offerings, many of them from so-called experts or near experts.

Since there is no single cause there can be no single panacea for accidents. On the other hand, the recognition by the courts of multiple accident-contributing elements has resulted adversely to the imposition of even reasonable penalties upon offenders of the traffic laws. Here the recognition of the contributing factors mitigates to the point of allowing, in many cases, the offender to escape without price the most serious infractions of the law. So widespread is this experience as to lead to the reasonable conclusion that reliance for any great assistance in accident prevention does not lie in the courts as they are now operated in the field of traffic regulation.

Sufficient recognition has not as yet been given to the fact that this big problem of street and highway safety throws upon the established routine and traditions of the courts a new social problem of tremendous dimensions with which they are not designed to cope. The processes of the courts are not singled out for criticism in themselves but to illustrate the failure of society as a whole to recognize the tremendous dimensions of the street and highway traffic safety problems and to provide adequate methods and organizations to deal with these problems effectively.

More than a year ago the Congress directed the Bureau of Public Roads to undertake a study of the problem involved and to submit a report. Acting in cooperation with the Highway Research Board the Bureau has produced a report, or rather a series of reports, dealing with the following subjects:

1. Nonuniformity of State motor-vehicle traffic laws.
2. Skilled investigation at the scene of the accident needed to develop causes.
3. Inadequacy of State motor-vehicle accident reporting.
4. Official inspection of vehicles.
5. Case histories of fatal highway accidents.
6. The accident-prone driver.

These reports have all been transmitted to Congress and are being printed as House Document No. 462. By acting through the Highway Research Board not only the previous studies which had been made by that Board were available, but it was possible to secure the assistance of the individuals who were already working in the several fields of investigation and who have devoted their best efforts to the studies and the resulting reports. Further, a number of the leading authorities, representative of organizations primarily concerned in the traffic safety field, served as an advisory committee to make suggestions as to the scope of the studies and the production of the report.

It is not the purpose of this paper to review the findings of these reports, but, on the basis of the material developed, to propose an action program for the immediate future and to fix in so far as possible the responsibility for the initiation of this program. Neither is it the purpose to prove by the use of statistical material the urgent necessity for enlarging, and quickening the tempo of, sound national programs directed toward the control of the tragic record of accidents and fatalities. A responsible attitude of good citizenship and intelligent selfishness places the road builders and road building industry of the nation behind every effort to advance the cause of highway safety.

In this social problem already grown to such alarming dimensions that it ranks as one of our greatest national problems, while most of the implications and indica-

[1] Paper presented at the Thirty-fifth Annual Convention of the American Road Builders' Association, Cleveland, Ohio, January 17, 1938.

tions are discouraging, there is one important encouragement. Under the coordinating influence of the Automotive Safety Foundation, 12 national organizations which are most intimately and directly concerned with traffic safety problems have united in accepting and recommending a comprehensive model program for each State to increase traffic efficiency and to reduce accidents. This program brings into a coordinate entity the elements of legislation, motor-vehicle administration, enforcement, engineering, education, training personnel, and research. It places responsibility for action upon the governor, the State officials, and the legislature supported by a nonofficial organization of civic and business groups. The combination of official and public groups is conceived to constitute the State safety organization. With this program the Bureau of Public Roads is in entire accord and holds it to be indicated by all the important studies and researches which have been made in this field.

While it may appear to the public at large that inadequate progress is being made in advancing the cause of highway safety, it certainly holds promise of a greatly accelerated rate of progress that all the most important organizations engaged in this field have agreed upon the program most needed and have joined their efforts toward the common end of making the program effective upon a national scale. The effort of this paper therefore is to reduce to concrete terms the necessary steps to be taken and in so far as possible to suggest the responsibility of initiation of the component parts of the program. Only by action on a national scale can even reasonable progress be made in the reduction of accidents and in the freeing of our streets and highways from hazards to permit the enjoyment of their convenience and service.

To carry into effect the existing knowledge in the field of accident prevention, the following eight-point program is submitted. It is not intended to include all of the steps that will be necessary, but it does provide a sound foundation for traffic control and regulation in the interests of traffic safety. Neither are the elements of this program independent but on the contrary they are inter-dependent, and to an extent overlapping. Several of these which are important parts of others are given individuality for the purpose of emphasis. The action program recommended follows:

1. Uniform State motor-vehicle traffic laws.
2. Skilled investigation of traffic accidents.
3. The establishment of a uniform system of accident reporting.
4. The establishment of an adequate highway patrol including the official inspection of vehicles.
5. The establishment of complete and final authority over the issuance and revocation of drivers' licenses.
6. A highway improvement program divided into two general classes of projects:
   a. Those of the emergency type.
   b. Those for the long-time plan.
7. A plan of State and Federal safety organization adequate to secure on a wide scale the adoption and enforcement of the action program here proposed.
8. A national educational program.

The scope of each element of this program is indicated but not intended to be fully developed in this discussion.

1. *Uniform State motor-vehicle traffic laws.*—This subject has received long and careful attention. Through the organized effort of the National Conference on Street and Highway Safety a series of five proposed model laws were drafted and have been widely distributed. While a considerable number of States have adopted these laws in whole or in part there yet remains a serious nonuniformity in the major principles which affect highway safety. It is not proposed that the motor-vehicle laws must be identical in every detail, but they must be in those matters which even remotely affect the safety of motor-vehicle operation. The driving habits of individuals tend to become fixed, and particularly in times of stress or emergency the reactions are involuntary. Now that the traffic between communities and between States has become universal the necessity for replacing uncertainty of the law with certainty is self apparent. The necessity for drivers knowing that they do not face new traffic laws or conditions when they cross State borders cannot be denied. But the existing condition is much more serious than this as indicated in these examples:

Eight States do not require that all motor-vehicle operators be licensed.

Two States fail to provide a minimum age limit for the driving of a motor vehicle.

Fourteen States permit the operation of motor vehicles by minors 14 or 15 years old.

Twenty-two States do not prohibit the issuance of drivers' licenses to habitual drunkards or narcotic addicts.

Twenty-four States do not prohibit the issuance of drivers' licenses to those afflicted with mental disabilities.

Only 11 States require drivers to be able to read highway warning signs printed in English.

In 6 States which do require the licensing of motor-vehicle operators, no examination or test is included as a prerequisite to the issuance of such license, and in 5 others the applicants may be examined only when the official issuing the license suspects they are unfit to drive.

Only 30 States require every applicant for a driver's license to be examined for competency and in these the examination varies widely.

Only 8 States require a test of vision, 15 a knowledge of traffic laws.

Unquestionably there should be a strict uniform license law permitting licenses to be issued only after a competent examination including tests of vision, ability to read traffic signs, knowledge of traffic laws, and demonstration of ability to operate the vehicle.

In only 27 States has there been adopted a manual of uniform traffic control devices. The rules of the road governing the operation of vehicles upon the highway vary so greatly from State to State that confusion is inevitable. Nine States do not require vehicles to be driven to the right of the highway at all times. Six States do not provide that passing must be on the left of the overtaken vehicle. Passing on curves is specifically prohibited in 36 States and on the crest of hills in 35 States, at intersections with other highways in 34 States. The provisions with respect to the equipment of motor vehicles and physical characteristics such as length, width, and height, have a wide variation with many inconsistencies.

Further discussion of this point is hardly necessary to indicate the fundamental necessity of a uniform motor-vehicle law between the States in the interests of safety. The only possibility of providing for this part of the action program lies in the adoption by the State legislatures of the necessary uniform laws. A guide to the points of divergence from the uniform code will be found in the bulletin Nonuniformity of State Motor-Vehicle Traffic Laws that is available for distribution by the Bureau of Public Roads.

2. *Skilled investigation of traffic accidents.*—An intelligent attack on the highway accident situation must depend upon two details which, while simple in concept, are not easy of achievement. There must be information as to the circumstances under which each accident occurs, and there must be sufficient analysis to record where, and the manner in which, accidents are happening repeatedly. Accident data are essential to an intelligent and efficient police enforcement program within the urban districts, and the highway patrol can provide important information in the rural districts. Within the urban areas the establishment of especially trained squads which are ready on call to investigate each accident without loss of time is essential. It may not be practicable at once to establish accident squads in the rural police organization sufficiently extensive to investigate all accidents, but it is possible to establish a number of special accident squads and to train each member of the highway patrol in the correct procedure to investigate and to report accidents so that a high general level of accuracy in reporting may be attained.

So long as we depend for accident data on ex parte information and make inadequate provision for the securing of reliable and disinterested reports, just so long will our knowledge of the facts be insufficient and open to question. It will not be possible to secure impressive accident reduction until it is recognized that every accident is the resultant of a number of causes and circumstances in the absence of any one of which the accident would not have occurred or would have had different consequences. No contributing cause is so unimportant that it may be overlooked or dismissed. That only a beginning has been made in this field in a very few States is convincingly revealed by the analysis presented in the case histories of the fatal highway accidents published by the Bureau of Public Roads. Certainly the establishment of a complete system of accident investigation and reporting will require much more adequate organization than now exists but the cost will be small in comparison with the losses in life and property.

3. *The establishment of a uniform system of accident reporting.*—The uniform reporting of accidents is partially covered by the preceding discussion, but requires in addition the adoption of a national standard form. Much work has been done upon the formulation of such a form by the National Safety Council, the Bureau of the Census, and others, and further work is now in progress. It is essential that the terms be clearly defined, and the statistical methods employed give accurate results. In the studies made by the Bureau of Public Roads and the Highway Research Board the lack of accurate and sufficient statistical data relating to accidents, even those involving fatalities, was an insuperable obstacle in the production of a more determinate report. For example, the national reports of motor-vehicle fatalities are divided between urban and rural on the basis that urban accidents are those in cities of 10,000 and upwards, and all others are classified as rural. Taking into consideration the fact that a very large percent of the total population lives in places of, say, 1,500 to 10,000 people, it is inevitable that a large percentage of fatalities reported in the rural category actually involve urban and not rural conditions. This probable discrepancy is further accented by the fact that so large a percentage of fatal accidents involve pedestrians. It is apparent that effective efforts to combat accidents are utterly dependent upon accurate and complete statistical data.

4. *The establishment of an adequate highway patrol including the official inspection of vehicles.*—In most of the States the highway patrol organization for the rural districts, and in most of the cities, the traffic police, are wholly inadequate in numbers and equipment to patrol the mileage over which there is appreciable traffic. This condition of inadequacy in numbers is further aggravated by the addition of so many miscellaneous duties that too little time is left for patrol work. The most complete code of motor-vehicle laws is of little avail unless there is proper enforcement. An increase in the number of trained patrolmen in every State is necessary.

Only 23 States now provide for the periodical inspection of motor vehicles, but all of these do not include all types. The inspection laws vary in detail but are uniform in the attempt to prevent the operation of mechanically defective vehicles. The establishment of inspection requirements for the safe mechanical condition of motor vehicles and their continuous enforcement is an important "must" in the action program.

5. *The establishment of complete and final authority over the issuance and revocation of drivers' licenses.*—In the development of this discussion the importance of the official charged with the administration of the motor-vehicle laws must be more and more apparent. The lack of essential laws in a large number of States fixing the qualifications of those who are permitted to operate motor vehicles upon the public ways has been recorded. The disclosures in the bulletin upon the accident-prone driver sustain the conclusion that the motor-vehicle administrator must have authority to suspend or revoke the license of operators, and that this power must be exercised. The discretionary authority to revoke licenses should by law be obligatory action in the more serious offenses. Thirty States now require that a license be revoked for conviction of manslaughter; 36 States, for driving while under the influence of intoxicants; 31 States, for failure to stop after an accident; and 25 States, for reckless driving. Certainly these offenses justify the revocation of licenses in each State.

But the fact of the existence of the accident-prone driver, which is now established beyond reasonable doubt, justifies the suspending or revoking of licenses for much less grave offenses than these enumerated. Twenty-three States have recognized this by providing discretion to suspend or revoke for habitual recklessness or negligence, 22 States provide the same discretionary authority to revoke the license of drivers involved in a serious accident, and 11 States for any sufficient cause. The recognition of the responsibility resting upon the individual driver for accident prevention so far outweighs any other consideration that a sound action program must include, as the most effective weapon of society in attacking the problem of accident prevention, the generally exercised power to revoke drivers' licenses for infraction of the traffic laws.

6. *A highway improvement program divided into two general classes of projects*: (*a*) *Those of the emergency type, and* (*b*) *those for the long-time plan.*—This year the State-wide transport surveys carried on in cooperation between the State highway departments and the Bureau of Public Roads will begin to reach usable form. There will be available for the first time in any State complete information as to the types and conditions of highways, the amount and character of use, and all other information which can conceivably have a direct relationship to the safe use of the highways.

The extent to which highway conditions enter as a contributing factor into more serious accidents is unknown and to an extent indeterminate. Much that has been said in criticism of highway conditions confuses the fundamental issues of highway safety and highway capacity measured by speed and number of units. Between 1925 and 1936 highway usage measured in terms of gasoline consumption increased by an estimated amount of 110 percent, while registration in numbers of units increased 42 percent. The gas consumption per registered vehicle has increased just under 50 percent. From these facts it is apparent that motor vehicles are being used on a steadily increasing rate per average unit, and even with these increases the rate of accidents measured in miles of vehicle operation shows a decrease.

With the definite facts of the public use of highways in every community of the nation, it is readily apparent that the providing of safer highways must be through the elimination over large mileages of those conditions which to the best of our knowledge are most likely to be contributory factors in accidents. This is the keynote to the emergency program which should be put into effect determined by the data of the transport surveys. As an illustration of the type of work included—a rechecking of the system of warning signs and signals, the relocating of these to fit the generally increased speed, the elimination of unnecessary signs, the marking of all curves with safe driving speeds if below the legal limits, the correction of sight distances particularly at intersecting roads, and the widening and maintenance of shoulders.

The increased operating speeds demand wider roads and the narrower widths which were reasonably safe for speeds of a few years ago must be supplemented by nonskid material, the shoulders widened, slopes flattened, and deep ditches eliminated. For the long-time program, particularly for new multiple-lane roads, all the accepted elements of safe design to permit continuous safe traffic flow, including the division of opposing lanes by a neutral area and the elimination of cross traffic, should be provided. Separation of grades between the railroads and important intersecting highways must be a first consideration.

7. *A plan of State and Federal safety organization adequate to secure on a wide scale the adoption and enforcement of the action program here proposed.*—Just how the Federal Government fits into the general scheme of an adequate traffic safety organization is not clear beyond debate, but there are considerations of public policy which prompt the suggestion that no wholly new board, commission, or other Federal authority is desirable. To be effective, such a Federal organization would have to duplicate organization, authority, and operations now lodged in some Federal department. There is need for a correlation of the Federal activities and relationships between the Federal departments themselves, and between the Federal Government and the States in both the official and public aspects. A plan of Federal organization that can be made effective at once and make use of the going operations of the

(*Continued on page 51*)

AN AUTOMATIC RECORDER FOR COUNTING HIGHWAY TRAFFIC

Reported by R. E. CRAIG, Junior Highway Engineer, Division of Highway Transport, United States Bureau of Public Roads

IN PREPARING the initial plans for the State-wide highway planning surveys now being conducted by the highway departments of 43 States in cooperation with the Bureau of Public Roads, it was realized that, in order to obtain anything like complete traffic data for the entire rural mileage, counts on a large part of this system must be made on a limited schedule; and it was believed that continuous records showing typical traffic patterns would be invaluable in estimating traffic from these short counts. In addition, these records were needed to provide a basis for analyzing various daily, weekly, seasonal, and other traffic patterns in determining the relative reliability of various methods of sampling traffic. The need of a better basis than had previously existed for predicting future traffic was still another reason for obtaining continuous records. However, the cost of obtaining such records by manual counts was so great that their accumulation, except in a few experimental operations, could not be justified by the value of the results.

Before the first State-wide highway planning surveys were begun late in 1935, sporadic efforts had already been made to develop a counting and recording machine which would supply traffic records economically. The immediate need for this equipment in conducting highway planning surveys lent sufficient impetus to these efforts to make possible the construction of a satisfactory model in the fall of 1935.

The real problem in constructing a satisfactory automatic traffic recorder was the development of a reliable means of detecting the passage of vehicles, preferably some method which would not involve the use of a detector pad laid on the surface or inset in the pavement, and which could be produced and operated at reasonable cost.

After investigation of available equipment and detailed consideration of a number of suggested methods it was concluded that the most practical method for detecting the passage of a vehicle at permanent installations was the adaptation of the photoelectric cell. This cell is based on the principle that the conductivity of certain elements is proportional to the amount of light falling on the element. Photoelectric equipment for counting purposes had been in use for a sufficient length of time to demonstrate its efficiency and reliability under controlled conditions.

The recorder developed was designed to count passing vehicles without counting pedestrians. This was done by using two parallel beams of light, approximately 30 inches apart, directed across the roadway upon photoelectric cells. A standard photoelectric relay unit is designed as a switch to be operated by the simultaneous interruption of both light beams. This switch (the counter relay) operates the contact which, in turn, controls and operates the counting circuit. Pedestrians normally interrupt only one beam at a time and are not recorded.

The photoelectric tubes are very sensitive and can be adjusted to record vehicles passing at high speeds. The machine is designed to count as many as 24,000 interruptions of the light beams per hour. Infrared ray filters were installed in the light source to render the beams practically invisible, thus eliminating hazard and annoyance to passing drivers. Figures 1 and 2 show one of the types of photoelectric automatic traffic recorders being used in the highway planning surveys. Two types of automatic recorders are shown in figure 3.

The recording mechanism is designed to print on standard adding machine tape once every hour, recording the day, hour, and minute, and the cumulative traffic total. Figure 4 shows a sample section of tape. The number of vehicles passing each hour is obtained by subtracting each total from the succeeding total. Postmeridian time is indicated by a dash under the hour. The recorder is timed by a self-starting synchronous motor of the type used in electric clocks.

The recording or printing circuit is designed so that if the current fails, the recorder will stamp automatically the time of the failure and the cumulative counter reading. In case the recorder clock is found to be slow upon inspection, the time at which the power failure occurred is recorded and the proper corrections can be made to the record if there has been only one interruption of current.

INSTALLATION OF TRAFFIC RECORDER DESCRIBED

Manufacturers can supply machines with auxiliary mechanical clocks to keep the equipment on time in the event of power failures. However, the dependability of the power supply even on rural installations has proved to be such that the additional cost of this equipment has rarely been considered justified.

The recorders now being used count and record the total number of vehicles passing the point at which they are installed. However, they can easily be adapted to count and record only vehicles proceeding in one direction. This can be accomplished by adding relays that will permit electrical impulses to be sent to the counting mechanism only when the beams of light are interrupted in the proper order.

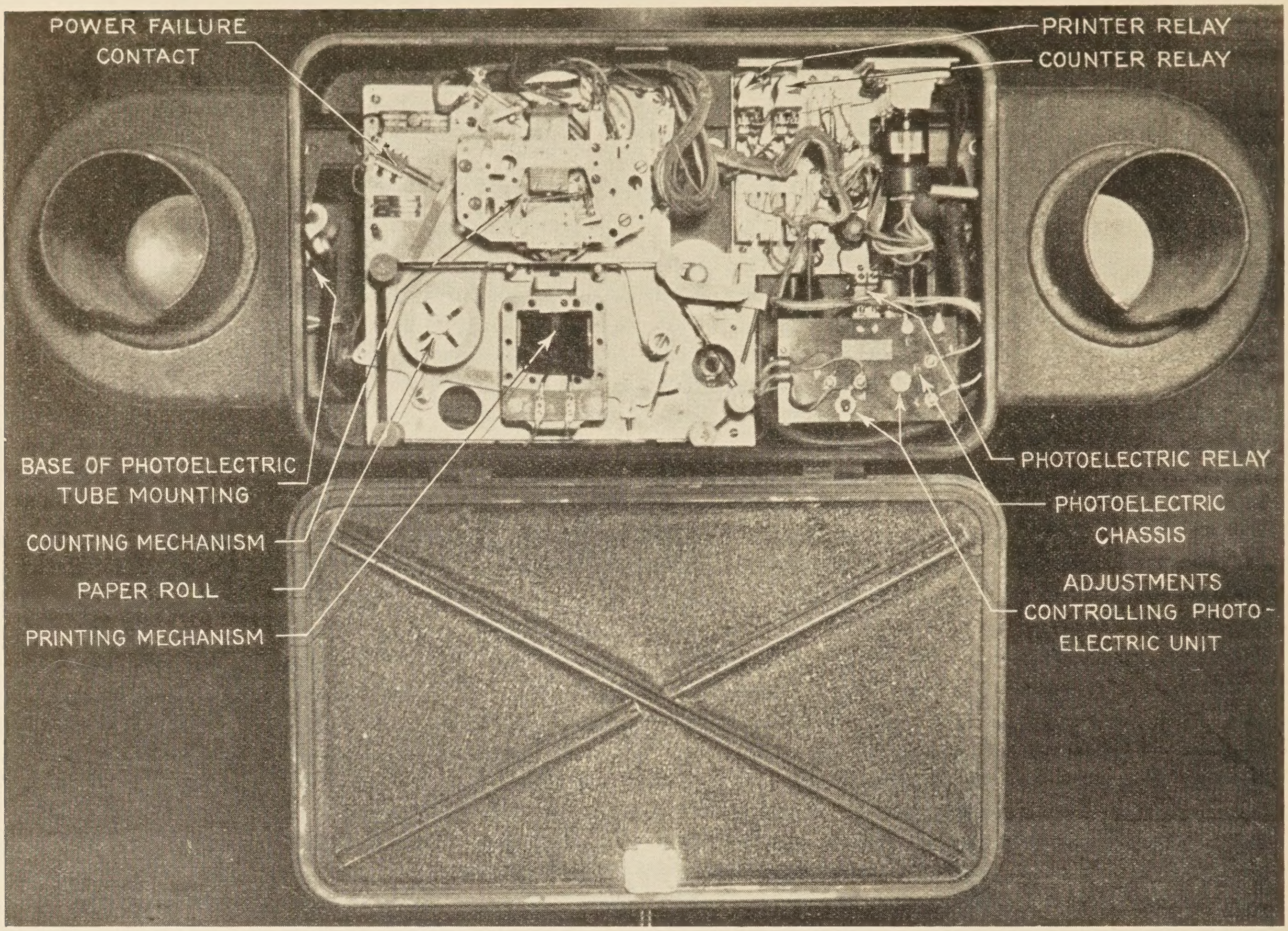

Figure 1.—Recording and Printing Apparatus in One Type of Automatic Traffic Recorder.

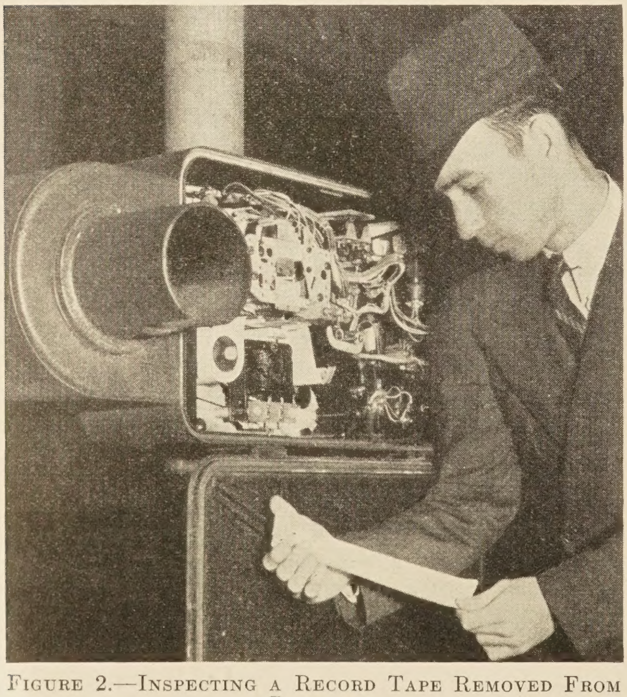

Figure 2.—Inspecting a Record Tape Removed From a Recorder.

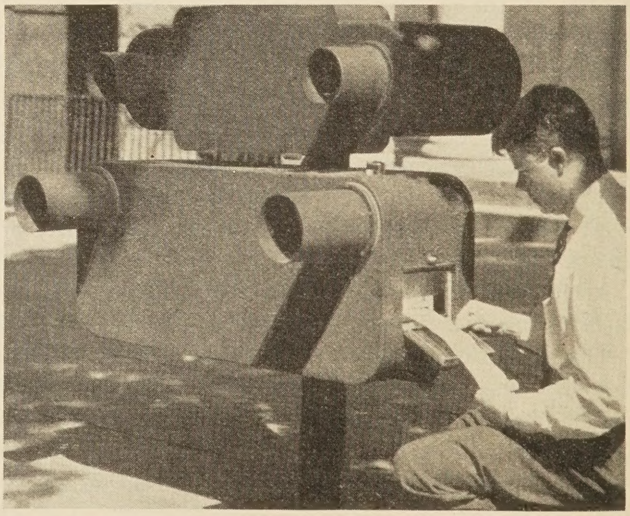

Figure 3.—Two Types of Automatic Traffic Recorders.

In the early experimental work, an effort was made to count trucks and busses independently of the total traffic by placing a third light beam, operating an independent counter, at a sufficient height above the roadway to clear the tops of passenger cars. Satisfactory results were not obtained with this unit, however, because a large number of light trucks are approximately the same height as passenger cars and were not recorded; in addition, an appreciable number of passing trucks were found to be so loaded that each registered two or three times. The count obtained with this device was not accurate and the third beam was not incorporated in the final design of the recorder. No serious effort has since been made to develop a traffic counter that will record trucks and busses independently, as sufficiently accurate estimates of the percentage of truck and bus traffic are ordinarily obtainable by making short manual counts.

The traffic counter operates on single-phase, 110-volt, 60-cycle alternating current and, therefore, is usually installed near electric transmission lines supplying such power and where there is little likelihood of current failure. Installations are usually made away from built-up sections, especially schoolhouses, where there is likely to be a grouping of pedestrians. Groups of pedestrians will frequently interrupt both light beams simultaneously, resulting in extra counts. The number of under-counts, resulting when two vehicles pass simultaneously in front of the recorder and are recorded as one vehicle, is reduced by selecting a location where there is little chance of vehicles traveling in the same direction passing each other, as at a narrow section of the road, on the top of a hill, or on a curve. Installations on 3-lane roads have, as a rule, been made only at points at which vehicles proceeding in the same direction are prohibited from passing. Satisfactory results on 4-lane roads have been obtained where the opposing lanes of traffic are divided and the recorders are installed to count traffic moving in one direction only.

Figure 5 illustrates a typical installation for recorders in ordinary locations. The light source and recording unit are mounted so that the light beams make an angle of approximately 23° with a line transverse to the roadway. By installing the equipment at a skew with the roadway, the projection of the light beam on a vehicle is such that it will not permit the beam to pass between the body of the vehicle and protruding equipment, such as trunks or spare tires. This eliminates a number of extra counts that would be caused by the interruption of the light beams by accessories if the beams were directed perpendicular to the centerline of the roadway. Experience has demonstrated that the proper height of the light beams above the roadway is approximately 3 feet 8 inches. At this height the beams do not pass through the windows of passenger cars, nor do they pass under trucks of ordinary design. When installed on curves the beams should be parallel to the superelevated surface. The specifications under which recorders have been purchased require that the equipment operate satisfactorily with a distance between the light source and receiving unit of 50 feet, and this is usually the maximum distance for field installations. However, the equipment has operated satisfactorily at distances considerably in excess of 50 feet.

The recorder and light source are mounted on posts consisting of 4-inch pipe set in concrete to a depth of 3 feet below the surface of the ground. The concrete is cast around a mold slightly larger than the pipe's outside diameter, and after the concrete has set, the pipe is slipped into the hole and properly secured. Wedges are used, if necessary, to assure rigidity. In some instances, pipe standards having threaded joints at the ground level have been used. The advantage of these methods is that the equipment can be easily moved to a new location when desirable.

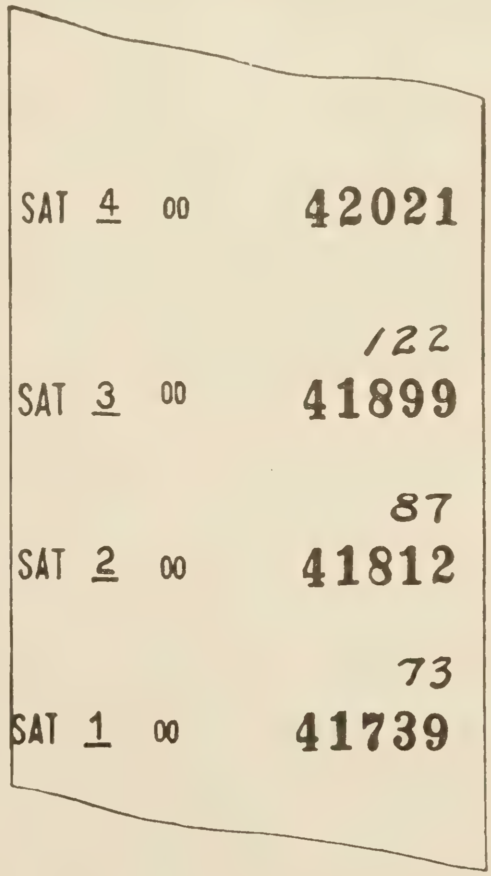

Figure 4.—Section of Record Tape From an Automatic Traffic Recorder.

A box containing a meter, fuses, and master switch, is attached to the power line pole. Connections are made from the master switch to the equipment, wires being run inside the pipe supports wherever possible. If the cross connections are carried over the roadway, care is taken to place them a safe height above the road. In installing cross connections, advantage has been taken of any ready means of carrying the connections under the roadway, such as through a culvert or underneath a bridge. All exposed wires are carried in waterproof conduits. Figure 6 shows a typical automatic recorder installation.

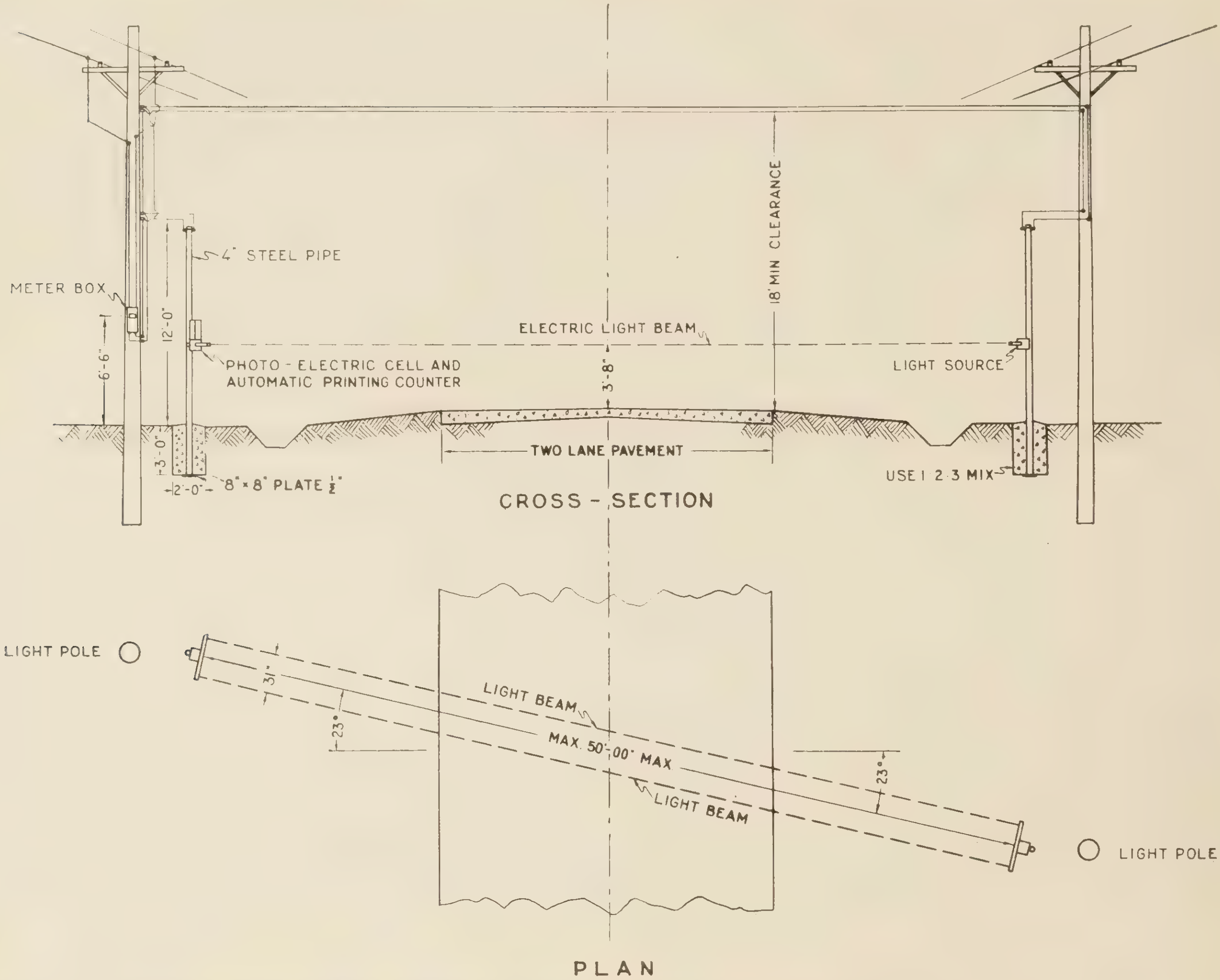

Figure 5.—Typical Arrangement of Equipment in Installing Automatic Traffic Recorders.

Figure 6.—Automatic Traffic Recorder Installation in Michigan. Note Guard Posts to Protect Recorder From Traffic.

Experience indicates that it is advisable to protect automatic recorders by installing them behind existing guard rails or natural barriers. Otherwise, it has been found necessary to install special guard rails to prevent damage to them.

MANY DIFFICULTIES OVERCOME IN OBTAINING SATISFACTORY PERFORMANCE

At the time the majority of the automatic recorders in use in the planning surveys were installed, knowledge of the performance of photoelectric equipment was limited largely to those who had done development work with them. Although the equipment was known to be affected by stray light and the intensity of the light beams directed on the photoelectric cells, many unanticipated difficulties were encountered.

One of the first problems was the abnormally short life of lamp bulbs in the light sources of several installations. For no apparent reason the lamp bulbs in these installations failed to give a reasonable length of service. Investigation led to the discovery that the voltage being supplied was in some instances as much as 20 or 30 volts above the required 110 volts. Untimely lamp failures were eliminated either by requiring the power company to supply the proper voltage or by installing resistance coils in the light source to reduce the voltage supplied to the lamps.

At different periods through the day machines would sometimes fail to count traffic or would record a large number of vehicles when only a few had passed the recorder. Apparently the trouble was not caused by stray light as a number of these failures were occurring at night. The trouble was corrected when methods of focusing the light beams were improved and the size of lamp bulbs used in the lamp source was increased from 32 to 50 candlepower.

In instances where insufficient light reached the elements because of condensation of moisture on the inside of the lenses in the receiving unit, heating elements were installed or a deliquescent substance was placed back of the lens to absorb moisture. These measures, however, did not completely solve all of the problems, as some recorders still performed erratically. A study of the conditions under which the recorders were operating revealed that intermittent operation was now confined largely to machines operating under weather conditions that produced high humidity. Moisture was collecting around the base of the photoelectric tubes, causing a leakage of current that resulted in erratic operation of the counter. To eliminate this leakage, heaters were installed to keep the base of the tubes dry. In extreme cases, connections were coated with beeswax to insulate exposed surfaces and prevent current leakage.

Although stray light and humidity produce the same type of counting failures as insufficient light, adjustment of the photoelectric equipment must be carefully made, or, in remedying one condition, the other will be accentuated. The operation of the photoelectric relay depends upon the amount of current passing through the photoelectric tubes dropping below and rising above certain critical values. If the conditions under which the equipment is operating are such that the proper change of current does not occur when the light beams are blocked, the relay may fail to operate, giving no count, or it may not operate positively, causing the contacts to "chatter" and produce extra counts.

The solution of the problem required: (1) That the best possible adjustment of light beams be made; (2) that some provision be made to eliminate excess moisture and stray light where the machines were subjected to an exceptional amount of either; and (3) that the photoelectric equipment be adjusted to provide adequate factors of safety against failure by insufficient light and stray light or humidity.

It is apparent from the map in figure 7, which gives the locations of the 344 automatic traffic recorders now in operation, that this equipment is required to operate under wide ranges of temperature. Occasionally machines in the north are subjected to temperatures of 40° F. below zero, and in some desert regions to temperatures as high as 126° F. Like all machines required to operate under wide ranges of temperature certain precautions must be taken to insure satisfactory operation under extreme conditions. To prevent the stopping of the clock because of the congealing of oil in the rotor in cold weather, heaters are furnished and recommended for use whenever the machines are subjected to temperatures below freezing. However, cases have been found where machines have operated at 5° below zero without the aid of heaters. To accomplish this, the machines must be in perfect adjustment.

In one region it was found desirable and economical to use an insulated housing for the recorder. Experiments to determine the most economical combination of heaters to use under different temperature conditions showed that three heaters (one in each arm of the periscope, and one in the recorder box) would maintain a temperature difference of 42° F. between the recorder mechanism and the outside air, when the machine was enclosed in an insulated housing. This would be necessary only in subzero weather, and it is recommended that only the heaters in the periscope be used in moderately cold weather.

Extreme heat will also affect the operation of the recorder. The caesium on the cathode of the photoelectric tube will vaporize under temperatures in excess of 150° F., and sufficient current will flow through the tube, even when there is no light on it to prevent the operation of the photoelectric relay. Old tubes are affected in the same manner at temperatures less than 150° F. The recorder would be subject to such extreme heat only in exceptional cases. One State has reduced

FIGURE 7.—LOCATIONS AT WHICH AUTOMATIC TRAFFIC RECORDERS ARE BEING OPERATED IN CONNECTION WITH THE STATE-WIDE HIGHWAY PLANNING SURVEYS.

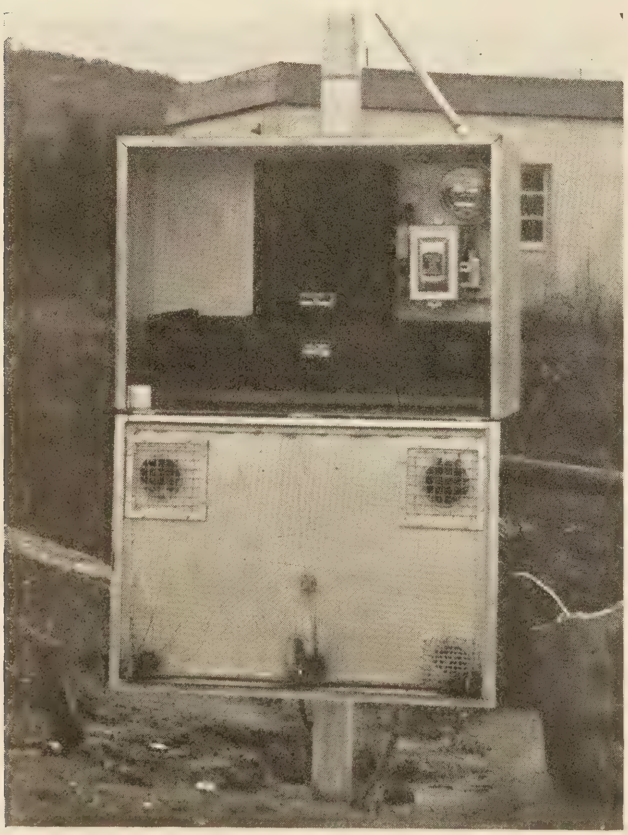

FIGURE 8.—AUTOMATIC TRAFFIC RECORDER INSTALLED IN AN ALUMINUM BOX FOR PROTECTION AGAINST HEAT.

the likelihood of difficulties from this source by enclosing the recorders in aluminum boxes. The box, as shown in figure 8, provides a dead air space which acts as insulation around the recorder, and the light-colored surface reflects rather than absorbs heat.

IMPROVED MAINTENANCE HAS INCREASED EFFICIENCY OF MACHINES

Heat also affects the infrared ray filters, causing them to fade because of the melting and running out of the gelatinous substance between the parallel glass plates. A new type of filter, consisting of a single glass plate, is now being used to replace the old filters when failures occur.

In one instance, a short time after a State had begun operating automatic recorders it was found that one of the machines was not recording traffic from late afternoon until morning. A check of the machine showed it to be in perfect working order, but when inquiry was made of people living in the vicinity, it developed that the recorder interfered with their radio reception and someone was blocking the light beams to prevent this disturbance. As soon as the State devised and installed a filter that eliminated radio interference, the recorder was no longer molested and produced satisfactory 24-hour records. Since that time provision has been made for elimination of radio interference, wherever necessary, at the time of installation.

In a few instances States installed automatic traffic recorders with the receiving units facing north to minimize the effect of stray light. It was found that during certain hours on bright days light-colored vehicles passed the machines without being counted. The phenomenon is accounted for by the fact that the light-colored vehicles will, during certain hours of the day, reflect enough light to replace the usual light from the light source of the recorder so that the machine fails to record the vehicle. However, the resulting errors were insignificant, because the time during which they occurred was limited and the number of light-colored vehicles on the highways was negligible. Any errors of this nature may be eliminated, however, by installing the receiving unit so that light cannot be reflected into the lens of the receiving unit by passing vehicles.

In the new models of automatic traffic recorders, all weaknesses in the early equipment have been considered and provisions are being made to eliminate them. In a counter recently developed the effects of both reflected and stray light are reduced by using an amplifying unit designed for use with "chopped" light. The chopped light is produced by placing the light source behind a shutter which is rotated at high speed. Reflected light will not replace the usual light supplied by the light source; and reflected light, therefore, cannot affect the operation of the counter.

The automatic traffic counters were probably the first photoelectric equipment ever installed to operate over a wide range of climatic conditions. To obtain satisfactory operation of the machines, it was necessary that each be adjusted for the particular range of conditions to which it was exposed. The making of these adjustments required a thorough knowledge of the operation of photoelectric equipment. Schools in a number of conveniently located cities were, therefore, conducted by the manufacturer who had the first contract to furnish machines. These schools were attended by representatives of all but two of the States in which machines were installed at that time. Performance improved so rapidly that the average operating efficiency of the machines throughout the country rose from approximately 66 percent to approximately 88 percent during the first month's operation after conducting the schools, and since that time the operating efficiency has been steadily increasing.

Improved methods of maintenance were developed at the schools with the result that good records have since been obtained at low cost. The method most generally used involves the appointment as supervisor of some person who has attended or has had special instruction similar to that given at the schools. The supervisor, who is usually assigned other duties in addition to those connected with the maintenance of this equipment, maintains a central headquarters and visits the machines only when notified by local representatives that the equipment is not operating properly. No other person is permitted to make repairs or replacements of any parts except burned-out bulbs, which may be replaced by certain local representatives of the State.

Although the supervisor is the only one permitted to make repairs, local representatives of the State, such as maintenance employees, State police, or other State employees who pass the recorder in regular line of duty, are instructed to observe the machines at such times to determine if they are functioning. If no click is heard when a vehicle passes, the main office is advised immediately and the supervisor is sent to make repairs. Arrangements are also made for some local employee to remove and forward the record tape to the central office once a week. This same employee is instructed in the method of making certain minor adjustments, and he also replaces the bulbs in the light source at periodic intervals to prevent failure caused by burned-out bulbs.

MACHINE COUNTS CHECK CLOSELY WITH MANUAL COUNTS

In maintaining the machines it should be remembered that while interruptions in operation which prevent the accumulation of records for considerable periods of time are serious, minor interruptions which cause the loss of only a few hours of record or even the occasional loss of a day or two of records will not seriously affect the value of the results obtained. In spite of short interruptions, enough information is usually available on which reliable estimates of the missing counts may be based so that the effect on the final results is negligible.

Some States that keep accurate records of the performance of their recorders have found that where machines are adequately maintained, the average operating efficiency of all machines in the State will exceed 95 percent. Individual machines frequently operate at 100 percent efficiency as long as 3 or 4 months at a time. Collisions, power and equipment failures, and other factors, any one of which will discontinue operation of the recorder, prevent an efficiency of 100 percent over an extended period of time.

There are two sources of error in results obtained by the photoelectric type of traffic recorder that should be mentioned. The simultaneous passage of two vehicles is recorded as one vehicle. Offsetting this, single vehicles with peculiar bodies or with large openings on the body, such as tractor-truck semitrailer combinations, are frequently recorded twice or more. These errors tend to compensate each other and check counts indicate that generally the machine count is within 1.5 percent of the actual traffic. Since the object in using automatic traffic recorders is to obtain records from which traffic trends can be determined, slight errors of this nature do not impair the value of the record.

It has been found that as a general rule automatic traffic counters record quantities in excess of actual figures. The accuracy of the automatic count also appears to vary with the volume of traffic, more accurate results being obtained on heavily traveled roads than on lightly traveled roads. The explanation for this is that the percentage of peculiarly shaped vehicles (farm machinery, etc.) is highest on lightly traveled roads, and also that more vehicles pass simultaneously in front of the recorder on heavily traveled roads, causing overcounts to be more nearly balanced by undercounts.

When properly adjusted, a machine may be relied upon to operate continuously with the same percentage of error, the amount of which is determined by the type of traffic peculiar to the location. In contrast, individuals are known to differ in their ability to count the number of vehicles passing a given point. These differences can be attributed to the fact that when an individual counts traffic for a considerable period of time, he cannot maintain the same degree of accuracy because of the monotony of the task.

Table 1 shows the results of manual counts made to check a number of automatic recorders located at different points throughout the country.

TABLE 1.—*Comparison of automatic traffic recorder counts and manual counts of traffic made to check their accuracy*

Length of count	Count made— Manually	Count made— Mechanically	Difference
Hours	*Vehicles*	*Vehicles*	*Percent*
21	6, 464	6, 445	0. 29
11	2, 704	2, 708	. 15
13	2, 001	1, 998	. 15
13	1, 372	1, 372	----
11	811	829	2. 22
9	770	782	1. 56
16	569	599	5. 27
2	529	540	2. 08
13	450	454	. 89
9	371	386	4. 04
3	344	342	. 58
3	327	336	2. 75
2	318	321	. 94
4	224	224	----
2	219	221	. 91
3	144	148	2. 78

As a result of manual counts made in one State it was suggested that a special circuit be designed for use in automatic recorders located on roads carrying little traffic. This circuit would control the counting mechanism in such a manner that once both light beams were blocked and a count made, another count could not be registered until both light beams were again free. This would help to prevent overcounts on little-traveled roads. A special circuit for such use is already being developed. This circuit will make it possible to obtain more reliable counts on roads carrying a large number of horse-drawn vehicles.

In order to provide a convenient system for tabulating figures taken from machines, the record card shown in figure 9 was developed. On the back of the first weekly record card for each recorder a detailed sketch of its location is made. Under "Remarks" any unusual conditions that may affect traffic are entered. Data obtained directly from the tapes of properly operating recorders are entered in black ink. All estimated data for periods when the machine is known to be functioning improperly are entered in red ink. Thus, when an analysis of the records is made, the analyst has before him in a convenient form practically all of the information needed.

Form 24 H. P. S.

SOUTH CAROLINA
AUTOMATIC TRAFFIC COUNT RECORD

Station 2 County Darlington

Location On US Rts. 15 & 52, Primary System, 1.8 miles South of Society Hill Week Beginning April 18, 1937

DAY	SUN.	MON.	TUES.	WED.	THUR.	FRI.	SAT.	TOTAL
Date	18	19	20	21	22	23	24	
Hour			A. M.					
12- 1	22	25	23	13	25	29	15	152
1- 2	19	23	17	17	20	13	18	127
2- 3	21	11	12	26	15	11	19	115
3- 4	12	11	19	25	11	12	7	97
4- 5	14	21	18	8	12	18	14	105
5- 6	18	16	16	27	25	17	22	141
6- 7	34	41	27	50	41	45	30	268
7- 8	30	51	41	59	55	71	56	363
8- 9	61	69	68	115	92	104	62	571
9-10	97	71	108	104	116	45	99	640
10-11	115	94	125	90	122	98	73	717
11-12	110	85	97	82	93	100	91	658
				P. M.				
12- 1	77	78	91	92	77	84	101	600
1- 2	90	104	98	123	81	93	97	686
2- 3	127	83	85	144	123	95	95	752
3- 4	145	92	81	115	117	106	98	754
4- 5	147	91	121	127	95	109	90	780
5- 6	178	104	119	111	98	102	71	783
6- 7	151	95	83	80	73	88	69	639
7- 8	108	65	46	63	74	87	38	481
8- 9	70	40	41	45	52	81	50	379
9-10	77	36	28	26	38	45	23	273
10-11	68	36	47	32	36	36	14	269
11-12	60	39	38	31	34	45	25	272
Total	1851	1381	1449	1605	1525	1534	1277	10622
% Aver. Wk. Day	121.9	91	95.5	105.8	100.5	101.1	84.2	
Weather Condition	Fair	Fair	Partly Cloudy	Partly Cloudy	Fair	Fair	Rain	

REMARKS:

FIGURE 9.—SAMPLE WEEKLY RECORD CARD USED IN TABULATING DATA OBTAINED BY AUTOMATIC TRAFFIC RECORDERS.

COUNTERS PLACED AT CAREFULLY SELECTED LOCATIONS

The best method of estimating missing data for comparatively short periods will depend upon the particular circumstances. When the record for part of a day is lost, but the record for the rest of the day is adequate, an effort should be made to establish the relationship between the available data for that day and the data for the corresponding days in each of the two preceding and each of the two succeeding weeks. These relations can then be used to obtain a reasonably accurate estimate of the required data.

Ordinarily, the hourly distribution and volume of daily traffic from Monday through Friday is fairly uniform for a given road. Therefore, when data are missing for a short period on one of these days, a safe estimate can often be made by simply averaging the counts for the corresponding hours shown for the other 4 days of the same week.

To obtain the most valuable records by the use of automatic traffic recorders, it is essential that the recorders be properly located. In selecting locations the special uses to which the data are to be adapted must be considered. These uses generally are:

1. To aid in expanding sample counts that are obtained at other points on the highway system.

2. To provide a basis for analyzing various daily, weekly, seasonal, and other traffic distributions, or "patterns" in connection with determining the relative reliability of various methods of sampling.

3. To provide a basis for predicting future traffic.

In addition, there are a number of other uses which may be made of automatic traffic recorder data. Records obtained by these machines will: Provide a means of studying the relations between Sunday traffic volumes and weekday traffic volumes during the year; aid in studying the frequency distribution of daily traffic volumes; and assist in investigating traffic fluctuations produced by the opening of new roads or improvement of old roads. Specially equipped machines are now being used to study fluctuations within the hour.

To accomplish these purposes with a minimum number of machines, special care must be taken to locate the recorders so that each traffic pattern developed from a continuous record will be typical of a certain class of traffic. This suggests that the first step is to classify all roads according to the class of traffic carried; that is, tourist, farm-to-market, combination tourist and farm-to-market, metropolitan, etc. The next step is to pick typical locations for each classification at which it will be easiest to isolate the effect of the predominant class of traffic.

Probably the most important use of data recorded by automatic traffic recorders is to furnish a basis for establishing fundamental traffic trends and determining normal traffic patterns. These trends and patterns are of great importance in connection with predicting future traffic and in checking the dependability of various methods of sampling traffic.

Complete data for a considerable period of time are required to determine normal traffic patterns. A seasonal traffic pattern, for instance, is not merely a curve showing seasonal variations in traffic for a certain year, but it is a traffic pattern based upon counts made for several years. This pattern will indicate the usual seasonal variation together with the degree to which it may be expected to vary from year to year. Similarly, traffic patterns must be determined for days of the week, hours of the day, and in certain cases, intervals during each hour. A traffic pattern cannot be considered as fixed, as changes are constantly occurring.

Additional phases of this problem may be indicated by pointing out that in order to determine the normal seasonal traffic variation at a certain location, it is necessary to know the underlying growth tendency (secular trend) as indicated by records over a considerable number of years. Obviously the normal distribution of traffic by days of the week or hours of the day cannot be determined without, at the same time, determining seasonal variation. Once normal trends and patterns are established, it will be possible to isolate the influences of general and local economic conditions and often unusual factors influencing traffic patterns can be identified. Data collected by hours over a period of several years also serve as a basis for determining schedules for taking limited samples that will yield satisfactory results.

The greatest progress in ascertaining the influence of general and local conditions upon traffic can be made by keeping the machines at fixed locations for long periods of time. Therefore, automatic recorders should not be moved from one location to another unless the number of available recorders is so small that they can be used only to develop factors for the expansion of short counts. Expansion factors obtained in one year and applied to short counts obtained in another are of questionable reliability, especially where there is no reliable information regarding the secular trend of the traffic patterns on these roads.

COUNTER RECORDS USED IN EXPANDING MANUAL COUNT DATA

In connection with the problem of deriving factors to be used in expanding short manual counts obtained at many points, it is desirable to obtain answers to the following questions for each available set of data:

1. What is the relation between the number of vehicles passing during the period of the day when the manual counts are scheduled, and the number of vehicles passing during the entire 24-hour period?

2. What is the relation between the average daily traffic from Monday to Friday and the average daily traffic for the whole week?

3. What are the relations between the average daily traffic for each month and the average daily traffic for the year?

Since these basic relations are desired for traffic passing each machine, it is convenient to arrange the data in forms similar to the partially filled forms shown in figures 10 and 11.

On different classes of roads, these relations are found to be quite different. By classifying the influences that are known to account in part for the variations in the relations, and by modifying the relations in accordance with the data obtained at manual control stations where a number of repeat counts are obtained at intervals throughout the year, a number of classified groups of expansion factors are obtained. From these groups of expansion factors, those applicable to a single route where short sample counts have been made can be selected and applied.

Arrangement of the data in the form shown in figures 10 and 11 also facilitates investigation of the relative reliability of various methods of sampling traffic. In studies of this type, it is assumed that counts have actually been made on the schedule being investigated, with the first count on the schedule beginning on the first day

PENNSYLVANIA

Station: E-382

Automatic Recorder Data for One Month by Days of the Week

Relationship between the 8 a.m. to 4 p.m. traffic and the 24-hour traffic

Route: Pa. 284

Month: March 1937

Day of the week and date	Traffic 1/ 24 hours	Traffic 1/ 8 a.m. to 4 p.m.	Percentage 8-4 traffic is of 24-hour traffic	Other data and remarks
	Vehicles	Vehicles		
Sunday - March 7	648	335		
14	310	164		
21	542	233		
28	508	279		
Total	2008	1011	50.35	
Monday - March 1	351	138		
8	327	132		
15	281	150		
22	323	140		
29	323	140		
Total	1605	700	43.61	
Tuesday - March 2	386	194		
9	318	136		
16	255	141		
23	304	120		
30	307	137		
Total	1570	728	46.37	
Wednesday-March 3	505	234		
10	286	121		
17	152	77		
24	450	165		
31	301	123		
Total	1694	720	42.50	
Thursday - March 4	799	399		
11	305	137		
18	369	192		
25	363	159		
Total	1836	887	48.31	
Friday - March 5	355	162		
12	361	151		
19	320	123		
26	354	194		
Total	1390	630	45.32	
Saturday-March 6	436	197		
13	414	170		
20	525	255		
27	434	194		
Total	1809	816	45.11	
Total				
4 Sundays	2008	1011		
23 Weekdays	8095	3665		
4 Saturdays	1809	816		
Average				
Sunday	502	253	50.4	
Weekday	352	159	45.2	
Saturday	452	204	45.1	
Adjusted average day for the month 2/	388	179	46.1	

1/ When machine failures have necessitated estimates for an entire day, do not enter estimated figures; however, figures for a day which include reliable estimates for only a portion of the day should be entered.

2/ Computed by the formula $\frac{5A + B + C}{7}$ (A represents average weekday; B, average Saturday; and C, average Sunday) to provide correct weighting in the event of extra Saturdays or Sundays, or missing data. This average may differ slightly from that obtained by dividing the total number of vehicles for the month by the number of days in the month.

FIGURE 10.—FORM USED IN SUMMARIZING EACH MONTH'S TRAFFIC DATA.

Route: Pa. 284 PENNSYLVANIA Station: E-382

Automatic Recorder Data by Months Year: 1937

A yearly record by months showing: (1) the number of vehicles for the average weekday and for **the adjusted daily average;** (2) the percentage that the adjusted daily average is of the **average weekday;** (3) the percentage that the adjusted daily average of each month is of the adjusted daily average of the year, and (4) the percentage that the 8 a.m. to 4 p.m. traffic is of the 24-hour traffic for Sunday, Monday to Friday, Saturday, and Sunday to Saturday.

Factors influencing the traffic pattern:

Type of traffic 1/ ____________

Percent passenger cars 2/ ____________ Percent foreign vehicles 2/ ____________

Remarks 3/ ____________

Month	Number of vehicles		Percentage the adjusted daily average is of the average weekday	Percentage the month daily average is of the year daily average	Percentage that the 8 a.m. to 4 p.m. traffic is of the 24-hour traffic			
	4/ Average weekday (Monday to Friday)	5/ Adjusted daily average (Sunday to Saturday)			Sunday	Monday to Friday	Saturday	Sunday to Saturday
1937								
January	274	297	108.4	69.1	48.8	42.7	45.1	44.1
February	287	326	113.6	75.8	50.4	43.2	44.3	44.8
March	352	388	110.2	90.2	50.4	45.2	45.1	46.1
April	306	349	114.1	81.2	53.6	43.8	44.2	45.8
May	391	489	125.1	113.7	42.6	45.0	41.8	43.8
June	437	569	130.2	132.3	35.5	45.8	31.5	40.6
July	383	528	137.9	122.8	34.3	38.9	35.0	36.7
August	385	593	154.0	137.9	30.7	36.9	29.7	33.4
September	366	498	136.1	115.8	39.5	42.1	41.0	41.0
October	331	392	118.4	91.2	46.8	40.8	44.0	42.6
November	341	380	111.4	88.4	51.5	45.7	48.6	47.4
December	314	353	112.4	82.1	51.2	48.4	44.4	48.4
Daily average for the year	6/ 347	6/ 430	123.9	--	7/ 41.1	7/ 43.1	7/ 40.3	7/ 42.1

1/ Interstate, recreational, suburban, coal hauling, farm-to-market, etc.

2/ Insert when available.

3/ Such as: "Almost exclusively farm-to-market traffic in a community where there is little night travel and an unusual number of horse-drawn vehicles."

4/ Average of all days of the month except Saturdays and Sundays.

5/ Adjusted daily average for the month, including Saturdays and Sundays, computed by the formula $\frac{5A + B + C}{7}$. See footnote 2 on the preceding table.

6/ Ideally the daily average for the year would be obtained by dividing the annual total by 365, but inasmuch as 100 percent complete data are not always available, the suggested method is to divide by 12 the sum of the adjusted daily averages for the months without regard for the varying lengths of the months or the varying ratios of Saturdays and Sundays to weekdays. This procedure will result in a close approximation to the ideal figure.

7/ Similar to note 6 above, the preferred method of obtaining the percentage that the yearly 8 a.m. to 4 p.m. traffic is of the yearly 24-hour traffic would be to divide the total 8 a.m. to 4 p.m. traffic by the total 24-hour traffic, but, in order to prevent unrepresentative weighting of months with complete data as compared with months with partial data, the sum of the daily average 8 a.m. to 4 p.m. traffic for the 12 months is divided by the sum of the daily average 24-hour traffic for the 12 months to obtain this percentage.

FIGURE 11.—FORM USED IN SUMMARIZING TRAFFIC DATA BY MONTHS.

of the year. By advancing the date of initial operation successively to each day throughout a complete period, a group of samples can be obtained which, when expanded according to the best available methods, can be studied by various statistical methods to obtain some measure of the reliability of the sample. This same procedure can then be extended to other proposed sampling schedules. After the relative reliability of a number of schedules is known, future traffic surveys can be planned so as to obtain the desired information in the quickest and most economical manner.

Because the automatic traffic recorders have been in use but a short time, the records are as yet inadequate to enable determination of normal seasonal patterns, or the causes of deviations from the normal patterns. Such determinations will be necessary, however, in connection with the isolation of individual influencing factors. After the effects of each of a number of factors can be distinguished, it is hoped that roads can be scientifically classified into groups having like traffic characteristics. When this is done, many of the changes in the flow of traffic may first be identified, and later predicted.

Figures 12, 13, and 14 show typical traffic patterns developed from records obtained by automatic recorders.

COST OF OPERATING COUNTERS DISCUSSED

A recent survey disclosed the average cost of operating one automatic recorder at a rural location for a month to be as follows:

Overhead	$3. 69
Supervision	4. 04
Maintenance:	
Labor	6. 57
Subsistence	2. 48
Travel	8. 51
Power	4. 05
Supplies, etc	2. 20
Total	23. 81
Preparation of records [1]	7. 86
Grand total	39. 40

Costs of operating recorders at urban locations would probably be less because of reduced travel distance and lower power rates.

The average cost of installing one machine is $124.67. This cost varies widely, depending on the amount of travel required to reach the location.

The yearly cost of obtaining traffic counts by the automatic traffic recorders is small when compared

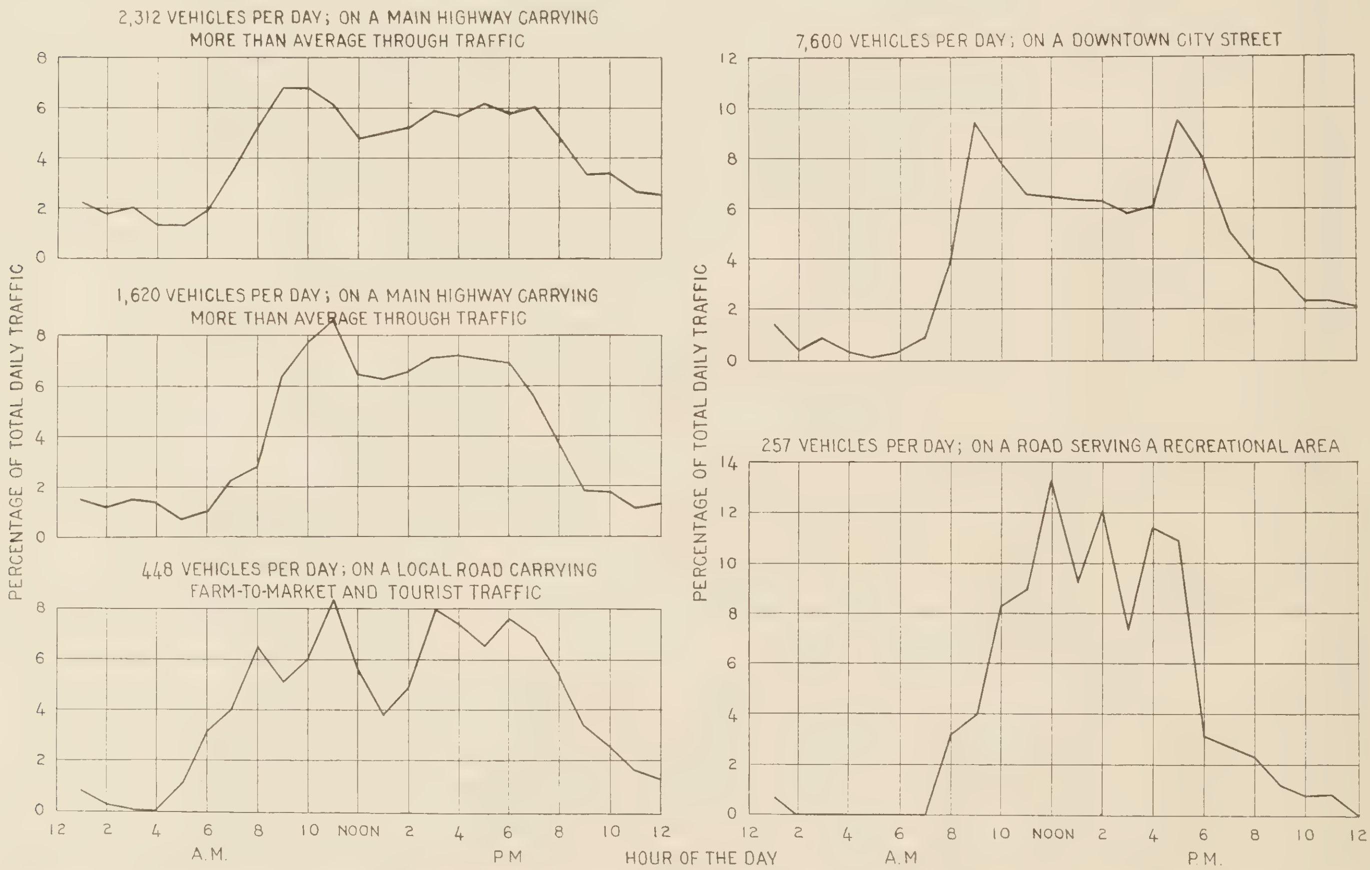

FIGURE 12.—EXAMPLES OF HOURLY VARIATIONS IN TRAFFIC VOLUME ON ROADS CARRYING DIFFERENT CLASSES OF TRAFFIC DURING 1937.

[1] Preparation of records covers the cost of transferring figures from record tape to permanent card forms.

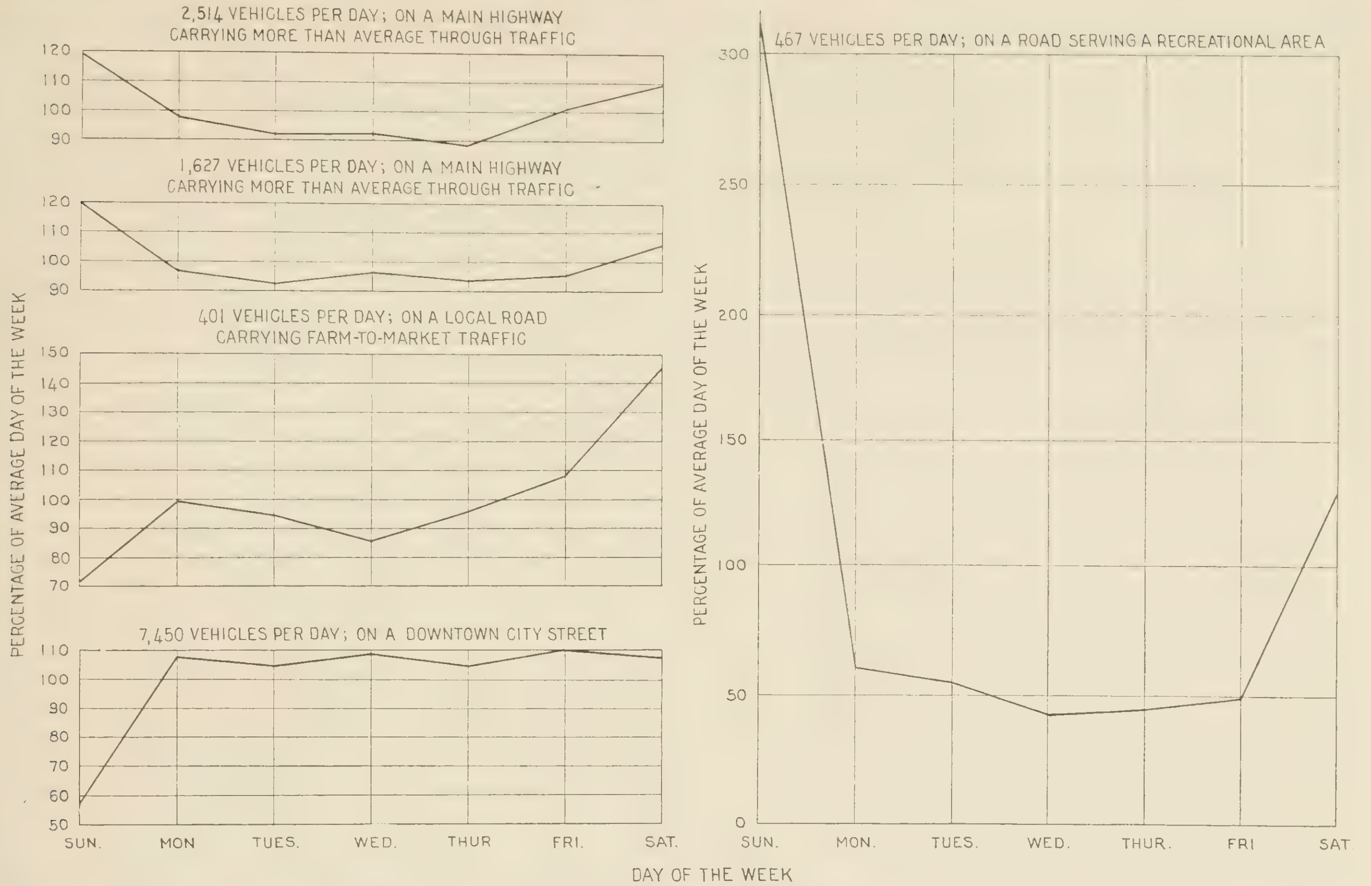

FIGURE 13.—EXAMPLES OF DAILY VARIATIONS IN TRAFFIC VOLUME ON ROADS CARRYING DIFFERENT CLASSES OF TRAFFIC DURING 1937.

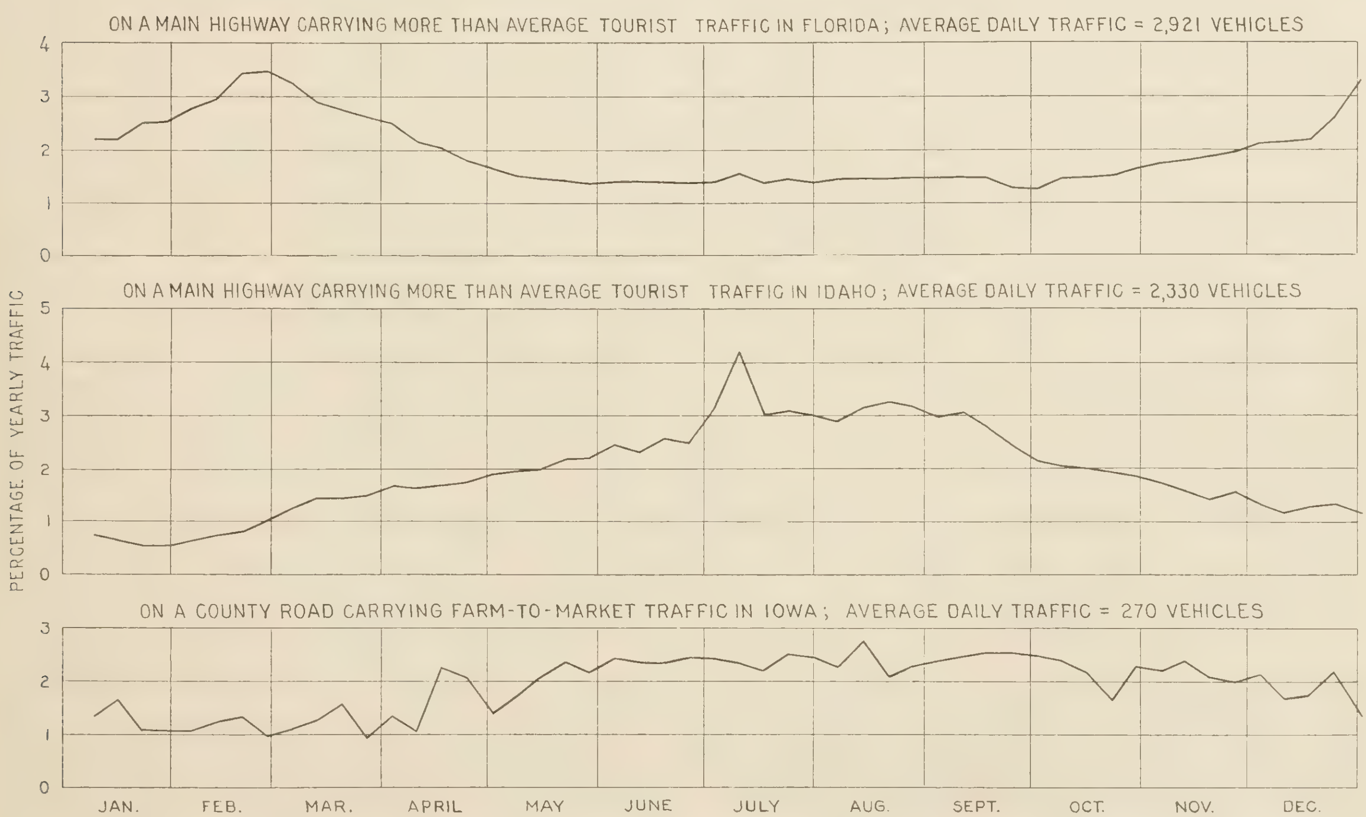

FIGURE 14.—WEEKLY VARIATIONS IN TRAFFIC VOLUME ON ROADS CARRYING DIFFERENT CLASSES OF TRAFFIC DURING 1937

with the cost of obtaining the same record manually. The following is an estimate of the annual cost of operating the average automatic traffic recorder:

Depreciation (based on assumed 5-year life and average first cost of $406.00)	$81.20
Installation (based on 5-year period and average installation cost of $124.67)	24.93
1 year's operation costs at $39.40 per month	472.80
Total	$578.93

The estimated yearly cost of obtaining the same record manually is between $6,022.50 and $8,212.50. This estimate is based on reliable figures, which show that the average cost of making an 8-hour count ranges between $5.50 and $7.50.

Before comparing the cost of counting traffic manually with the cost of automatic counting, it should be pointed out that a man stationed at an intersection can count traffic on all roads entering the intersection, whereas an automatic counter obtains a count for only one road. In addition, manual counts will give the composition and direction of traffic flow. However, as automatic traffic recorders are used to obtain continuous records, where the number of vehicles passing a point by time intervals is the information desired, and because only occasionally will more than one distinctive yet representative traffic pattern be obtainable at an intersection, the estimated cost of obtaining such records by the two methods may be compared. On the basis of these estimates, approximately 10 to 14 years' records could be obtained by the use of automatic traffic recorders for the cost of obtaining 1 year's manual record. As the number of automatic traffic recorders in operation increases and methods of inspection and collection of records are improved, the cost of operating each machine will probably decrease.

Considering the economy of the automatic traffic recorders, it might be asked why machines are not used exclusively. One reason is that in traffic surveys it is not enough to determine only the number of vehicles which use the highways. It is generally desired to classify the vehicles as passenger cars, trucks, tractor-trucks and semitrailers, and busses. Moreover, another classification distinguishes between those vehicles having license tags from States other than that in which they are observed, commonly called "foreign" vehicles, and those vehicles having license tags of the State in which they are observed, commonly called "local" vehicles.

Thus, a comprehensive traffic survey makes necessary numerous manual counts. However, it is believed that the most economical and desirable plan for conducting traffic surveys would be one in which most of the actual counting would be done by machines, and manual counting would be restricted to a minimum number of counts at a few control stations, all of which would be operated for the purpose of obtaining the necessary samples of classified traffic. Ratios between the various types of vehicles observed at the manual control stations could then be applied to all the vehicles counted by the machines.

ATTEMPTS BEING MADE TO DEVELOP PORTABLE COUNTERS

The automatic traffic recorder which has been described was designed for permanent installation to provide continuous records for long periods of time. The installation expense and electric power requirements of these machines make it impossible to extend their use to assist in accumulating the desired sample counts at thousands of points throughout a State, or in connection with a city traffic survey at hundreds of points within a city. Attempts to develop a satisfactory, low-cost, portable automatic recorder for this work have been in progress for a number of years. Efforts have been intensified since 1936 when many of the States began their planning surveys.

The most difficult problem encountered in the attempt to develop portable machines has been that of designing a suitable detecting unit that could operate economically as a self-contained unit. Efforts have been made to develop a suitable road switch, consisting of two pieces of spring steel, separated at intervals by spacers and encased in rubber. The road switch is placed on the road surface and is connected to a storage battery and counting unit. An electrical impulse actuates the counting unit each time the wheels of a passing vehicle press the spring steel strips together.

Only recently the Bureau has been experimenting with an air switch, which consists of a small rubber tube and diaphragm arranged to operate an electrical contact. The tube is placed on the road surface and, when compressed by the wheels of a vehicle, sufficient air is displaced to move the diaphragm. The movement of the diaphragm causes an electric contact to actuate a counting mechanism. This type of switch offers attractive possibilities.

Portable machines utilizing either the contact switch or the air switch may soon be available. However, experiments with such devices have been confined to paved roads. The problem of adapting them to unpaved roads still remains to be solved if these machines are to be of more than limited value in counting traffic. This consideration, of course, is unimportant in connection with city traffic surveys. The road switch detecting unit appears ideal for city traffic counts because of its ability to detect vehicles traveling in the same direction in different lanes, even when one vehicle lags only slightly behind the other. Also, whenever desired, road switches could be installed in a single traffic lane, or a group of machines could be installed, each of which would record traffic moving in a single lane.

A portable automatic recorder with a single-beam photoelectric detecting unit, operated by batteries, has recently been designed. It is expected that a model of this machine will soon be constructed and ready for testing. This machine offers particularly attractive possibilities for use on unpaved rural roads, and may be the means of effecting a considerable saving in the cost of future traffic surveys.

Numerous attempts have been made to develop detecting units of other types, including the use of hydraulic tubes on the road surface, sound equipment, and magnetic circuits, but thus far none of these attempts has proved successful.

The requirements of a satisfactory portable machine have been considered to be:

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

SUMMARY

Experience in the development and use of automatic traffic recorders indicates that they are a practical means of obtaining traffic records needed in planning future highway and street improvements. Present developments can be summarized as follows:

1. Three hundred and forty-four automatic traffic recorders located on all types of roads are now in use throughout the country, accurately counting and recording, hour by hour, all passing vehicles.
2. Records now being obtained from automatic traffic recorders are making available to traffic engineers, for the first time, complete traffic records for a large number of selected points which can be used in studying the fluctuations in traffic flow.
3. With a knowledge of the fluctuations in traffic flow, engineers can arrange future schedules for counting traffic to produce the most accurate results at minimum cost.
4. When records are obtained over a period of years, predictions of future traffic volumes and future traffic requirements can be made with much greater accuracy than is possible today.
5. A valuable basis is being provided for deriving and checking factors for expanding short counts being made in the current State-wide highway planning surveys.
6. Present developments in the field of portable automatic traffic recorders indicate that it is reasonable to expect that in the near future machines will be used extensively in making traffic counts.
7. Machines are well adapted to use in connection with city traffic surveys, and it is probable that they will be used extensively in cities in the future.

An Action Program to Advance Safety on the Highways

(Continued from page 36)

Government would be the establishment of an interdepartmental committee with representatives assigned from all of the Federal organizations which now have authority over, and responsibility for, elements of the safety problem under the Federal laws. In addition to this official organization there should be an advisory committee composed of representatives of the important national associations which are engaged in the traffic safety field in its broad aspects. This plan, together with the plan of organization of the State safety authority, would form a complete national structure for the formulation of an adequate nation-wide program and its effective operation.

8. *A national educational program.*—One of the most assuring steps that has been taken in the field of education is the action by the National Education Association and the American Association of School Administrators to prepare a yearbook on safety. This important undertaking will be supplemented by various bulletins and other useful material to be distributed to all the public schools of the country to serve as a background for sound safety instruction to school children. Too much emphasis cannot be placed upon the importance of this whole activity.

One of the most valuable contributions to a permanent safety program which will doubtless result from this organized study by the educators will be an evaluation and decision as to the supplementary safety activities which should be undertaken or continued on an even broader scale in connection with the public schools. One of the greatest hopes for improved safety conditions lies through the implanting of correct thinking and habits in those who are now passing through the public schools. Illustrative of these supplementary activities are the driver training and school patrol sponsored by the American Automobile Association. In addition, a widespread program of public education and of specialized training of traffic officers and engineers is under way by national organizations through funds provided by the Automotive Safety Foundation. This list of organizations is a notable one, and has been mentioned in connection with the formulation and recommendation of a safety program for each State.[2]

Every indication points to progress during the coming year in the safety movement far beyond that made in any previous year, but the concept of adequate governmental organization and comprehensive laws must be the objective continuously recognized as fundamental in the establishment of a permanent safety program.

[2] These organizations include the following: American Automobile Association, American Legion, Automotive Safety Foundation, General Federation of Women's Clubs, Harvard Bureau for Street Traffic Research, Highway Education Board, International Association of Chiefs of Police, National Automobile Dealers Association, National Congress of Parents and Teachers, National Grange, National Safety Council, Northwestern University Traffic Safety Institute.

STATUS OF FEDERAL-AID HIGHWAY PROJECTS

AS OF APRIL 30, 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	$1,253,020	$616,510	65.3	$5,515,900	$2,757,095	264.9	$1,803,950	$901,220	20.1	$6,172,520
Arizona	2,386,118	1,682,950	109.3	1,364,414	923,937	74.8	772,235	420,301	37.4	1,879,053
Arkansas	2,956,064	2,917,364	180.0	1,206,419	1,194,729	79.9	75,203	74,606	4.6	4,345,009
California	6,776,131	3,711,531	150.1	8,403,393	4,421,759	147.1	4,140,304	2,216,853	106.8	3,316,338
Colorado	3,013,619	1,676,271	109.9	2,328,788	1,275,892	83.4	399,730	212,490	5.1	3,494,978
Connecticut	783,198	389,196	9.3	231,520	108,123	.7	1,160,550	570,541	11.5	1,729,010
Delaware	534,818	263,575	21.0	274,800	137,400	4.7	448,727	211,154	13.9	1,490,258
Florida	924,037	460,069	27.2	2,512,942	1,256,471	52.3	865,860	432,930	15.3	3,937,210
Georgia	2,120,355	1,018,985	123.4	6,756,057	3,378,024	318.7	1,667,760	833,880	81.0	6,557,782
Idaho	2,621,404	1,529,374	198.9	1,221,597	728,194	90.0	808,628	481,300	17.3	1,772,276
Illinois	10,675,567	5,201,039	309.8	9,039,189	4,442,023	179.2	3,618,550	1,809,200	77.0	4,680,102
Indiana	5,905,003	2,907,247	137.9	3,703,691	1,851,845	108.9	3,362,803	1,681,160	64.7	3,310,534
Iowa	6,937,712	3,192,716	226.0	5,571,442	2,529,856	165.0	1,800,583	727,242	54.8	2,844,929
Kansas	4,658,997	2,303,965	262.3	3,652,634	1,826,221	95.2	2,833,489	1,416,770	596.2	5,068,510
Kentucky	2,378,681	1,183,735	62.3	3,733,512	1,866,756	113.6	4,248,626	2,120,314	160.2	2,813,517
Louisiana	582,531	286,501	15.0	6,378,335	1,341,935	39.5	7,078,353	1,584,260	51.7	2,791,480
Maine	1,865,369	932,090	50.7	2,016,676	1,005,403	44.4	795,770	397,880	20.5	1,035,545
Maryland	930,330	465,145	13.4	1,814,594	905,534	28.9	460,360	230,180	.5	2,512,396
Massachusetts	4,417,322	2,208,660	20.3	1,976,395	988,197	4.1	619,286	309,498	4.6	3,307,942
Michigan	6,508,320	3,187,232	166.9	6,545,668	3,202,434	136.3	595,620	297,185	14.3	3,830,650
Minnesota	6,431,138	3,176,084	323.4	4,014,115	1,995,813	174.7	1,145,332	562,052	59.8	4,285,584
Mississippi	2,804,601	1,393,045	139.5	4,956,990	2,477,790	222.3	1,938,320	737,110	76.9	4,222,157
Missouri	8,527,179	4,154,997	450.7	5,149,144	2,527,800	154.5	3,801,530	1,597,774	131.0	4,343,668
Montana	3,740,954	2,093,009	277.7	2,276,138	1,279,948	106.1	139,957	78,723	10.8	4,601,919
Nebraska	2,606,553	1,292,467	271.1	5,044,399	2,509,383	449.9	4,301,948	1,520,660	246.7	3,400,408
Nevada	2,488,928	2,051,622	132.5	708,345	614,171	62.5	495,241	429,091	22.3	2,028,945
New Hampshire	360,810	177,963	6.5	937,460	465,122	16.0	469,863	202,010	8.8	1,201,201
New Jersey	2,055,959	935,415	20.3	2,762,676	1,380,133	19.9	129,000	64,500		2,769,460
New Mexico	4,300,658	2,640,385	290.9	1,567,329	1,055,938	73.6	552,340	336,750	77.1	1,918,786
New York	13,749,759	6,346,752	241.3	13,582,754	6,563,430	227.4	3,408,540	1,702,770	50.1	5,538,798
North Carolina	5,119,154	2,552,906	381.4	6,486,833	3,056,552	266.1	912,320	435,200	69.5	4,016,537
North Dakota	1,114,612	1,036,055	186.5	2,089,261	2,048,991	122.4	911,550	751,975	68.5	3,908,298
Ohio	4,515,291	2,177,861	58.8	8,836,712	4,387,910	99.0	1,640,600	820,260	13.8	9,235,680
Oklahoma	3,460,745	1,800,034	170.4	3,197,998	1,647,335	118.2	2,567,125	1,363,103	131.7	4,774,615
Oregon	3,938,162	2,308,406	121.9	1,834,370	1,103,345	95.2	750,347	429,580	21.7	2,569,108
Pennsylvania	12,903,979	6,407,944	176.3	7,572,135	3,768,776	121.8	1,948,209	973,067	35.9	7,023,406
Rhode Island	921,999	442,608	8.1	1,182,420	591,210	16.7	113,877	56,938	1.1	1,223,518
South Carolina	3,762,555	1,590,753	260.9	5,397,247	2,299,943	246.8	1,161,235	524,336	50.5	2,112,881
South Dakota	2,372,349	1,332,002	246.1	2,710,372	1,498,990	253.9	1,796,211	1,004,810	100.6	3,740,788
Tennessee	1,873,280	933,864	70.0	3,645,444	1,822,722	115.3	2,410,990	1,146,978	64.3	5,257,234
Texas	13,689,667	6,822,126	883.6	11,426,859	5,669,912	647.0	4,105,502	1,958,460	246.2	9,790,045
Utah	1,349,100	954,211	130.8	940,050	672,512	58.7	298,920	213,484	7.3	2,174,978
Vermont	1,052,720	505,707	29.6	1,679,730	739,095	43.1	132,807	61,184	.7	612,911
Virginia	3,312,069	1,646,536	154.2	5,454,263	2,686,455	153.1	1,243,376	597,712	43.9	2,441,324
Washington	2,309,729	1,201,310	75.6	3,962,820	2,081,530	50.3	1,192,618	622,913	33.0	1,544,781
West Virginia	1,476,181	741,784	42.1	1,575,497	1,045,843	46.7	768,617	447,392	21.2	2,816,062
Wisconsin	8,350,793	4,042,181	278.8	5,066,103	2,339,277	113.8	468,993	220,620	6.8	3,830,809
Wyoming	2,803,771	1,720,254	300.7	1,347,552	824,022	135.4	351,645	214,978	17.9	1,445,080
District of Columbia										
Hawaii	777,827	379,041	13.2	681,510	337,470	12.4	651,400	325,025	10.4	1,396,047
Puerto Rico				1,075,539	535,790	20.3	60,920	30,360	.2	668,225
TOTALS	190,399,118	98,991,477	8,001.9	191,410,031	96,169,036	6,274.7	77,425,720	36,358,779	2,986.2	171,783,292

CURRENT STATUS OF UNITED STATES WORKS PROGRAM HIGHWAY PROJECTS

(AS PROVIDED BY THE EMERGENCY RELIEF APPROPRIATION ACT OF 1935)

AS OF APRIL 30, 1938

STATE	APPORTIONMENT	COMPLETED			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
		Estimated Total Cost	Works Program Funds	Miles	Estimated Total Cost	Works Program Funds	Miles	Estimated Total Cost	Works Program Funds	Miles	
Alabama	$4,151,115	$3,936,706	$3,887,955	136.9	$260,300	$260,300	7.8				$2,860
Arizona	2,569,841	3,163,876	2,531,293	193.7	38,548	38,548					
Arkansas	3,352,061	3,281,921	3,250,581	360.5	50,280	50,280		$49,746	$49,746	4.0	1,454
California	7,747,928	7,876,715	7,495,718	262.3	217,622	217,579	.3				34,632
Colorado	3,395,263	2,378,891	2,301,910	99.4	97,797	95,414	6.0				997,939
Connecticut	1,418,709	1,378,104	1,263,206	21.2	55,490	55,000	1.2	124,130	64,435	.2	36,067
Delaware	900,310	870,612	842,125	65.2	10,234	10,234	.2	26,712	17,000	4.4	30,951
Florida	2,597,144	2,606,631	2,526,144	99.1	38,957	38,957					32,043
Georgia	4,988,967	2,004,937	1,936,445	112.8	2,473,464	2,205,084	116.7	441,600	441,600	30.1	405,838
Idaho	2,222,747	2,274,551	2,167,058	185.9	33,341	33,341		19,098	19,098		3,250
Illinois	8,694,009	7,855,079	7,579,988	447.5	1,169,926	1,088,926	40.8				25,095
Indiana	4,941,255	5,284,060	4,810,764	238.0	49,000	49,000					81,491
Iowa	4,991,664	5,237,324	4,884,857	528.3	105,902	104,865	.3				1,942
Kansas	4,994,975	4,749,621	4,695,918	381.8	229,126	226,954	10.9	7,144	7,144	.1	64,959
Kentucky	3,726,271	3,625,014	3,413,535	355.0	274,897	274,897	3.5				37,839
Louisiana	2,890,429	2,930,067	2,588,240	165.6	239,168	200,933	1.5	97,087	97,070	10.4	4,186
Maine	1,676,799	1,628,405	1,605,203	74.7	62,149	62,149	1.7				9,447
Maryland	1,750,738	773,435	766,648	27.2	547,536	547,536	11.2	235,866	218,812	4.8	217,742
Massachusetts	3,262,885	2,222,219	2,221,591	18.2	1,939,136	980,003	1.0				61,291
Michigan	6,301,414	6,663,691	5,945,844	288.6	284,921	284,921	3.3	223,938	63,746	.3	6,903
Minnesota	5,277,145	6,417,998	5,175,372	901.8	84,950	79,000					22,773
Mississippi	3,457,552	3,233,802	3,228,502	226.5	169,450	168,410	9.7				60,641
Missouri	6,012,652	5,290,265	5,208,397	776.9	785,410	730,708	.6	34,390	32,294		41,253
Montana	3,676,416	3,597,114	3,564,349	200.7	95,385	95,385	.1	8,462	8,462		8,220
Nebraska	3,870,739	3,433,440	3,321,591	362.3	446,353	446,353	8.3	70,270	70,270	1.8	32,525
Nevada	2,243,074	2,321,908	2,204,928	110.1	84,970	38,146	1.7				
New Hampshire	945,225	880,906	843,253	37.7	121,092	101,301	5.7				671
New Jersey	3,129,805	1,611,294	1,539,963	31.1	1,559,926	1,559,926	4.4				29,916
New Mexico	2,871,397	2,812,672	2,806,612	213.7	43,071	43,071		14,681	12,196		9,518
New York	11,046,377	10,777,954	10,272,533	170.5	43,700	43,700	.2	231,783	231,783	1.2	498,360
North Carolina	4,720,173	4,609,836	4,539,338	284.6	120,761	120,761	5.4	17,090	9,816		50,259
North Dakota	2,867,245	2,481,905	2,433,968	377.9	367,530	367,529	33.6	30,870	30,870	5.1	34,878
Ohio	7,670,815	6,967,085	6,851,506	294.9	703,332	697,332	3.7				121,978
Oklahoma	4,580,670	4,553,518	4,309,166	400.8	239,470	239,470	7.6	17,000	17,000	1.6	15,034
Oregon	3,038,642	3,189,864	2,969,387	164.4	45,580	45,580		11,846	11,846	1.0	11,829
Pennsylvania	9,347,797	8,024,397	7,438,451	262.7	1,999,961	1,743,728	20.0	19,481	19,481	.2	146,137
Rhode Island	989,208	1,113,140	989,208	18.8							
South Carolina	2,702,012	2,381,649	2,148,589	226.2	551,692	498,752	23.4	9,664	9,664	1.5	45,007
South Dakota	2,976,454	2,663,066	2,657,877	482.9	288,937	288,937	22.0	11,800	11,800		17,840
Tennessee	4,192,460	3,535,127	3,471,384	135.3	713,268	713,268	18.0				7,808
Texas	11,989,350	12,730,037	11,604,156	1,108.6	377,632	339,431	9.1				45,763
Utah	2,067,154	2,164,325	1,923,078	205.9	112,055	112,055	.1				32,020
Vermont	924,306	1,060,594	902,441	23.2	13,865	13,865					8,000
Virginia	3,652,667	3,484,973	3,285,362	938.6	287,731	284,434	14.7				82,871
Washington	3,026,161	3,364,831	2,940,420	164.2	65,824	65,824	.7				19,916
West Virginia	2,231,412	2,109,240	1,963,718	86.4	275,023	267,639	14.1				55
Wisconsin	4,823,884	5,217,570	4,734,584	343.4	91,394	89,300	.3				
Wyoming	2,219,155	2,173,387	2,165,009	152.4	33,287	33,287					20,859
District of Columbia	949,496	950,000	949,496	8.8							
Hawaii	926,033	955,853	871,389	17.4				62,530	54,644	.6	
TOTALS	195,000,000	184,849,609	174,029,050	12,790.6	17,899,443	16,052,113	409.8	1,765,188	1,498,777	67.3	3,420,060

CURRENT STATUS OF UNITED STATES WORKS PROGRAM GRADE CROSSING PROJECTS

(AS PROVIDED BY THE EMERGENCY RELIEF APPROPRIATION ACT OF 1935)

AS OF APRIL 30, 1938

STATE	APPORTIONMENT	COMPLETED					UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
				NUMBER					NUMBER					NUMBER			
		Estimated Total Cost	Works Program Funds	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Works Program Funds	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Works Program Funds	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	
Alabama	$ 4,034,617	$ 3,812,416	$ 3,801,471	49	1	12	$ 285,519	$ 219,219	4								$ 13,927
Arizona	1,256,099	1,300,469	1,216,144	15		5	18,841	18,841									21,114
Arkansas	3,574,060	3,296,774	3,288,785	56	6	31	236,101	235,211	2		2	$ 41,806	$ 41,806	1			8,258
California	7,486,362	7,345,501	7,186,523	47	8		112,295	112,295				10,000	10,000	5			177,544
Colorado	2,631,567	2,319,850	2,249,587	27	3	21	355,944	355,944	3								26,036
Connecticut	1,712,684	479,557	479,463	3	1	1	1,157,071	1,135,710	7								97,511
Delaware	418,239	130,000	128,144	1			279,052	279,052	2								11,043
Florida	2,827,883	2,475,666	2,457,348	31	5	6	57,888	57,888			7	178,690	178,690	1		63	133,956
Georgia	4,895,949	832,305	823,283	18	7	19	1,561,189	1,561,189	24	8		942,260	942,260	12	2	38	1,569,217
Idaho	1,674,479	1,393,286	1,364,907	20	3	12	252,696	252,696	2		6	4,261	4,261			3	52,615
Illinois	10,307,184	8,786,475	8,653,162	65	8		1,601,134	1,594,730	11			47,000	18,000	2			41,292
Indiana	5,111,096	4,774,115	4,632,083	42	15		450,720	450,720			162						28,293
Iowa	5,600,679	4,566,124	4,462,921	98	9	8	1,092,875	1,089,000	8								48,758
Kansas	5,246,258	4,403,154	3,977,319	55		5	1,197,631	1,178,217	3	1	2	112,152	19,148	2		1	71,574
Kentucky	3,672,387	1,357,377	1,336,725	19	5		1,984,219	1,694,487	5	6		612,579	612,579	3	1		28,596
Louisiana	3,213,467	1,881,670	1,872,707	19	2		667,588	667,559	7			644,918	595,438	4	1		77,763
Maine	1,426,861	1,268,330	1,261,145	19	1	4	160,788	142,540	1	1							23,176
Maryland	2,061,751	701,588	696,981	5	4	18	918,674	868,674	5	1	11	320,163	320,163	2	1	1	175,933
Massachusetts	4,210,833	2,993,173	2,990,739	22	4		865,680	865,680	4			249,991	249,991	1			104,423
Michigan	6,765,197	6,864,894	6,560,765	44	8		101,477	101,477				120,000	102,955	1	1		
Minnesota	5,395,441	4,815,817	4,769,278	83	13	50	590,070	584,020	3								42,143
Mississippi	3,241,475	2,570,838	2,568,720	53	6	16	385,300	385,300	6	1	2	119,100	119,100	2		5	168,355
Missouri	6,142,153	4,734,413	4,565,049	42	1		1,566,960	1,566,960	7		1	1,650	1,650			1	8,494
Montana	2,722,327	2,536,719	2,506,972	37	7		245,576	185,931	1	1		9,684	9,684		1		19,741
Nebraska	3,556,441	2,886,587	2,836,606	76	3	24	468,259	468,259	5			194,329	194,329	3			57,248
Nevada	887,260	877,374	864,025	8	3		13,308	13,308				4,257	4,257			5	5,670
New Hampshire	822,484	791,275	791,208	9	4	6	53,297	29,170	1			2,106	2,106			1	
New Jersey	3,983,826	3,095,189	3,087,143	20	6	1	812,334	812,334	4	3		44,730	44,730		1		39,619
New Mexico	1,725,286	1,700,885	1,693,233	19	1		25,879	25,879				3,129	3,129			1	3,045
New York	13,577,189	11,676,570	11,347,946	35	47		1,939,150	1,939,000	10	3		94,000	94,000				196,243
North Carolina	4,823,958	3,507,998	3,488,045	50	18		1,081,059	1,081,059	12		115	118,900	118,900	2			135,954
North Dakota	3,207,473	2,748,506	2,738,428	55	4		389,012	389,012		1							80,033
Ohio	8,439,897	2,520,630	2,399,382	19	7	13	6,249,227	5,766,081	40	1		20,000	20,000			1	254,435
Oklahoma	5,004,711	3,930,018	3,910,607	60	9	40	1,141,944	1,008,844	5	3		1,350	1,350			1	83,910
Oregon	2,334,204	2,294,365	2,240,272	16	6	2	74,215	74,215	1								19,717
Pennsylvania	11,483,613	9,075,239	8,362,371	71	18	9	2,850,615	2,683,567	15	5		150,473	150,473	5			287,202
Rhode Island	699,691	701,817	692,910	4	3												6,781
South Carolina	3,059,956	2,142,194	2,112,048	40	12	38	496,874	496,874	5	4	6	134,706	134,706	1	1	4	316,328
South Dakota	3,249,086	2,818,322	2,816,055	60	5	53	175,186	175,186	6			269,350	210,392	17			47,452
Tennessee	3,903,979	2,623,353	2,592,497	40	3	39	1,032,200	1,032,200	6	1	1	95,370	95,370	1			183,912
Texas	10,855,982	9,967,037	9,952,950	127	14	121	478,460	478,459	1	1	13	324,540	324,540	1		15	100,032
Utah	1,230,763	1,203,377	1,190,847	17	1	1	18,461	18,461									21,455
Vermont	729,857	751,992	705,786	10	7	20	10,900	10,900									13,171
Virginia	3,774,287	3,074,819	2,928,040	47	19	23	783,978	783,978	6	1		4,506	4,506			1	57,763
Washington	3,095,041	2,973,671	2,937,098	22	12	11	91,167	89,782	1								68,161
West Virginia	2,677,937	1,559,891	1,557,923	14	3	6	1,037,711	1,037,211	12			78,855	78,855	2		1	3,948
Wisconsin	5,022,683	4,471,868	4,437,324	37	6	10	402,360	402,157		1	11	97,748	97,748	1		13	85,454
Wyoming	1,360,841	1,214,014	1,203,724	13			111,212	111,212	1								45,905
District of Columbia	410,804	417,779	410,804	3													
Hawaii	453,703	284,891	284,005	3			179,710	169,698	2								
TOTALS	196,000,000	154,950,172	151,431,498	1745	328	625	36,061,806	34,700,186	238	43	339	5,052,603	4,805,116	69	9	155	5,063,200