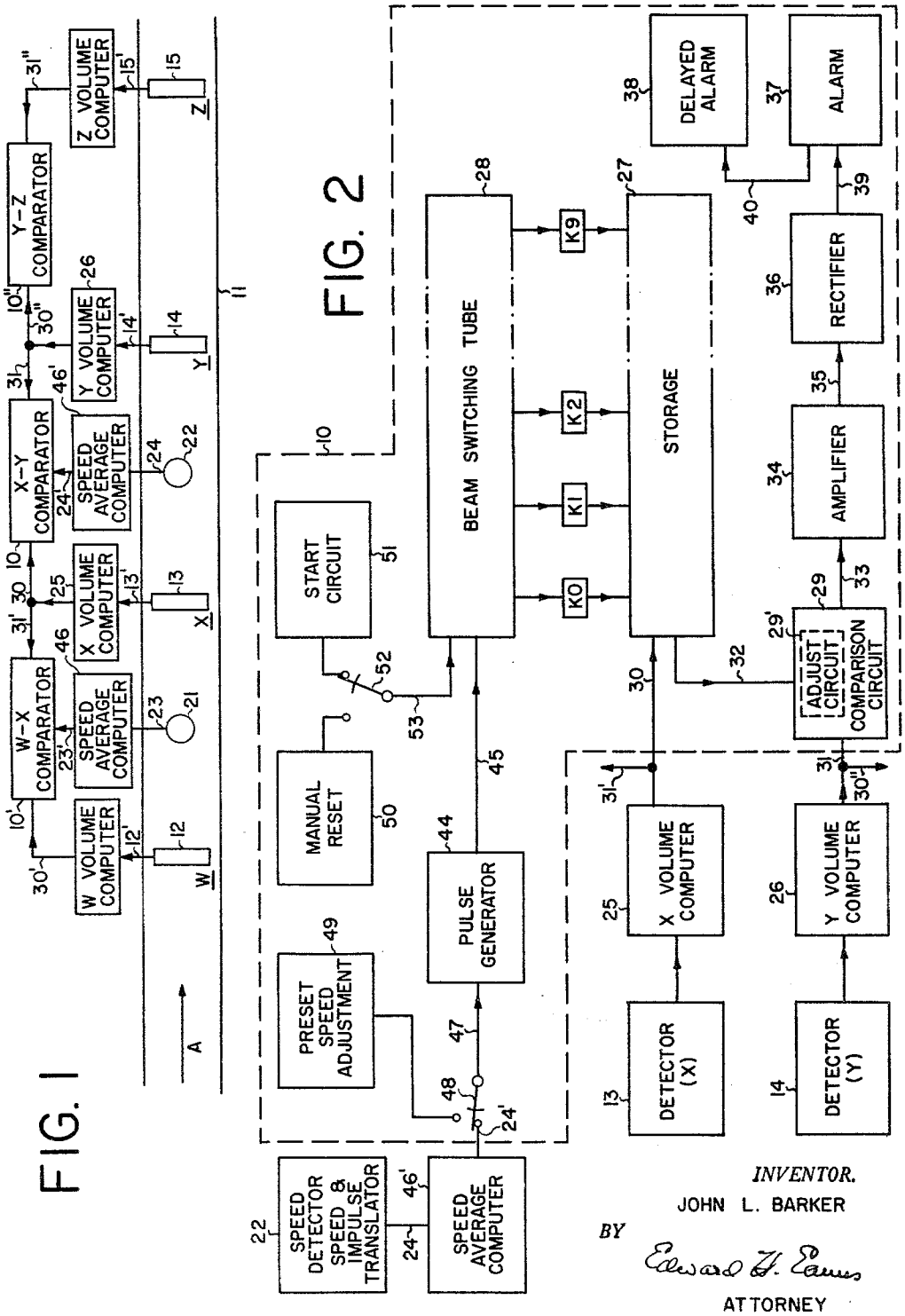
May 25, 1965 J. L. BARKER 3,185,959

TRAFFIC MONITORING SYSTEM

Filed Dec. 24, 1959 5 Sheets-Sheet 1



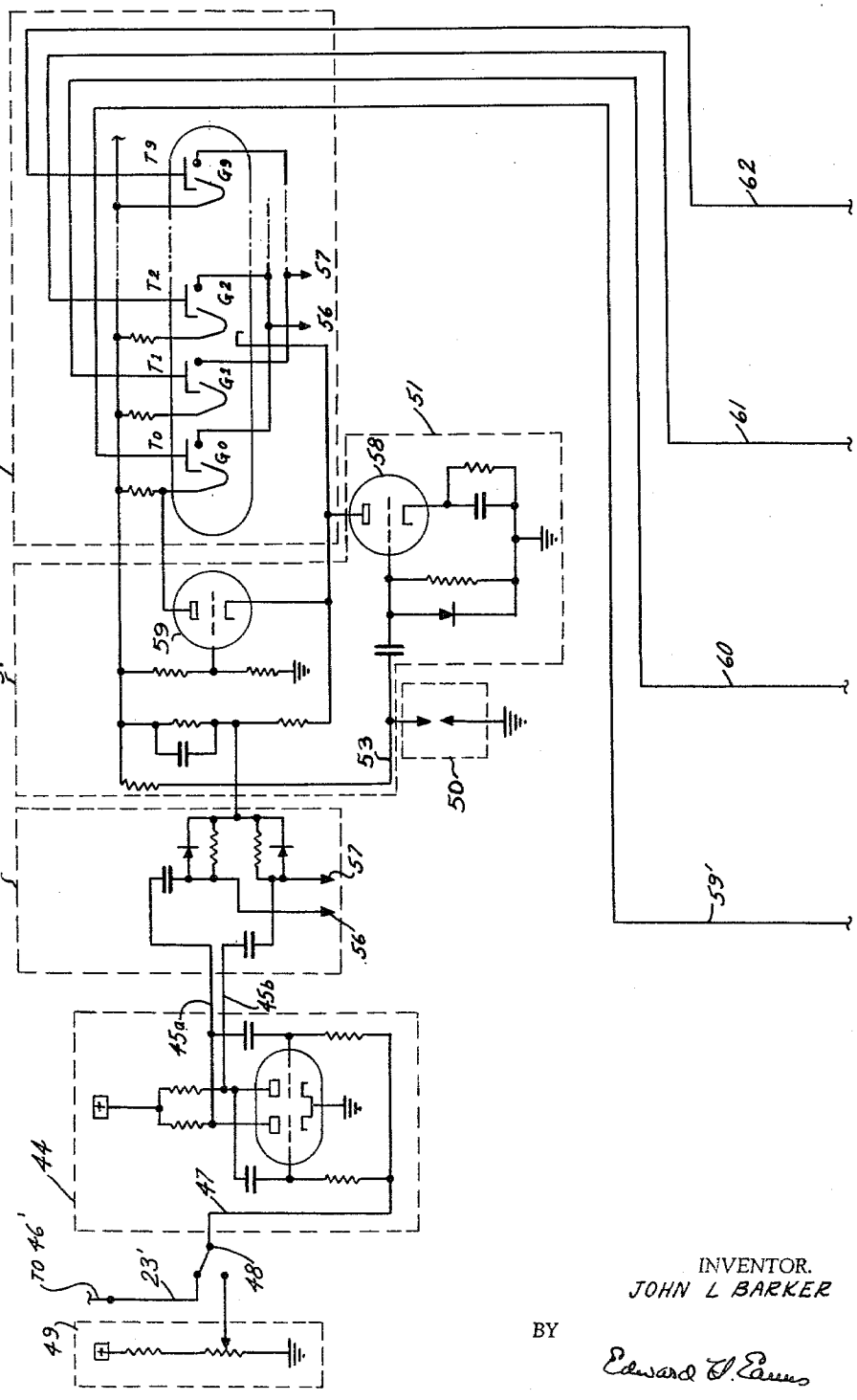

INVENTOR.
JOHN L. BARKER
BY
Edward H. Eames
ATTORNEY

May 25, 1965 J. L. BARKER 3,185,959

TRAFFIC MONITORING SYSTEM

Filed Dec. 24, 1959 5 Sheets-Sheet 2

FIG. 3a




INVENTOR.
JOHN L BARKER

BY

Edward L. Barnes

ATTORNEY

May 25, 1965 J. L. BARKER 3,185,959

TRAFFIC MONITORING SYSTEM

Filed Dec. 24, 1959 5 Sheets-Sheet 3

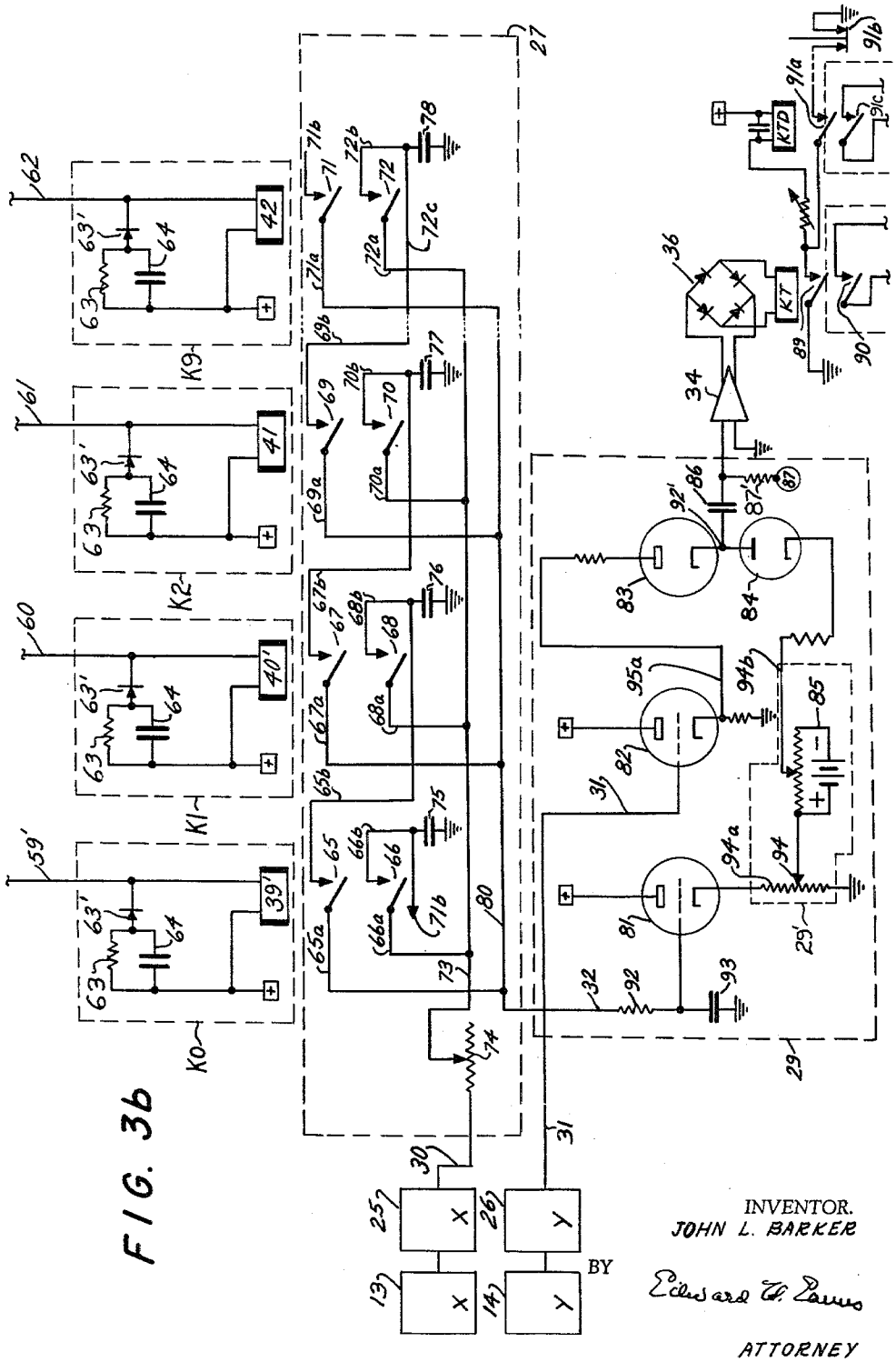



FIG. 36

INVENTOR.
JOHN L. BARKER

Edward W. Barnes

ATTORNEY

May 25, 1965 J. L. BARKER 3,185,959

TRAFFIC MONITORING SYSTEM

Filed Dec. 24, 1959 5 Sheets-Sheet 4

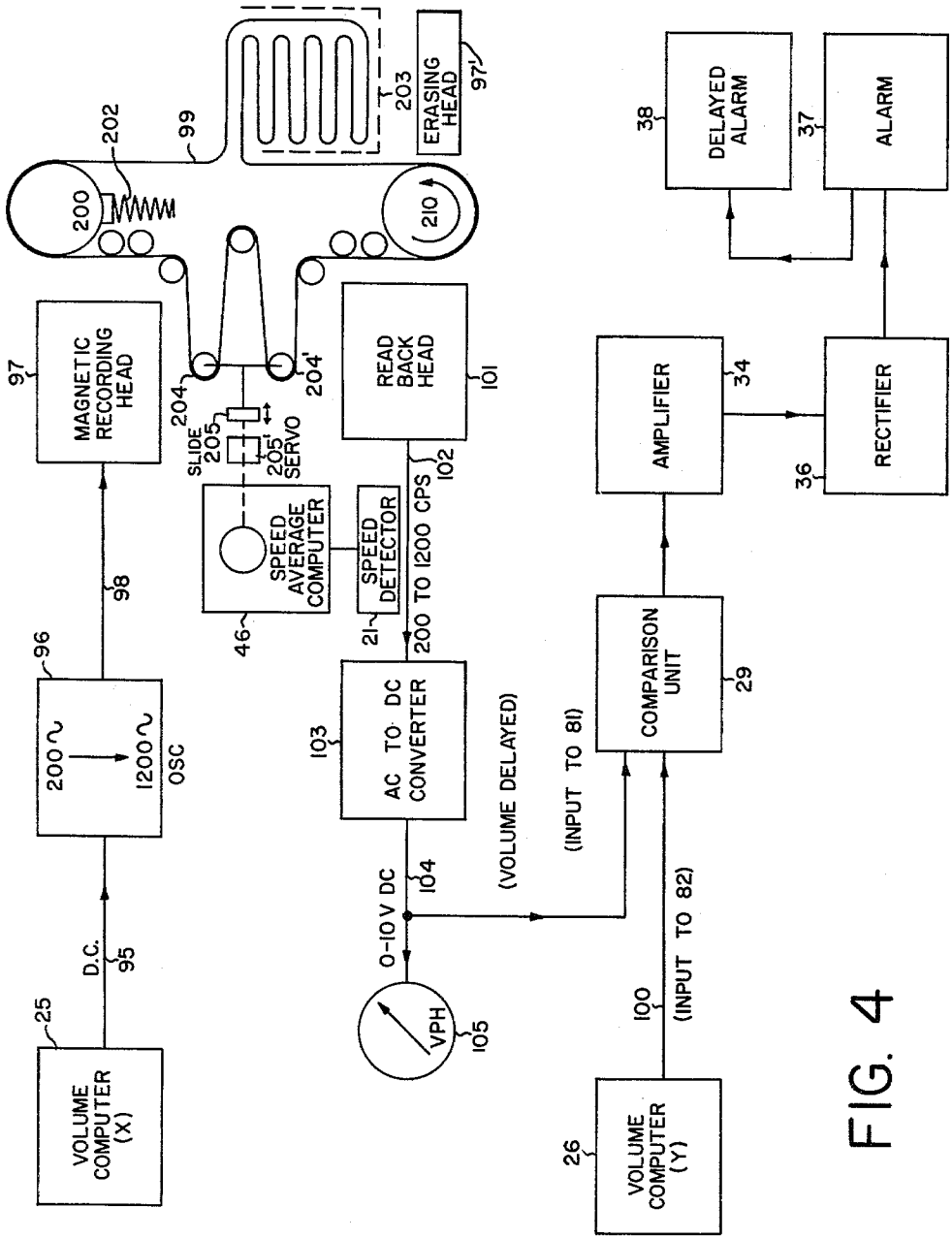



FIG. 4

*INVENTOR.*

JOHN L. BARKER

*BY*

Edward H. Baum

ATTORNEY

May 25, 1965 J. L. BARKER 3,185,959

TRAFFIC MONITORING SYSTEM

Filed Dec. 24, 1959 5 Sheets-Sheet 5

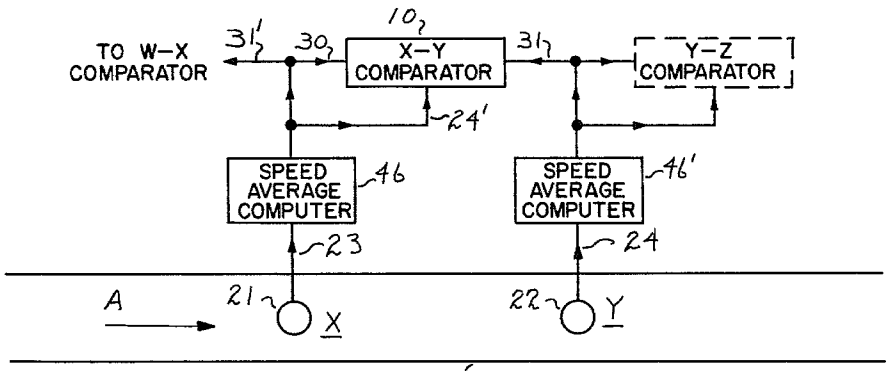



FIG. 5

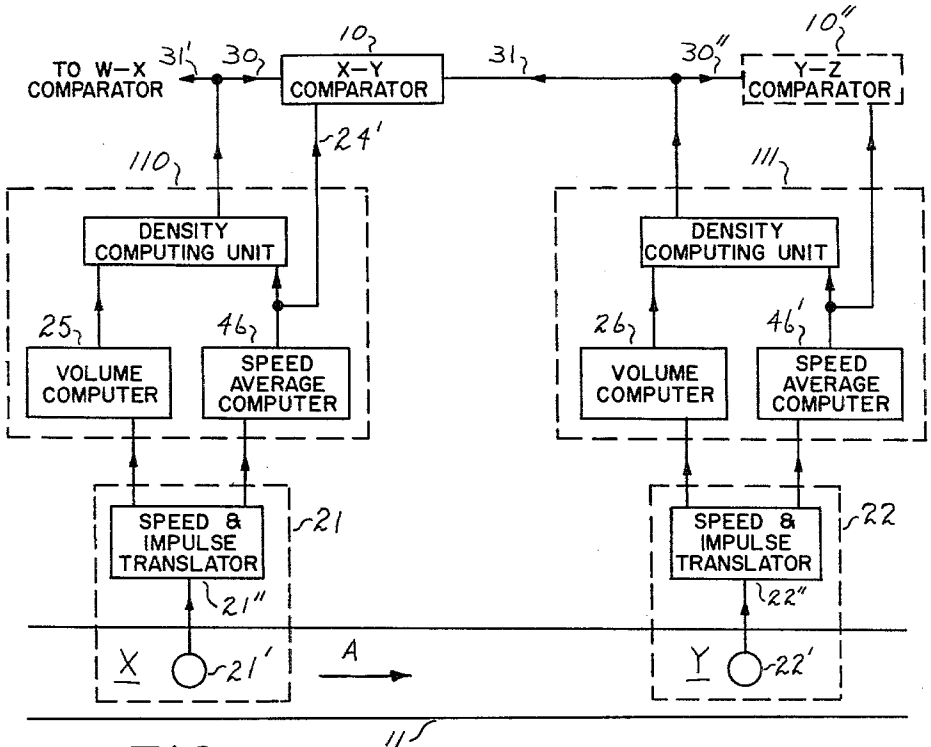



FIG. 6

*INVENTOR.*
JOHN L. BARKER

*BY*

Edward W. Barnes

ATTORNEY

United States Patent Office 3,185,959 Patented May 25, 1965



3,185,959

# TRAFFIC MONITORING SYSTEM

John L. Barker, Norwalk, Conn., assignor, by mesne assignments, to Laboratory for Electronics, Inc., Boston, Mass., a corporation of Delaware

Filed Dec. 24, 1959, Ser. No. 861,975
22 Claims. (Cl. 340—38)

This invention relates generally to traffic monitoring systems, and more particularly to a system for monitoring the flow of traffic along a roadway or traffic lane by means of comparison of traffic volume or other characteristic of traffic flow at spaced points along the roadway or traffic lane.

The present invention provides a traffic detection system which rapidly senses stoppages or large decreases in traffic flow on a highway by the comparison of similar characteristics of vehicle traffic along the highway at a series of similar traffic sensing stations. In a restricted area, where traffic is normally free flowing within specified relatively confined lanes such as a tunnel or bridge, it is of prime importance to detect rapidly any stoppage or large decrease in flow of vehicle traffic. It is also desirable to locate the point of stoppage as closely as possible. The system, which is the subject of the present invention, will allow the speed of response for recognition of the stoppage to be selected to a large degree by the distance between each of a series of sequential sensing stations.

From one aspect of the invention the volume of traffic flow along a highway is determined over a time period, at each of a series of volume sensing stations. The term traffic volume is used in the sense of the number of vehicles passing a given point per unit time. The traffic volume determined at one station is stored and delayed for a time period corresponding to the travel time of the traffic from said one station to a succeeding station downstream in the traffic flow. The traffic volume determined currently at said succeeding station is being determined at a point in time corresponding to the end of such time delay period, and the previously determined, stored and delayed volume is compared with the current volume determined by such succeeding station. In normal, free flowing traffic, consecutively determined volumes of the same traffic should be substantially equal since, if the stations are not too widely separated, the compared volumes will be of substantially the same group of vehicles in the traffic flow. However, if the current volume is substantially lower than the previously stored volume of the same traffic flow this will indicate some impediment or stoppage of traffic between or immediately beyond the two compared stations. The interference or failure of normal free flow of traffic is sensed and a remote indicator or alarm can be operated.

Similarly from other aspects, current traffic speed information at one station or location may be compared with stored and delayed traffic speed information from a preceding station or location, or current traffic density information at one station or location may be compared with stored and delayed traffic density information from a preceding station or location. In this connection the term traffic density is used in its meaning of vehicles per unit length of roadway, such as vehicles per mile, for example. Thus traffic volume, speed and density represent rates of traffic flow.

In accordance with a preferred form of the invention the output circuit is operated in response to a differential of the compared volumes or other traffic flow characteristic where the current volume or other particular characteristic is lower than the previous volume or other such particular characteristic. However, response may be provided to a higher current level, as compared to the previous level, if desired.



The invention herein disclosed has as its general object the provision of a traffic monitoring system which automatically compares the volume or other characteristic of traffic flowing past two or more points along a roadway which are displaced both in time and position.

A further object of this invention is the provision of a traffic flow detection device which utilizes a unique method of comparison of two same variable quantities displaced in time.

A more particular object of the invention is to provide a traffic monitoring system or traffic flow detection system which senses the traffic volume or other flow characteristic of a portion of a stream of traffic flowing past a point along a roadway and develops a signal in accordance with such volume or other characteristic which signal is delayed in time and compared with a second signal developed in accordance with the volume or corresponding other characteristic of substantially the same portion of traffic after such portion has moved to a second point along the same roadway.

Another object of this invention is the provision of a traffic flow detection device which contains a substantially continuously operating information storage and read-out circuit.

A further object of this invention is the provision of a traffic flow comparison system wherein the same characteristic of traffic is sensed at more than two sensing stations spaced along a roadway and the information sensed at any intermediate sensing station is both compared immediately with information which had been previously sensed and stored from the next preceding sensing station and is also stored for later comparison with the information sensed at the next succeeding sensing station.

And a further object of this invention is to provide a traffic flow characteristic comparison device which is continuously operating and is capable of having its operation modified in accordance with variations in vehicle speeds.

A traffic flow detection device embodying the invention in its preferred form, and the manner of using the same, is described herein with reference to the drawings in which:

FIG. 1 illustrates in diagrammatic form a highway with detector stations sequentially spaced along its edge for employing traffic volume detection and comparison in connection with the traffic monitoring system, which is the subject of this invention;

FIG. 2 illustrates in diagrammatic form a preferred form of traffic monitoring system which is the subject of this invention;

FIGS. 3*a* and 3*b* illustrate in schematic form the preferred form of traffic monitoring system which is illustrated in FIG. 2;

FIG. 4 illustrates in diagrammatic form an alternate embodiment of the invention;

FIG. 5 illustrates in diagrammatic form another alternate form of traffic monitoring system employing vehicle traffic speed detection and comparison; and

FIG. 6 illustrates in diagrammatic form a further alternate form of traffic monitoring system employing vehicle traffic density detection and comparison.

A diagrammatic showing of the preferred embodiment is made in FIG. 1 of several vehicle traffic volume detection devices disposed adjacent to a highway 11. Four detector stations, W, X, Y and Z are illustrated, each station including a detector 12, 13, 14 and 15 respectively, feeding information via leads 12', 13', 14' and 15' respectively to W volume computer, X volume computer, Y volume computer and Z volume computer respectively. W volume computer feeds information into W–X comparator 10' via 30', X volume computer feeds information into W–X comparator 10' via 31 and into X–Y comparator 10 via 30, Y volume computer feeds information into

X–Y comparator **10** via **31** and into Y–Z comparator **10''** via **30''** and Z volume computer feeds information to Y–Z comparator via **31''**.

The detector stations, W, X, Y and Z are sequentially spaced along the highway **11**. The direction of traffic flow along highway **11** is designated by the arrow A. In FIG. 1 are illustrated the well known treadle type vehicle detectors. These are shown by way of illustration only, and other types may be used, such as the radar type detector which is the subject of my copending application Serial Number 511,995 filed May 31, 1955, now Patent Number 2,965,893 granted December 20, 1960.

Although for simplicity I illustrate the treadle type detector I prefer to use the radar type detector which is the subject of the aforementioned application, since it requires no permanent installation on the road and can easily be moved from place to place.

As vehicles pass over detector **13**, for example, each vehicle is detected and a signal is sent to X volume computer via channel **13'** and then after computation of the volume of traffic is made, the information is passed on to W–X comparator **10'** via channel **31'** and to X–Y comparator **10** via channel **30**. The information passed to W–X comparator is compared with information previously received via channel **30'** from W volume computer while the information passed to X–Y comparator is stored for future comparison with information to be received by comparator X–Y from Y volume computer via channel **31**.

The detections are made so that the volume of traffic is determined on a short time basis so that each volume is measured after a comparable time period for one half to two minutes, for example to display the fine detail of the traffic pattern. This pattern will progress along the highway and arrive at detector **14** at station Y, for example, at a time later than its arrival at station X.

If the instant of measurement of the volume at W is designated $T_0$ then the instant of measurement of volume at station X may be designated $T_1$. The volume measured at X is measured at the time $T_0+\Delta T$, or $T_1$ with $\Delta T$ being the travel time of vehicular traffic from W to X. The volume measured at X will be essentially the same as the previously measured volume at W if traffic is flowing normally without any stoppages.

If the information obtained via detectors **12** and **13** is fed to W volume computer and X volume computer respectively and by each computer to W–X comparator, with the information fed via W volume computer to W–X comparator stored and delayed for the time required for vehicle travel between W and X and at the end of the delayed period the delayed volume from W and the current volume from X are compared, in that the volume measurement of W is subtracted for the volume measurement of X, then the answer or resultant will be very small for normal flows. The answer will be a large negative value if there develops a stoppage or impedance to traffic between the stations W and X.

Similarly, the volume measurement at X will be compared with the volume measurement at Y with the volume measurement at X delayed for a time period equal to vehicle travel time between stations X and Y.

Any number of detectors may be used along a highway and the number of detectors used and the spacing of the detectors will be a determinant of the accuracy of this system. A representative spacing of detection stations would be 500 feet which would give approximately 10 to 15 seconds travel time per vehicle between detector stations for traffic speeds of 33 to 22 miles per hour, for example, but other spacings may be used.

Speed detectors **21** and **22** are shown in FIG. 1 disposed along the road and feeding information detected thereby to speed averaging computers **46** and **46'** by means of connections **23** and **24** respectively and via connections **23'** and **24'** to comparator W–X and X–Y respectively. The speed detectors **21** and **22** in FIG. 1 may, by way of example, include a speed sensing unit RS1 and a speed and impulse translator illustrated and described in my copending application, Serial Number 732,248, filed May 1, 1958, now Patent Number 3,059,232 granted October 16, 1962.

As more fully described in my said copending application 732,248, speed and volume information in the form of varying Doppler frequencies, are applied to a speed and impulse translator which separates the information and provides outputs, in the form of direct current pulses for each vehicle detected and an increasing direct current voltage corresponding to the speed of the detected vehicle. The speed information, as translated by the speed and impulse translator is applied to a speed averaging computer, also more fully described and explained in my said copending application, from which is derived an output voltage representative of the average speed of the speeds detected on a per vehicle basis.

This average speed information can be utilized to modify the operation of the detection devices to compensate for variations in vehicle speed between sampling points.

When the speed of vehicles can reasonably be expected to remain substantially constant only one speed detector is necessary for a long stretch of road. However, when the speed of vehicles is subject to change such as on grades or as a result of turns, two or more speed detectors may be required to accurately ascertain speed of traffic flow.

When a speed detector including a speed sensing unit RS1, a speed and impulse translator and speed average computer is employed in the system, the volume information received from the speed and impulse translator may be applied to a volume computer so that a separate volume detector, as for example **12**, at station W may be eliminated and the speed sensing unit RS1 and speed and impulse translator may serve to produce both volume and speed information.

The speed detectors can be any familiar speed detector used for this purpose such as my speed detector described in my said copending application Serial Number 732,248. If the speed of vehicle traffic may be expected to remain relatively constant over a long stretch of highway only one speed detector may be employed with a series of several detector stations then a pre-set adjustment may be employed in lieu of the additional speed detectors. The pre-set speed adjustment may be manually adjusted to simulate a desired speed as more fully described below.

Referring to FIG. 2 a diagrammatic showing of the embodiment of this invention is presented with blocks utilized to show the various components of the system. Components which would be contained in the detector station X, for example, are illustrated by boxes **13** and **25** representing the detector (X), **13** and X volume computer **25** with an input into X–Y comparator **10** enclosed in a broken line box **10**. The detector (X), **13** feeds X volume computer **25** with information and the detector (Y), **14** feeds Y volume computer **26** with information. The volume computers **25** and **26** may be of the type shown in my said copending application Serial Number 732,248, filed May 1, 1958, utilizing information received from the detectors and after having put this information in usable form volume computer **25** feeds into storage unit **27** via lead **30**, under the control of beam switching tube **28** and relays K0, K1, K2, etc. to K9.

Volume computer **26** feeds into comparison circuit **29**, via channel **31**, where comparison is made with the information out of storage **27** via channel **32** under control of beam switching tube **28**. The lead **31'** feeds information back to comparator **10'**, illustrated in FIG. 1, into the comparison circuit of comparator **10'** and the lead **30''** feeds information forward to comparator **10''**, illustrated in FIG. 1, into the storage of comparator **10''**.

In FIG. 2 the output of comparison circuit **29** is fed by channel **33** to amplifier **34** and by channel **35** to recti-

fier 36 and thence to alarms 37 and 38 by channels 39 and 40 respectively. In FIG. 2 the storage unit 27 is shown under the control of beam switching tube 28 with the relay units K0, K1, K2, etc. to K9 acting as intermediaries.

In order to more clearly understand the circuitry, it is necessary that an understanding of the function of the switching circuit in this invention be obtained. The switching circuit can utilize any switch commonly employed for sequential step-switching, and can be the familiar telephone stepping switch, if it is desired. I prefer to use a beam switching tube of the type manufactured and sold by the Burroughs Corporation and designated MBS tube 6700 which has a single cathode and ten targets so that one target at a time is in circuit, and the targets pass current sequentially or by steps. In this circuit the cycle of operation of the tube will be considered as the sequential stepping from one plate conducting, through sequentially conducting states in the other plates and back to conducting in the first mentioned plate.

The manner in which in the information is read into and out of the storage units, as will be more fully discussed later, provides the delay of the input volume for comparison at a later time. The difference in the time of read out and read in of a specific unit of volume data is determined by the travel time of the average group of traffic corresponding to this unit of volume data. This travel time as a result of the sequential operation of the switching circuit corresponds to this time of operation of all but one step in the cycle of operation of the switching tube.

A simple pulse generator, which is designated by the numeral 44 in FIG. 2 controls the stepping of beam switching tube 28 through channel 45. The rate of pulses generated in pulse generator 44 may be modified by the speed averaging computer 46′ which receives signals through channel 24 from a speed detector/speed and impulse translator 22 and applies its output by channel 24′+47 to pulse generator 44. Switch 48 is provided so that the preset speed adjustment 49 can be used when speed averaging computers and speed detectors/speed and impulse translators are not available.

Beam switching tube 28 can be reset and started manually by means of manual reset 50 or automatically by means of start circuit 51 by utilization of switch 52 which provides for a choice between either of these methods and applies the signal to the beam switching tube by means of channel 53.

Considering now FIGS. 3*a* and 3*b* which show in detail the schematic diagram of the system which is shown diagrammatically in FIG. 2. Switch 48 enables the operator to choose between preset speed adjustment 49 or speed averaging computer 46′. Preset speed adjustment 49 is a voltage divider which provides bias adjustment for flip flop pulse generator 44. Speed adjustment is made in accordance with previous experience and estimated speed of vehicles on the road and controls the rate of pulses emanating from pulse generator 44. The speed averaging computer, when used also does this; however, the speed averaging computer allows for variations and automatic adjustment in accordance with changes in speed of vehicles. Lead 23′ is connected to the output of a speed averaging computer. Line 47 is the input to the pulse generator allowing the speed averaging computer or the preset speed adjustment 49 to compensate for variations in vehicle speed between sampling points by changing the bias on flip flop 44 and therefore the rate of flip flop pulses. The pulses from flip flop 44 are applied to beam switching tube 28 by leads 45*a* and 45*b* through an input circuit which is designated generally by the number 55 in FIG. 3*a*, which feeds the pulses alternately by means of leads 56 and 57 to the even and odd grid respectively of the beam switching tube and thereby alternately and sequentially firing the plates as is well known in the art.

Since the beam switching tube is designed so that one target or plate conducts at a time, the targets conduct one after another continually, and if the first plate fires target $T_0$ while the remaining targets are non-conducting, the second pulse emitted from the pulse generator fires $T_1$, the first target $T_0$ then becomes non-conducting. The next pulse fires $T_2$ so that $T_2$ is the only target conducting in the ring, and so forth, so that the tube operates so as to have one target conducting at a time and these targets are conducting in numerical sequence. When the sequence has reached conduction in $T_9$, the next pulse from the pulse generator makes $T_0$ conducting and $T_9$ non-conducting, thus sequentially continuing around a ring. As suggested previously it is desirable to set the sequence of the beam switching tube so that the total cycle, less one step, of the tube is set for the time it takes a vehicle to pass from one sampling point to the next. The speed of pulses emanating from the pulse generator 44 determines the stepping speed and thus the timing of the cycle of the beam switching tube. This cycle is set by adjustment of the bias of the pulse generator and can be done either by preset speed adjustment 49 or by speed averaging computer 46′ as previously discussed.

As is common with this type of beam switching tube, start circuit 51 which is well known in the art for use in connection with the beam switching tube, allows for both automatically forming the beam and for clearing the tube. A negative pulse applied to the grid of tube 58, through the closure of start switch 50 will clear the switching tube by opening the common cathode circuit of the switching tube. At termination of the pulse, tube 58 again returns to a conducting bias but with no cathode conducting in the beam switching tube 28 the cathode of tube 59 goes highly negative causing it to become conducting, thus reducing the potential on the spade associated with plate $T_0$ which establishes conduction in the $T_0$ section. Once this conduction is established the cathode of tube 59 returns to a plus voltage sufficient to bias the tube to cut-off thus rendering the tube disconnected from the circuit of the beam switching tube 28 and normal operation continues in response to timing pulses from the pulse generator 44.

Thus the beam switching tube 28 is essentially a cyclic device having a number of discrete positions through which the device steps to complete its cycle. The time required to complete this cycle is variable depending upon the frequency of the pulse generator 44 which in turn depends upon the bias supplied from either preset adjustment 49 or the speed average computer 46′.

As appears subsequently, however, the cyclic device stores discrete quantities or values of traffic volume or of other traffic flow information from one detection location in each step of its cycle. During each step of the cycle, information is read-out or sensed which was stored in a previous step of the cycle, while concurrently storing new information in the present step of the cycle; thus the read-out information is delayed. If the cyclic rate of stepping is varied, the delay period is also varied.

Referring to FIG. 3*a*, the dotted lines in tube 28 and the dotted lines in the storage section 27 on FIG. 3*b* indicate the other six positions of these two elements which positions have not been shown in complete detail for convenience since the positions not shown are identical to those illustrated except that the six positions occur between $T_2$ and $T_9$ and K2 and K9. The circuit connections are entirely symmetrical.

Referring now to FIG. 3*b* the target $T_0$ of tube 28 is connected by means of lead 59′ to relay coil 39′, the target $T_1$ of the beam switching tube is connected by lead 60 to the coil of relay 40′, target $T_2$ of the switching tube is connected by means of lead 61 to relay coil 41 and target $T_3$ is connected by means of lead 62 to relay 42.

In the sequence of operation of the storage 27 it is imperative that only the contact associated with one position of the tube 28 be connected at a time to prevent sneak circuits that would otherwise bleed out the potential

stored in capacitors 75, 76, 77, etc., 78. To accomplish this, relay circuits K0, K1, K2, etc. K9 have resistor, rectifier and capacitor circuits arranged such as to delay only the pull-in operation of the relay coil 39', 40', 41, etc., 42.

This delay action on energization is accomplished by the combination of the relatively high impedance of the target circuit in the beam switching tube and capacitor 64, through the low forward resistance of diode 63' shunting the relay coil. When the target circuit is interrupted to deenergize the relay, the high reverse resistance of diode 63' isolates capacitors 64 from the coil and the relay drops out rapidly. This, in combination with the delayed energization of the next relay coil in the ring insures that there is a definite spacing between the closure of the circuits associated with the storage capacitors 75, 76, 77, etc., 78.

Capacitors or other circuitry for shunting the inductive kick of the relays are not shown although these can be used if it is desired.

Each of the relay coils has associated therewith two sets of contacts. Coil 39' has associated with it contact pairs 65 and 66. Coil 40' has associated therewith contact pairs 67 and 68. Coil 41 has associated therewith contact pairs 69 and 70, and coil 42 has associated therewith contact pairs 71 and 72. One side of one of the contacts associated with each of the coils is connected to line 73 which is connected through resistor 74 and line 30 to the output of volume computer 25 which, as has been explained above, has as its input the output of "X" detector 13. The remaining sides of these contacts are connected each to an individual capacitor which in turn has its remaining side grounded. Thus contact 66 has one side thereof connected by lead 66*a* to lead 73 and the remaining side connected by lead 66*b* to the ungrounded side of capacitor 75. Also one of the contacts 68 is connected over lead 68*a* to line 73 and the remaining side is connected over lead 68*b* to the ungrounded side of capacitor 76. Contacts 70 and 72 are connected in like manner with leads 70*a* and 70*b* connecting one side of contacts 70 to line 73 and the ungrounded side of capacitor 77, respectively, while leads 72*a* and 72*b* connect sides of contacts 72 to lead 73 and the ungrounded side of capacitor 78. As will appear below, the ratings of capacitors 75, 76, 77, etc. to 78 are selected so that these can properly store charges received from the volume computer 25. As explained above, the remaining six relay coils, associated contacts and associated storage capacitors, have been omitted for convenience, as indicated by the dotted section of storage 27, although it will be appreciated that such additional units are similar to those individually illustrated.

Each of the other contacts associated with the coils has one side thereof connected to lead 80 and its remaining side connected to the capacitor which is associated with its next adjacent relay in the forward stepping direction. Thus, one side of contacts 65 is connected by lead 65*a* to lead 80 and the remaining side is connected by lead 65*b* to the ungrounded side of capacitor 76 which is associated with its next adjacent relay 40'. Also, one side of contacts 67 is connected by lead 67*a* to lead 80 and its remaining side is connected by lead 67*b* to the ungrounded side of capacitor 77 which is associated with its next adjacent relay coil 41. Likewise, contacts 69 are connected by leads 69*a* and 69*b* to lead 80 and the ungrounded side of the next capacitor in the series of steps. A corresponding lead 72*c* from a corresponding contact on the relay of the next to last step in the series feeds to capacitor 78 of the last step. One side of the contact 71 is connected by lead 71*a* to lead 80 and the remaining side is connected by lead 71*b* to the ungrounded side of the first capacitor 75 thus closing the ring.

Lead 80 is connected to lead 32 which is connected to the grid of tube 81 of comparison circuit 29 through resistor 92. The other input to comparison circuit 29 is by lead 31 which is attached to the grid of tube 82 of that circuit. Lead 31 conveys to the comparison circuit the output of volume computer 26 which has received its input from detector 14.

In summary, therefore, the comparison circuit receives two inputs, one from volume computer 26 and the other from volume computer 25. The output of volume computer 26 is fed directly into the comparison circuit and is applied to the grid of tube 82, whereas the output of volume computer 25 undergoes storage and time delay and then appears on lead 32 by which it is applied to the grid of tube 81. By the circuitry the voltages on leads 31 and 32 can be compared within the comparison circuit.

The precise manner in which the output of volume computer 25 is stored in storage 27 and read out will be considered below. Storage and delay is necessary since the readings of computers 25 and 26 actuated respectively by detector 13 and detector 14 are displaced in time.

The cathode of tube 82 of the comparison circuit is attached to the plate of tube 83 and the cathode of tube 81 is attached to the cathode of tube 84 through differential control circuits 85 and 94 which provide for an adjustment of the difference to be allowed between the volumes as measured between "X" and "Y" stations during comparison.

The volume at the "Y" station is compared with the volume at the "X" station, with a suitable delay of the latter corresponding to the transit time of traffic between the two stations. Since the pattern of vehicles in the measured group may change or the average speed of the vehicles may change, and also since there may be some measuring errors, the delayed volume from "X" is reduced by a selected percentage by control 94 or by a desired predetermined amount by control circuit 85 before subtraction from the volume from "Y" in the comparison circuit.

By varying the percentage control 94 a percentage of the signal applied across the cathode 94*a* load resistor is tapped off at the control 94. This provides selection of a percentage of the signal representing a volume of traffic which signal itself will vary according to the traffic volume. It will be appreciated that the percentage by which the volume may reasonably be reduced by such control would be substantially less than 50% so that the percentage control adjustment tap would be adjusted subsatntially above the 50% point which is equivalent to ½ the resistance on the cathode load resistor.

The control circuit 85, on the other hand, may apply a maximum predetermined voltage by adjustment of the tap on the potentiometer associated with the control circuit. A fixed potential, such as a battery for example, is applied in adjustable proportion to oppose in part the signal tapped off the control 94.

The bucking effect from predetermined control 85 upon the signal tapped through percentage control 94 substantially subtracts the potential applied through the predetermined variable control 85 from the signal applied through the percentage control 94.

The cathode of tube 83 is tied to the plate of tube 84 and coupled by capacitor 86 to the input of amplifier 34 which is an A.C. amplifier. Diodes 83 and 84 form a clamping circuit whose operation will be considered below. An A.C. voltage 87 is applied through high resistance 87' to the input of amplifier 34. The output of high gain amplifier 34 is applied to bridge rectifier circuit 36 and thence to alarm relay coil KT. Coil KT activates contacts 89 and 90, contact 90 serving to control an alarm (not shown) in accordance with the signal received and the comparison made, and contact 89 serving to actuate coil KTD which has delayed action through its associated resistance-capacitance circuit to actuate contacts 91*c* to operate a delayed alarm (not shown).

In parallel with contact 89 is a lock-in contact 91*a* for

relay coil KTD, which provides a lock-in circuit for the coil KTD via reset contacts 91*b*, which may be used and remotely located if desired for holding the delayed alarm active until reset.

In operation, as vehicles actuate detector 13, signals are received in volume computer 25 and operated upon and put into usable form, as a direct current positive voltage with respect to ground and of magnitude proportional to the traffic volume as vehicles per hour or per minute for example. At the same time, pulse generator 44 is applying signals to the beam switching tube. Such signals are being applied at a steady rate as determined by the preset speed adjustment 49 or at a variable rate as determined by speed averaging computer 46'. The detections for the speed averaging computers are made at one or various points which may be close by but not necessarily at the volume detecting stations. For each pulse output from the pulse generator, the next successive target in the beam switching tube is made conducting and the relay associated therewith is energized so that its contacts close.

Assume that the apparatus of the beam switching tube and target $T_0$ is now conducting, and via lead 59' energizes coil 39' closing the contacts 65 and 66. Since contacts 66 are tied to line 73, the output of volume computer 25 is applied to capacitor 75 to store a charge corresponding to the volume. With the next pulse applied by pulse generator 44 to the beam switching tube, the target $T_1$ conducts and by means of lead 60 energizes coil 40' closing relay contacts 67 and 68. This allows capacitor 76 to be charged to the voltage on lead 73 and since target $T_0$ is no longer conducting relay coil 39' is no longer energized. Capacitor 75 therefore is no longer tied in to line 73 because contacts 66 are open. With the next pulse received from the pulse generator, the target $T_2$ conducts energizing coil 41 closing contacts 69 and 70 and at the same time contacts 67 and 68 are opened so that the voltage on line 73 is at that instant stored in capacitor 77 and the charges which were placed upon capacitors 75 and 76 are retained there since these circuits are open and there is no way for the capacitors to discharge. This occurs throughout the cycle of operation of the beam switching tube until the complete ring has been traversed and each of the storage capacitors has received a charge until target $T_0$ is made conducting for the second time thereby closing contacts 65 and 66 again.

At this instant, capacitor 75 is once again applied to line 73 and the charge on capacitor 75 is modified in accordance with the voltage appearing on line 73 so that if the voltage on 73 is identical at this instant with the voltage which was on lead 73 at the first time target $T_0$ was conducting, there will be no change in the charge of capacitor 75. However, if the voltage appearing on line 73 has changed, then capacitor 75 will be changed accordingly so that its charge represents the voltage on line 73 at the most recent instant target $T_0$ was conducting.

Also when target $T_0$ conducts, contacts 65 close thereby placing capacitor 76 in contact with line 80 so that the voltage of capacitor 76 is applied by lead 32 to the input grid of tube 81. At the same instant the output of volume computer 26 is being applied by means of lead 31 to the grid of tube 82 so that a comparison can be made of the output voltages of volume computers 25 and 26, with the present instantaneous voltage output of computer 26 being compared with the output of volume computer 25 at an instant which is earlier in time by one cycle of the beam switching tube, less one step of such cycle. Thus the comparison is made with the earlier volume received and stored for a time lag of one step less than one full cycle of the beam switching tube, and such volume being reduced by the adjusting circuits 85 and 94.

Both tubes 81 and 82 are operated as cathode followers and their outputs are applied to the clamping circuit composed of tubes 83 and 84. If the voltages on lead 32 and 31 as applied to the grids of tubes 81 and 82 respectively are equal, then current flows in the clamping circuit from ground through the cathode resistor of tube 81, through differential control circuits 94 and 85 to tube 84 and from tube 84 to tube 83, and thence through tube 82 from cathode to plate to the power supply.

Through cathode follower action a voltage corresponding to the measured volume from X appears across resistor 94*a*. The use of the cathode follower permits a usable current to be obtained without disturbing the voltage from which it is derived on the storage capacitor. A reduced voltage is derived from resistance 94*a* by way of the differential control circuits 94–85 and this reduced voltage appears on lead 94*b*.

Correspondingly, the currently received volume indicating voltage from Y appears by cathode follower action on lead 95*a*. So long as the voltage on 95*a* is equal to or greater than the voltage on 94*b* a relatively safe traffic condition is indicated, showing that there had been no substantial reduction in traffic volume between points X and Y for substantially the same group of vehicles which have traveled between these points.

Thus accordingly, with voltage on lead 95*a* higher than 94*b*, a current flows through the diodes 83, 84 which maintains junction 92' at a relatively low impedance for the A.C. derived from point 87 through a high resistance 87' and capacitor 86. Thus the input of the amplifier 34 is essentially clamped away from the A.C. and no output is provided from the amplifier for operation of the rectifier bridge 36 and the output relays.

However, if the voltage on 95*a* is less than the voltage on 94*b*, diodes 83–84 will become non-conducting and a high impedance will appear at junction 92'. The A.C. from point 87 is then not shunted by means of capacitor 86 and a low impedance point at 92' and therefore appears on the input to amplifier 34 which provides an output at the rectifier bridge 36 to operate the relays KT and KTD as previously described.

The traffic condition which caused the potential of lead 95*a* to be lower than 94*b* was such as to indicate there was a stoppage or impediment between stations "X" and "Y." Therefore, under this condition the high impedance of point 92', allowing some input to the amplifier with its associated output to rectifier 36, causes relay KT to close its contacts 90 thereby giving an alarm of the traffic conditions.

Returning to the storage circuit, it is seen that when target $T_1$ conducts, the contacts 67 and 68 are closed so that the voltage or charge in capacitor 76 is adjusted to coincide with the voltage on line 73 and at the same instant the charge in capacitor 77 is applied to one of the input circuits of the comparison circuits via contact 67 and leads 89 and 32.

This is the delayed volume out of "X" corresponding to the traffic which is now providing an output at the "Y" computer and applied to the comparison circuit over lead 31.

It will be noted that in each step of the step cycle the volume signal currently being received from one location "Y" for example, is being compared with the delayed volume signal as stored from the corresponding traffic volume as it previously passed the preceding location, "X" for example.

When one capacitor is being charged, its next following capacitor is being sampled so that when capacitor 75 is being charged capacitor 76 is being sampled; when capacitor 76 is being charged, capacitor 77 is being sampled; and so on around the ring set up by the beam switching tube.

Each time a capacitor is sampled it is compared with the output of the "Y" volume computer which is computer

26. Also the charge that is being sampled is a charge that was placed upon the capacitor one step less than one full cycle of the beam tube earlier so that one step less than a complete cycle delay has been achieved between the storage and the measurement, and if the period of the beam power tube is properly related to the detectors 13 and 14, for example, the same group of vehicles being sensed at 13 will be sensed at 14 and compared with the appropriate time delay.

The sampling is actually a comparison of the charge on the capacitor, as modified by the adjustable allowable differental, with the output of the "Y" volume computer as appearing on lead 73. It should be noted that the output of the volume computer 26 is applied to the comparison circuit and the potential of the capacitor is applied to the comparison circuit, and the capacitor which is being sampled is not discharged when it is being sampled. Also since the relays K0, K1, K2, etc. K9 select the capacitor to receive the charge, it does not matter at which physical point the volume computers are connected to the ring. Relays allow only one set of capacitors to be utilized at one instant so that only one capacitor in a ring can be charged and only one capacitor in a ring can be sampled at a particular instant.

Resistor 92 and capacitor 93 on the input to tube 81 prevent the loss of signals during switching and resistor 74 allows for some averaging of the output of computer 25 during the switching intervals. This prevents instantaneous changes in the capacitors due to instantaneous variations in the output of the volume computer. Since resistors 63, diodes 63' and capacitors 64 are designed to introduce a delay between relays and prevent overlap, resistor 92 and capacitor 93 are necessary to prevent false voltage variations from appearing at the output.

An alternate form of this invention is illustrated in FIG. 4. In this form the delay and storage of the output volume computer 25 is achieved by use of a magnetic tape which has placed thereon at any instant, the output of volume computer 25 representing detection at sampling station "X," is converted into an oscillating signal which signal is read back after a delay in time, the delay being determined by the length of tape between the recording head and the read back head, so that a comparison can be made with the output of the volume computer 26, representing detection at sampling station "Y."

The output of volume computer 25, which is a D.C. output, is fed over lead 95 to an oscillator which is capable of oscillating over a range of frequencies such as 200 cycles per second to 1200 cycles per second when the frequency of oscillation is set by the D.C. input at lead 95, so that the frequency is representative and proportional to the volume. This oscillator is indicated in FIG. 4 by numeral 96 and may, by way of example, be a sine wave generator of a type well known in the art. The only requirement is that the particular output frequency be a function of the D.C. with the frequency proportional to the amplitude of the D.C. which amplitude is proportional to the volume of traffic at the sampling station.

The output of the oscillator is applied via lead 98 to the magnetic recording head 97 and the recording head places the signal on tape 99. The signal is read back via the read back head 101 at a time later depending upon the length of tape between the recording head and the read back head and the speed of the tape. This signal read by the read back head 101 is then compared with the output of volume computer 26.

The read back head 101 reads off the tape the signal that had been placed thereon by recording head 97 and applies this signal over lead 102 to an A.C. to D.C. converter 103 so that the output of the converter 103 on lead 104 is substantially the same D.C. as the output of volume computer 26 over line 95. The signal via lead 104 is applied to the comparison unit 29 along with the output of volume computer 26.

The comparison unit is substantially the same comparison unit shown in FIGS. 2 and 3, and the output of the comparison circuit 29 is applied to amplifier 34 and rectifier 36, both of which are substantially similar to that described in FIGS. 2 and 3, and thence to alarm 37 or 38, also as previously described.

The D.C. signal output of lead 104 thus represents the output of volume computer 25 delayed and is the output of the volume computer which, after allowable differential adjustment as described above is compared with the output of volume computer 26.

By way of illustration FIG. 4 shows one method by which the desired delay between the recording and reading back may be obtained. The wheel or gear 200 represents a friction held wheel by a friction load 202. The wheel 210 represents a drive wheel which rotates counterclockwise and pulls the tape 99 through the series of wheels or gears past both the recording head 97 and the read back head 101 and deposits the tape 99 in a temporary storage 203, from which it continues in the loop.

By adjustment of a slide or trolley represented by 205, the wheels or gears will be moved so as to lengthen or shorten the tape between the recording head 97 and the reading head 101. Such adjustment may cause a difference in the frequency as read by the read back head on that portion of the tape recorded while such change of slide or trolley 205 is in process. However, by utilizing a very slow change of slide or trolley 205 distortion of the signal may be kept at a minimum and below the frequency at which a change in represented volume causes actuation of amplifier 24 after comparison of the signal is made.

This magnetic tape storage method of comparison has continuous storage and comparison rather than the discrete step-by-step storage and comparison of the method described previously and thus the magnetic tape method would theoretically have higher resolving power, although the two methods approach each other as the number of steps increases in the step-by-step method.

Manual adjustment of the length of the tape 99 between the recording head 97 and the read back head 101 may be made by adjustment of the slide or trolley 205. Adjustment of slide or trolley 205 to the right would shorten the length of tape between the heads 97 and 101 and thus compensate for a higher average speed of volume of traffic between two stations thus decreasing the delay of the signal between the two heads 97 and 101. Movement of slide or trolley 205 to the left would lengthen the tape 99 between the two heads 97 and 101 and thus compensate for a lower average speed of a volume of traffic between two stations causing an increase in the delay of the signal between recording and read back.

Automatic adjustment of the length of tape 99 between the two heads 97 and 101 may be obtained by employing a speed detector, as for example the speed detector 21 previously mentioned, associated with a speed averaging computer, as for example, the speed averaging computer 46 previously mentioned.

As more fully described in my said copending application Serial No. 732,248, aforementioned, the output of the speed averaging computer 46, in combination with the speed detector 21 is a D.C. voltage proportional to the average speed of vehicle traffic detected. This voltage may be used to drive a servo motor assembly 205', which assembly would move the slide or trolley 205 and position the slide 205 according to the amplitude of the voltage. The slide 205 may be moved to the right, to shorten the tape, for increased voltage on a position comparable to the average speed then being read in D.C. voltage and may be moved to the left, to lengthen the tape, for decreased voltage, to a position comparable to the slower average speed represented by the reduced voltage.

The servo motor assembly present in my speed averaging computer described in my said copending application 732,248 for obtaining a D.C. voltage comparable to

the average speed then read may be used to drive the slide **205**, through appropriate mechanical connections.

It will be appreciated that after the tape **99** is read back the signal on the tape is of no significant value and this part of the tape may be cancelled by erasing in the usual manner by employing an erasing head **97'** to prepare the same for rerecording so that a continuous roll of tape may be used and thus avoid change of tape.

Meter **105** is shown attached to lead **104** and this may be used to indicate the volume of vehicles being measured by volume computer **25** delayed.

If a speed averaging computer is used in connection with the embodiment shown in FIG. 4, there are various ways in applying its output to the system to achieve the necessary results. One suggested method is to use the output to control and vary the distance or length of tape **99** between the recording and read-out heads as indicated in FIG. 4. This variation of tape loop between recording and read-out would be inversely proportional to the speed of traffic sensed and would be gradual so as not to materially change the frequency as read-out in comparison with the frequency as recorded.

Although the present invention is described herein particularly in relation to one preferred aspect employing traffic volume sensing and comparison, it will be understood as noted earlier above that some other characteristic of traffic flow such as traffic speed or traffic density may be sensed and compared in a generally similar manner in accordance with the novel means or method of the present invention, within the scope of the invention.

Thus in the case of comparison of speeds, the speed detection/translation devices such as devices **21** and **22** might be located at the sensing locations X and Y, and the speed average computers **46** and **46'** and the like substituted for the volume computers **25** and **26** to provide suitable electrical outputs on lines **30** and **31** into the same storage and comparison means as in FIGS. 3*a*–3*b*, or on lines **95** and **100** into the storage and comparison means of FIG. 4 for example. Similar speed detecting and computing means might be substituted for the volume type detectors and computers at other locations W and Z for example with the storage and comparison means employing the electrical voltage representative of speed instead of the electrical voltage representative of volume.

Such speed detector and speed average computer combination may be of the type as more fully described and explained in my said copending application Serial Number 732,248, aforementioned, that senses and determines the speed of the individual vehicles passing a particular point and continually computes the average speed of a last predetermined number of such vehicles. Such speed average computer provides an electrical output which represents the latest running average or moving average speed as recomputed upon passage of each new or additional vehicle, and such output remaining substantially unchanged indefinitely until passage of a further vehicle.

In this connection FIG. 5 illustrates in block diagram an alternate form of traffic monitoring system, employing detection and comparison of average speed of vehicles in the traffic flow in lieu of traffic volume, the average speed of vehicles in the traffic flow being another characteristic of vehicle traffic.

FIG. 5 diagrammatically illustrates two vehicle speed sensing stations at X and Y disposed along a highway **11**. The speed detection units **21** at station X and **22** at station Y may be similar to the corresponding units **21** and **22** in FIG. 1 and explained in reference thereto, while the speed average computer **46** of station X and speed average computer **46'** of station Y may be similar to the speed average computers **46** and **46'** of FIG. 1.

As illustrated in FIG. 5, average speed information from speed average computer **46** for station X is applied via line **30** to X–Y comparator **10** for storage by the comparator, which may be similar to the comparator **10** previously described. Also speed information may be applied to X–Y comparator **10**, via input line **24'** thereof for example, for control of the pulse generator as illustrated in FIG. 2 and FIG. 3*a* to control the time delay in storage inversely with speed.

Current average speed information from speed average computer **46'** for station Y also is applied to the X–Y comparator **10** via line **31** for comparison with the stored average speed information. This average speed information from station Y may also be applied to a Y–Z comparator for example for storage and subsequent comparison with current average speed obtained from another detection or sensing station (not shown) further along the roadway downstream in the traffic flow. Similarly average speed information from computer **46** for X may be applied also via line **31'** to a W–X comparator (not shown) as current speed information for X for comparison with stored and delayed speed information from a station W upstream (not shown).

Where it is desired to employ traffic density as the traffic characteristic to be compared, both traffic volume and traffic speed could be sensed at the spaced locations X and Y and the traffic density in vehicles per unit distance along the roadway computed therefrom for each location by dividing volume by speed as in my copending application Serial Number 816,966 filed May 29, 1959 under the title "Traffic Density Computer," now abandoned, and the voltage output of such traffic density computers for X and Y respectively could be applied to the lines **30**, **31** of FIG. 3*b* or to the lines **95** and **100** as input to the storage and comparison means disclosed herein. As more fully described in my copending application S.N. 816,966, provision can be made for computing traffic density in generally inverse relation to speed alone at low traffic speeds, and in any event the electrical voltage output of the traffic density computer represents traffic density computed on a running or moving average basis which is readjusted automatically as additional vehicles pass the sensing station so as to represent the latest such information and to maintain its electrical output for the latest series of vehicles which have passed and indefinitely until readjusted by arrival of a further vehicle.

The speed detector **21'** provides a composite speed and passage impulse output, and the speed and impulse translator **21''** provides two electrical outputs therefrom. One output, a detector impulse when the vehicle is detected, is applied to a volume computer **25**, which volume computer may be similar to the X volume computer **25** in FIGS. 1, 2, 3*b* and 4. A second output, representing the speed of the detected vehicle, is applied to a speed average computer **46**. The speed average computer **46** may be similar to the speed average computer **46** in FIGS. 1 and 4.

Outputs from the volume computer **25** and the speed average computer **46** are each applied to a density computing unit which computes the density of the traffic flow as detected at station X. The output of the traffic density computer, represented by broken line block **110**, which is a continuous electrical signal representing the running or latest average traffic density, is applied via lead **30** to X–Y comparator **10** for storage and may be applied to a comparator, for example W–X comparator (not shown) for comparison with a previously stored value of traffic density from location W (not shown here). The X–Y comparator **10** may be similar to the X–Y comparator **10** in FIGS. 1, 2, 3*a* and 3*b*.

The output of the speed average computer **46** may be applied, as illustrated via lead **24'** to the comparator **10** to control the time delay in the storage, inversely with speed, similar to that described with reference to FIGS. 2 and 3*a*.

A second sensing station Y is represented including a substantial duplication of the components of the sensing station X, in FIG. 6.

The broken line box **22** represents a speed detection unit including a detection unit **22'** and a speed and impulse translator **22''**. The outputs of the speed and impulse translator **22''** are applied to the volume computer **26** and speed average computer **46'**. The output of the volume computer is applied to a density computing unit while the output of the speed average computer is applied to the density computing unit and to the Y–Z comparator **10''** (shown in broken line form).

The traffic density computer **111** provides an electrical output representing traffic density as detected at station Y which is applied to X–Y comparator **10** via line **31** for comparison with the stored traffic density having been detected at sensing station X. The traffic density computer **111** provides an output via line **30''** for storage by Y–Z comparator **10''** for comparison at a later time with traffic density information from another sensing station downstream in the traffic flow.

It will be appreciated that as an alternative to the response to lower current information, it may be desired to provide response when the current information is substantially higher in value than the previously stored and delayed information with which it is compared. This may be accomplished by interchanging the inputs **31** and **32** in the comparison circuit **29**. Referrng back to FIG. 3*b*, lead **32**, for example may be connected to the grid of tube **82** and lead **31** may be connected through resistance **92** to the grid of tube **81**, thereby interchanging the inputs **31** and **32**.

Obviously a double pole reversing switch may be employed to interchange the leads **31** and **32** between the grid of tube **82** and the resistance **92** as desired so that selection may be made for response by the same comparator between different differentials between delayed information and current information such as when delayed information value is higher than current information value or when delayed information value is lower than current information value. It will be obvious to those skilled in the art that other arrangements might be made for reversing the differential response.

It will be appreciated that in some traffic monitoring systems as herein described it may be desired to provide an indication in the form of an alarm or otherwise when any minimum differential between delayed information and current information occurs.

It has been described, with reference to FIG. 3*b* how response is provided when delayed information is of at least a minimum value above the current information value.

In order to provide separate response when delayed information is of at least a minimum value below the current information value as well as when the delayed information value is at least a minimum value above the current value, a second or additional comparison circuit, substantially as illustrated in FIG. 3*b*, including an adjust circuit and comparison circuit, an amplifier, a rectifier and an alarm, similar to those shown, may be added to the illustrated comparator between two sensing stations. For the second comparison circuit, the delayed information, as for example, from the storage **27** via line **32** would be applied to the grid of tube **82** instead of through resistance **92** to tube **81** and current information such as the current information on line **31** would be applied through resistance **92** to the grid of tube **81** instead of to the grid of tube **82**. With such additional comparison circuit connected as described the additional alarm would provide indication when current information were of a value substantially above the delayed information.

In this form one response is provided when current information value exceeds the value of delayed information and a different and separate response is provided when current information value is lower than the value of the delayed information.

Thus it has been described how response may be provided when the delayed information is of higher value than the current information, how response may be provided when delayed information is of a lower value than the current information and how response to both conditions may be provided.

A high impedance meter such as a vacuum tube voltmeter may be connected between leads **94***a* and **95***a* if desired to indicate the amount and polarity of difference between the current value and the stored delayed value of the traffic characteristic compared.

Although the above description has been primarily presented with respect to two to four traffic characteristic sensing stations obviously a larger number of sensing stations may be employed disposed along the same roadway, by addition of further units of the apparatus described or illustrated.

As the number of sensing stations along a roadway is increased and the distance between the stations is reduced a finer detail of the traffic flow will be detected and compared. The number of sensing stations employed and the distance between each sensing station depends upon the length of the roadway and the fineness of the detail of traffic flow desired to be detected and compared or the overall speed of response to a change in traffic flow by some of the series of stations.

Where multiple sensing stations, in excess of two, are disposed along a roadway a stoppage between two stations will provide somewhat different differentials between the delayed stored information and the current information depending upon the traffic flow characteristic detected, and which comparator of the series is observed.

If, for example, a stoppage of traffic occurs between two sensing stations, X and Y, but near X for example, and traffic backs up so that the traffic characteristic detected, average speed, for example, first becomes reduced at station X, the first indication would be a response to a reduced current average speed value at station X as the current average speed at X is compared with the previously stored and delayed average speed from W in the W–X comparator. Thus the differential at the W–X comparator would have the current value lower than the delayed stored value. Since the value of the average speed at X is also stored and compared with a new current average speed at Y, at a time later, the X–Y comparator would show a differential where the value of the delayed average speed would be lower than the value of the current average speed. This second differential determined by the comparator X–Y results from the fact that average speed output value provided by the speed average computer is maintained in the event of an absence of further input speed signals and the speed average value is reduced by the sensing of low speed vehicles rather than by an absence of vehicles passing the sensing station.

When the traffic flow characteristic of traffic volume is detected and compared a somewhat different differential between the current volume and the delayed volume would be sensed under like traffic conditions since the volume computation is based on time and computed traffic volume is reduced with time as well as when the number of vehicles passing the detection station is reduced.

From the above description it will be appreciated that where only two stations are employed a traffic impediment downstream beyond but near the second station will have a somewhat different effect from that of a similar impediment between the two stations where speed is the flow characteristic compared, since the impediment beyond the second station will ordinarily cause a reduction in traffic speed initially at the second station and thereby produce a lower value of the current input to the comparison unit in the comparator than the value of the stored delayed input into such comparison unit, but an impediment between the two stations will ordinarily shortly

cause a reduction in speed only at the first of the two stations, which, after some further lapse of time approximating or exceeding the travel time delay, will cause the stored delayed input into the comparison unit from the first station to be lower that the current input in such comparison unit from the second station.

Thus in the case of speed sensing at only two locations it may be desired to respond to a higher current speed signal value than the stored delayed speed signal value to sense traffic impediment between the stations rather than to sense traffic impediment beyond the second or current information station.

It also may be desired to respond individually to both differentials in the comparison by employing two comparison units, one arranged to respond to higher current information and the other to respond to lower current information in relation to the stored delayed information, as more fully described above.

Similarly, different effects may be obtained with traffic density where only two stations are considered, depending on whether the impediment is beyond the second station so as to cause an increase in current traffic density as sensed at the second station and a consequent relatively prompt differential of current value exceeding stored delayed value, or whether the impediment is between the two stations to cause an increase in traffic density at the first station relative to the traffic density at the second station and after the travel time delay to cause a consequent differential at the comparison unit of current value below stored delayed value, and the type of response can be selected as desired.

Where more than two stations are employed in traffic monitoring the earliest response will ordinarily be obtained by the comparator which has its current information first affected by the impediment for the traffic flow characteristic being compared, such current information being received from the downstream station of any pair of stations being compared, and the type of response desired can be selected accordingly.

Accordingly, the several objectives of the invention, as specifically aforenoted have been achieved with the presentation of the various methods and systems described. Obviously, two or more variations of the present invention may be employed in combination as desired and numerous changes, in construction, substitution and rearrangement of parts may be resorted to without departing from the spirit of the invention within the scope of the claims.

I claim:

1. A traffic monitoring system for comparing the volume of traffic passing two widely spaced locations on a roadway in the same direction, including in combination,

two detector means for sensing vehicles in the same lane of the roadway, said detectors being widely spaced from each other so that a vehicle moving in said direction will pass said detectors in sequence,

volume computer means individual to each of said detectors for generating a signal voltage in accordance with the volume of traffic detected by its associated detector,

means for storing the volume signal voltage generated by the computer means for the first of said detectors in said direction,

means for comparing signal voltages,

means for applying the signal voltage from said storage means to said comparison means after a time delay approximating travel time for such traffic between said detectors,

means for applying the signal voltage generated by the computer means for the second detector to said comparison means whereby the signal voltages are compared at a time substantially when the traffic so sensed at the first location before said time delay should be passing the second location after said time delay,

and indicator means activated by the output of said comparison means.

2. A traffic monitoring system for comparing the volume of traffic passing two locations in a roadway in accordance with claim 1, in which the comparison means includes

a cathode follower amplifier,

an input lead to the control grid of said cathode follower which receives the first signal voltage from the storage means,

a second cathode follower amplifier,

a second input lead to the control grid of said second cathode follower which receives the second signal voltage,

a variable clamping means whose clamping is a function of the relative outputs of said cathode followers,

means for applying the outputs of said cathode followers to said variable clamping means to control the clamping action thereof,

an alternating voltage source,

means connecting said source to said clamping means,

and means for detecting the amplitude of the unclamped alternating voltage.

3. A traffic monitoring system for comparing a characteristic of traffic flow of traffic passing two locations in a roadway including in combination

first detector means for sensing vehicles on the roadway,

generating means connected to said detector for developing a signal voltage in accordance with a characteristic of traffic flow of traffic detected by said detector,

a common lead to which the signal voltage is applied,

a plurality of capacitors,

switching means actuatable for selectively coupling said capacitors to said common lead,

cyclic stepping switch means, said stepping switch means actuating said coupling switch means to sequentially connect said capacitors one at a time to said common lead to store said signal voltage on respective capacitors in respective steps of said stepping switch means,

a second like detector means spaced from said first detector means,

second generating means connected to said second detector for developing a second signal voltage in accordance with the characteristic of traffic flow of traffic detected by said second detector,

comparison means for comparing voltages applied to two inputs to provide an output,

means connecting the second signal voltage to one of the inputs of the comparison means,

a second common lead connected to the second input of the comparison means,

second switching means actuatable for selectively coupling said capacitors to said second common lead, said stepping switch means actuating said second switching means to sequentially connect said capacitors one at a time to said second common lead in respective steps subsequent to said storage steps of said stepping switch means to apply to said second common lead the signal voltage previously stored on the respective capacitors,

and indicator means activated by the output of said comparison means.

4. A traffic monitoring system for sensing changes in the flow of traffic passing two locations spaced along a traffic lane, including

means for sensing traffic passing a first of said locations, said sensing means producing a signal representative of a flow characteristic of traffic passing said first location in said traffic lane,

second means for sensing traffic passing a second of

said locations spaced in the direction of traffic flow from the first location, said second sensing means producing a second signal representing a flow characteristic of traffic passing said second location in said traffic lane,

means for storing the first signal for a time period approximating the travel time of such traffic from the first to the second location,

means comparing the second signal substantially currently as sensed with the stored signal as delayed for said time period for providing an output signal representative of the difference between the first and second signals.

5. The invention in accordance with claim 4 wherein said sensing means are operable to produce an electrical signal having a value representative of the volume of traffic flowing in one direction past the respective first and second locations.

6. The invention in accordance with claim 4 wherein said sensing means are operable to produce an electrical signal having a value representative of the speed of traffic flowing in one direction past the respective first and second locations.

7. The invention in accordance with claim 4 wherein said sensing means are operable to produce an electrical signal having a value representative of the density of traffic flowing in one direction past the respective first and second locations.

8. In combination,

means for substantially continuously sampling the flow of traffic vehicles past a first location in a traffic lane, said sampling means deriving a first electrical signal having a value representative of a flow characteristic of a group of vehicles of said traffic flow,

means for substantially continuously storing said electrical value signal in the time sequence of its sampling,

further means for substantially continuously sampling the flow of traffic vehicles past a second location spaced from said first location in the direction of traffic flow from said first to said second locations, said further sampling means deriving a second electrical signal having a value representative of a flow characteristic of a group of vehicles of the traffic flow at said second location,

means comparing the second electrical value signal with the first electrical value signal stored a time period in advance of said second electrical value signal approximating the travel time for such traffic from the first to the second location for providing an output in response to the difference between said compared value signals whereby substantially the same traffic will be compared in normal free flow between said locations.

9. A combination as in claim 8 further including sensing means for sensing the speed of vehicles in said traffic lane, and means responsive to the sensing means for varying the storage time period for the output of the first electrical value signal to said comparison means inversely with the speed.

10. A combination as in claim 8 and in which said storage means includes cyclically operating means for cancelling the earliest said stored value signal after said comparison for reuse of said storage means for so storing the latest said first value signal.

11. A combination as in claim 8 including

means for providing an output in response to said difference exceeding a determined minimum, and including

dual means cooperating for adjusting said determined minimum, one of said dual means setting a desired preset minimum and the other of said dual means setting a minimum level of one of said compared signals.

12. A combination as in claim 8 in which the comparison means includes means for providing an output signal representative of a percentage difference between the two compared values of said signals.

13. A combination as in claim 8 and including means receiving said difference output for providing a further output in response to said difference output exceeding a predetermined value.

14. A combination as in claim 13 and including means for varying said predetermined value of said difference output in accordance with one of said electrical value signals.

15. A combination as in claim 8 in which said storage means includes

a loop of magnetic tape,

driving means for advancing said tape,

means for recording said first electrical value signal on said tape,

read-out means spaced along said tape from said recording means, said read-out means for supplying said stored electrical value signal to said comparison means for said comparison,

and means for erasing the previously recorded and compared signal from said tape before recording the latest said first electrical value signal in said sequence.

16. A combination as in claim 15 and including

means for varying the length of tape between said recording means and said read-out means inversely in accordance with the speed of traffic proceeding along said lane to vary the time period of storage of such stored signal in accordance with the travel time between said first and second locations.

17. A traffic monitoring system for a traffic lane for a given direction of flow of vehicular traffic including a series of traffic sensing stations spaced along said lane,

means at each sensing station for detecting the passage of individual vehicles,

and computer means for each station coupled to the detecting means thereof for developing therefrom an electricl signal representative of the rate of traffic flow passing said station,

said system also including means for receiving from each pair of adjacent spaced stations the said electrical signals from the respective stations of said pair,

means for storing the signal received from the first station of said pair in the direction of traffic flow,

means for comparing the signal currently received from the second station of said pair with the signal previously so stored as received from the said first station of said pair, said first station signal being stored for a time period representative of the travel time for the traffic between the two stations of said pair,

and means controlled by said comparison means for responding to any substantially lower rate of traffic flow at the second station of said pair as compared to the rate of traffic flow at the first of said pair of stations as represented by said compared signals, whereby an indication may be obtained of substantial impedance of traffic flow between any of said successive stations.

18. A traffic monitoring system as in claim 17 in which the detecting and rate of flow signal computer means for each station are common to the comparison and response means for the pair of stations including that station and the next preceding station and to the comparison and response means for the pair of stations including the said station and the next following adjacent station, whereby the number of said comparison and response means is one less than the number of stations in said series and the number of said computer means is equal to said number of stations in said series.

19. A traffic monitoring system for comparing the flow of vehicular traffic as it passes successive locations spaced along a traffic path including

means for sensing vehicles, said means for having an

output of a first electrical value signal averaged to be representative of a characteristic of flow of a series of successive vehicles passing the first of said locations,

second like vehicle sensing means for sensing the same characteristic of traffic flow passing a succeeding one of said locations downstream with respect to the traffic flow, said second sensing means having an output of a second electrical value signal averaged to be representative of said same characteristic of traffic flow of a series of successive vehicles at said succeeding one location,

menas for progressively storing said first electrical signal for a time lag of such storage approximating the time for such traffic to travel from said first to said succeeding one location,

means comparing said stored first signal with the second electrical signal to derive a difference electrical signal from said compared signals,

and means for responding to said difference signal exceeding a predetermined difference.

20. A traffic monitoring system as in claim 19 and which includes a long series of said successive locations each with individual said sensing means, and in which said system includes said storage and comparison means for each succeeding pair of said locations, said comparison means comparing the electrical signal currently received from the sensing means of any one of said series of locations with the stored and delayed electrical signal from the sensing means for the preceding one upstream of said series of locations and said storage means storing said currently received electrical signal for later comparison with the electrical signal currently to be received at such later time at the next succeeding such location downstream,



and means for progressively cancelling said stored compared signals after said comparison.

21. A traffic monitoring system as in claim 19 in which said characteristic of traffic flow is traffic speed and in which said traffic sensing means for the respective locations include speed average computer means individual to the respective locations for developing the respective signals.

22. A traffic monitoring system as in claim 19 in which said traffic flow characteristic is traffic density and in which said sensing means for the respective locations include traffic density computer means individual to the respective locations for providing the respective first and second electrical signals as representative of traffic density in number of vehicles per unit distance along the traffic path for the respective first and succeeding locations.


**References Cited by the Examiner**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 1,958,631 | 5/34 | Logan | 340—38 |
| 2,243,341 | 5/41 | Horni | 340—39 |
| 2,542,978 | 2/51 | Barker | 340—38 |
| 2,594,276 | 4/52 | Barker | 340—38 |
| 2,877,454 | 3/59 | Zedlar | 340—38 |
| 2,883,108 | 4/59 | Thorton | 340—38 X |
| 2,908,891 | 10/59 | Cass | 340—38 X |
| 2,917,732 | 12/59 | Chase | 340—38 X |

FOREIGN PATENTS

| | | |
|---|---|---|
| 84,114 | 8/54 | Norway. |



NEIL C. READ, *Primary Examiner.*

BENNETT G. MILLER, ELI J. SAX, THOMAS B. HABECKER, *Examiners.*