June 27, 1967 L. CASCIATO 3,328,791

TRAFFIC MONITORING SYSTEMS

Original Filed Jan. 13, 1961 6 Sheets-Sheet 1

FIG. 1

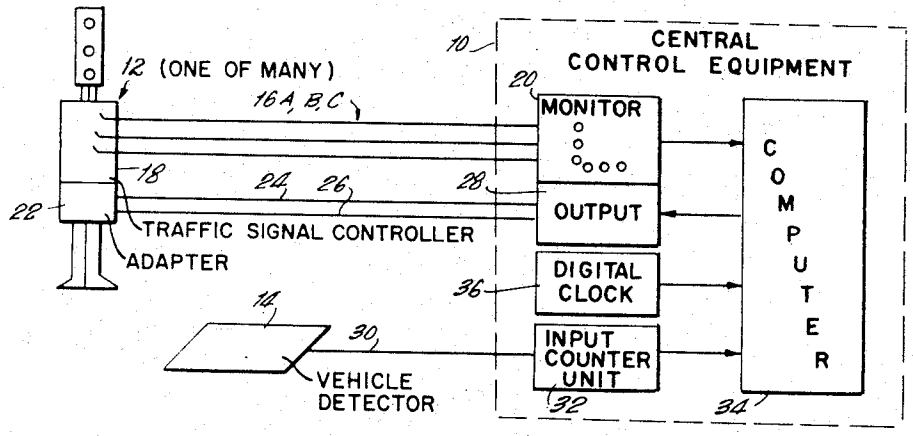
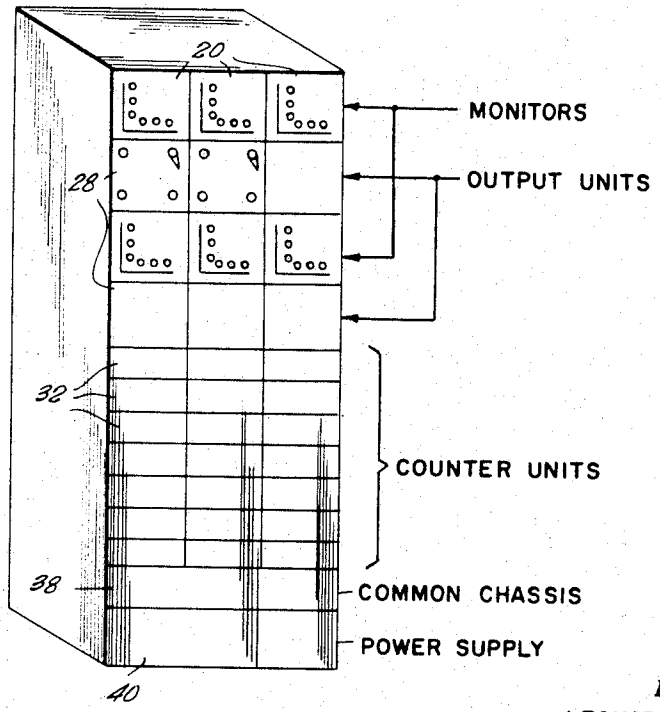


FIG. 2



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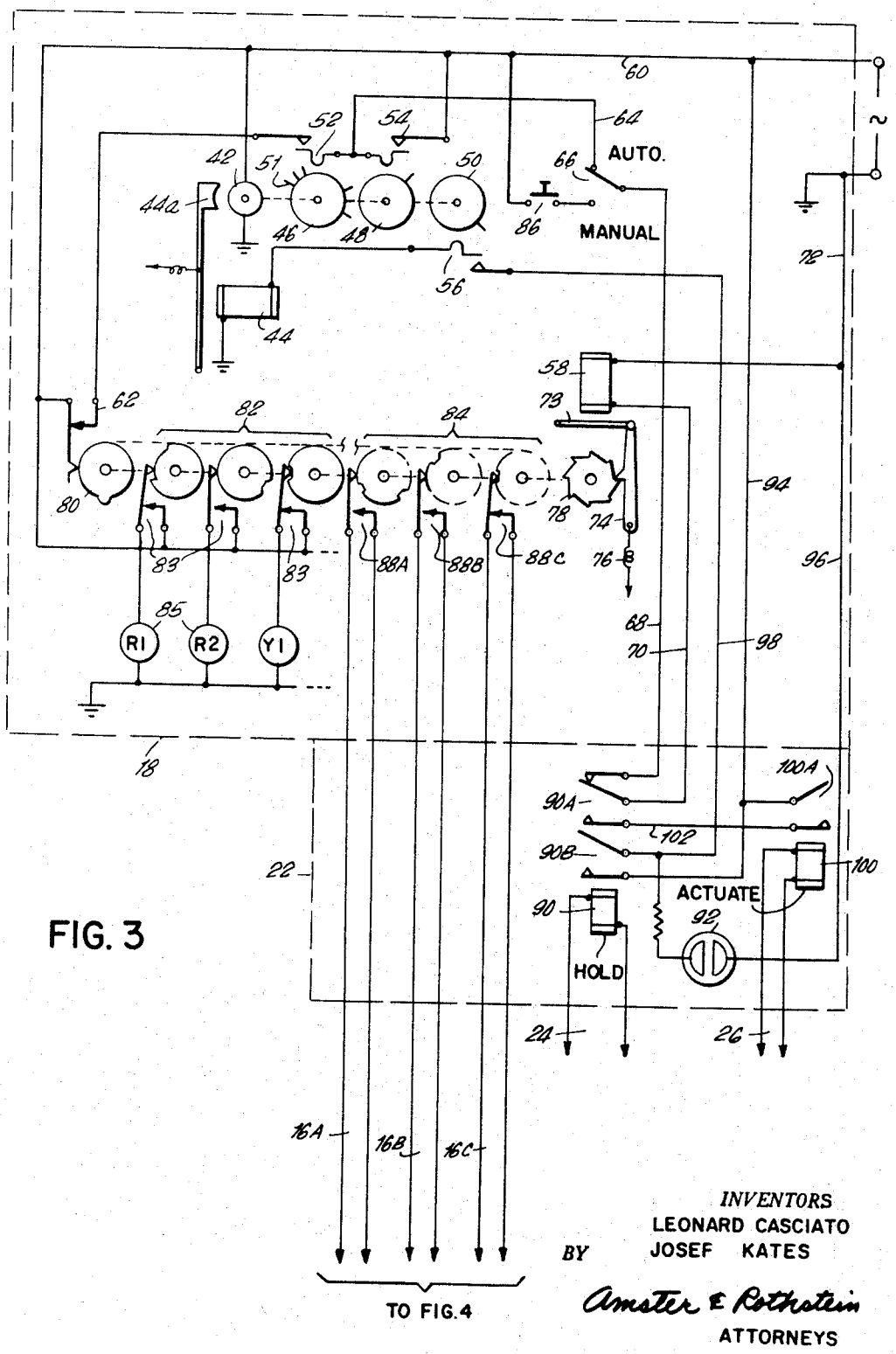


FIG. 3

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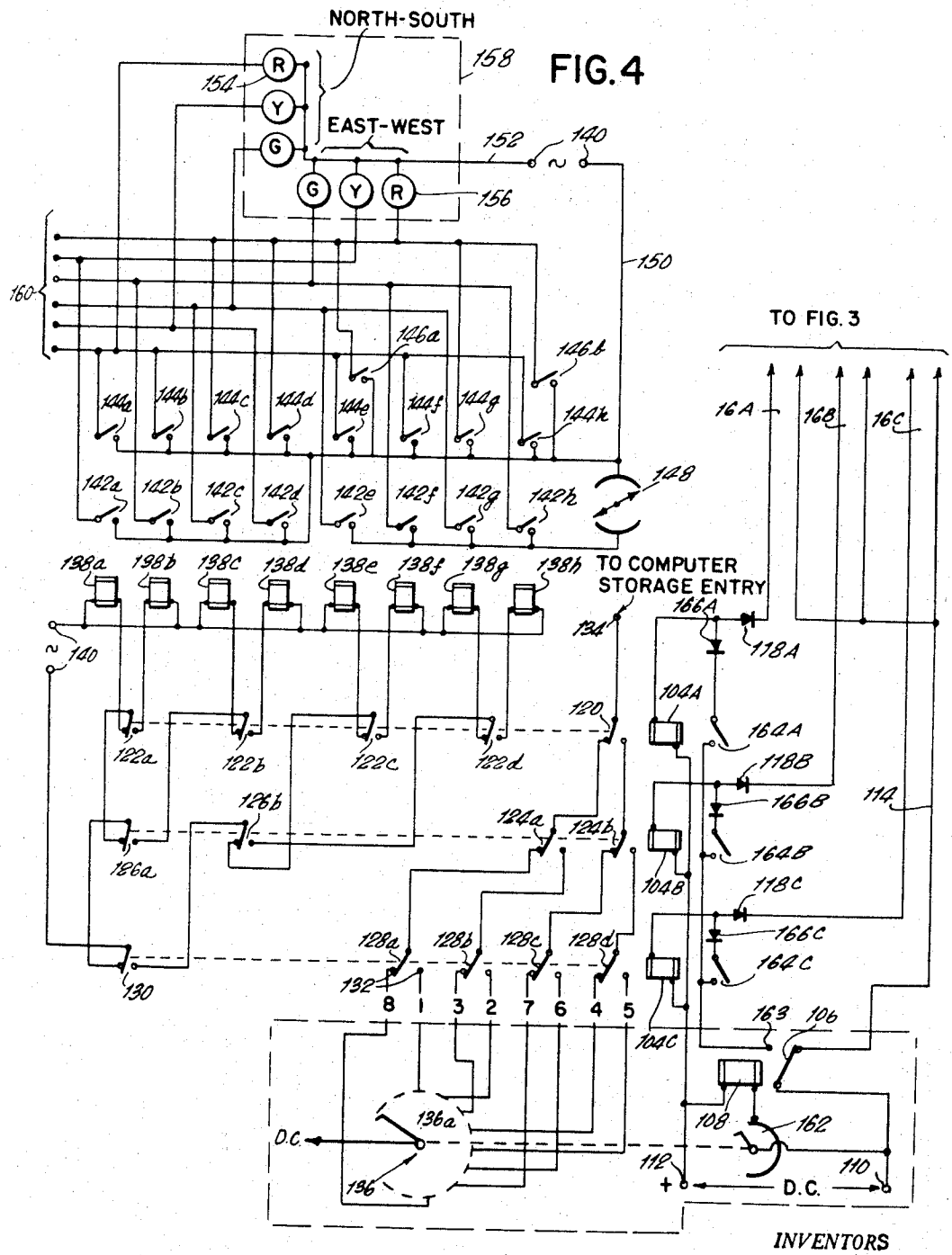


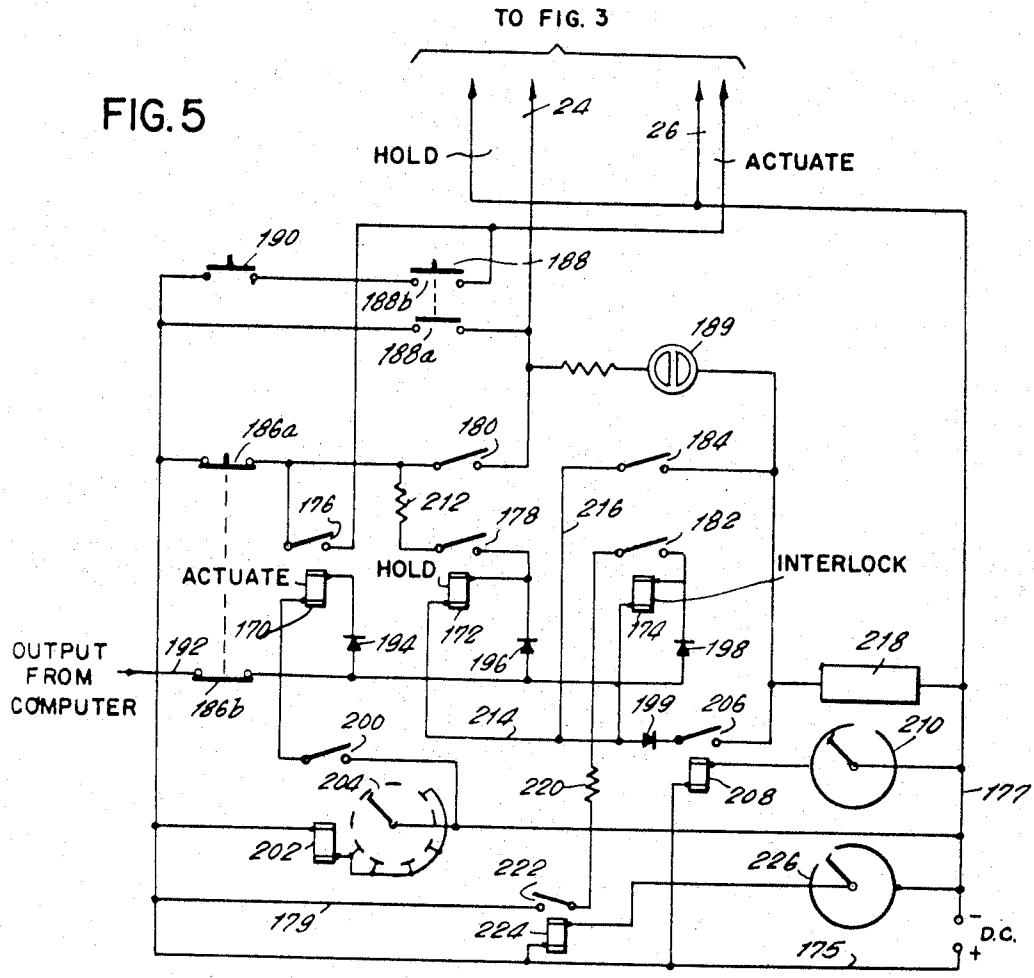
FIG. 4

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FIG. 5



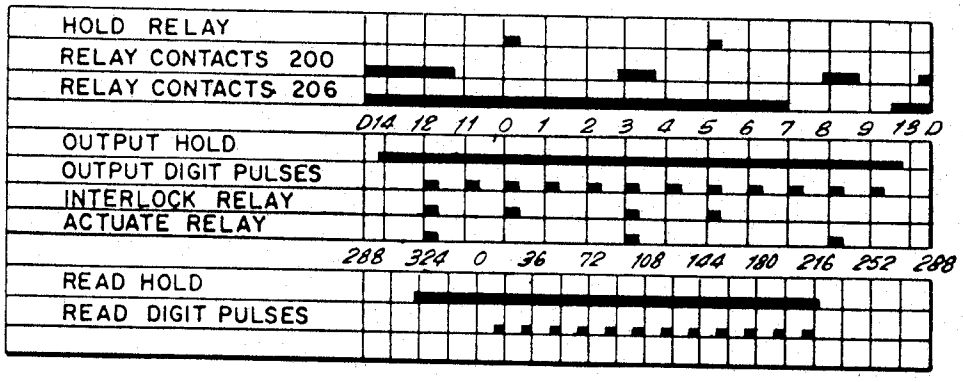


FIG. 6

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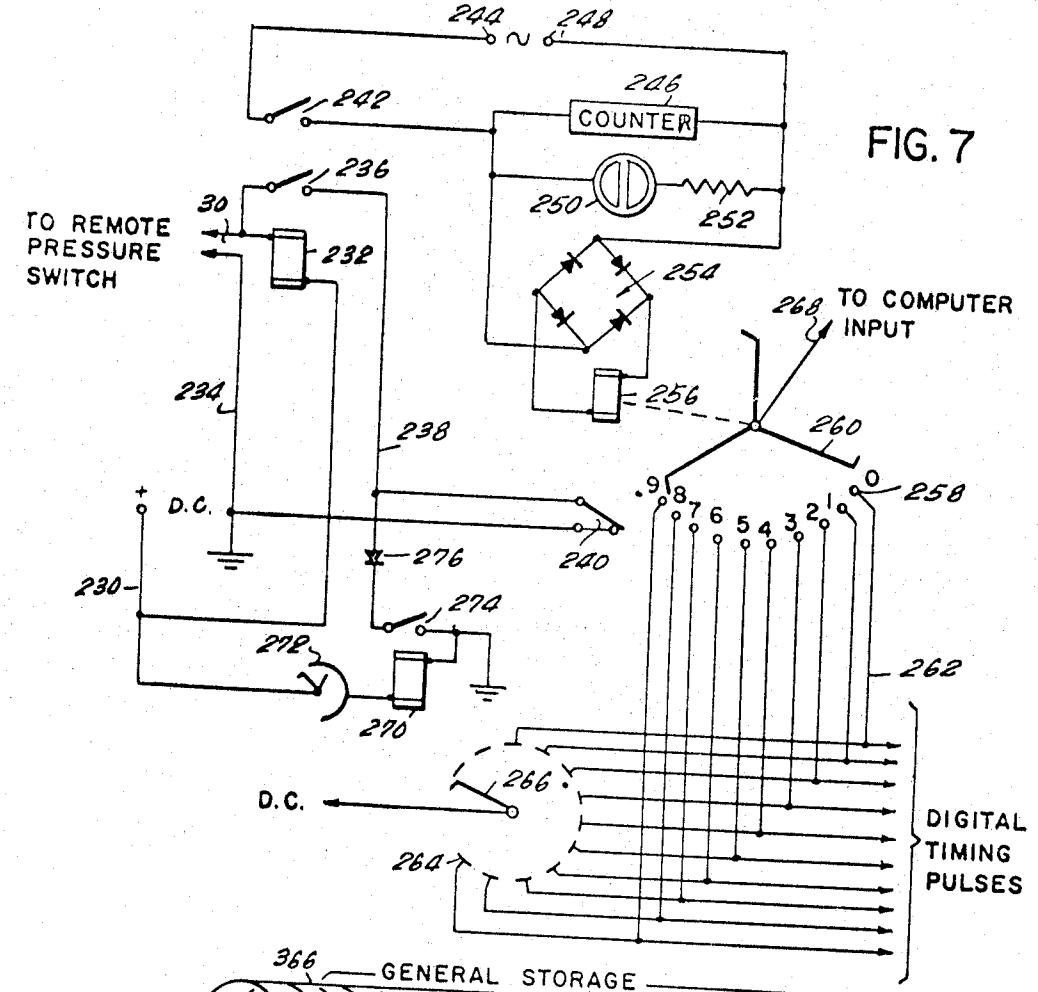


FIG. 7

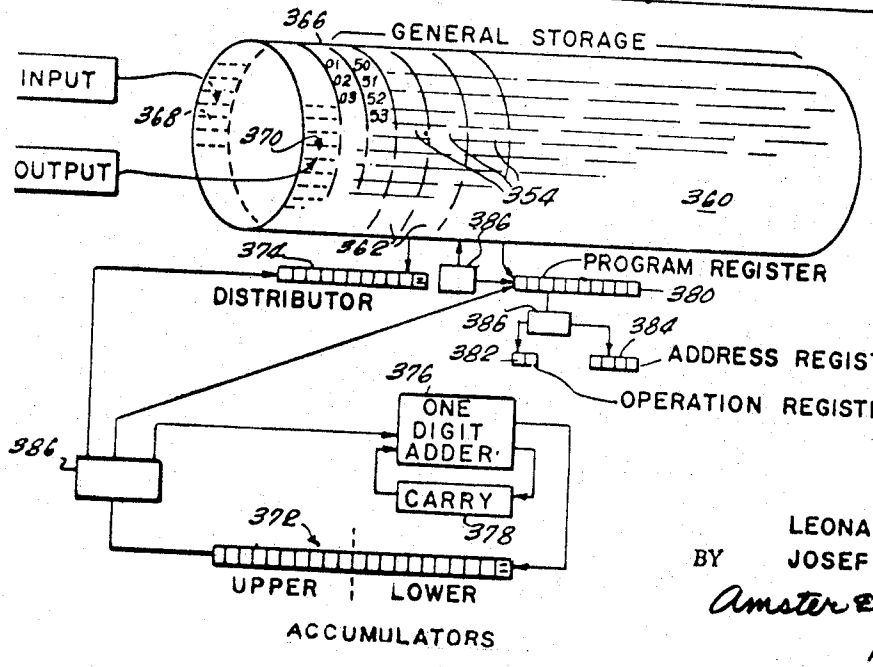


FIG. 9

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TRAFFIC MONITORING SYSTEMS

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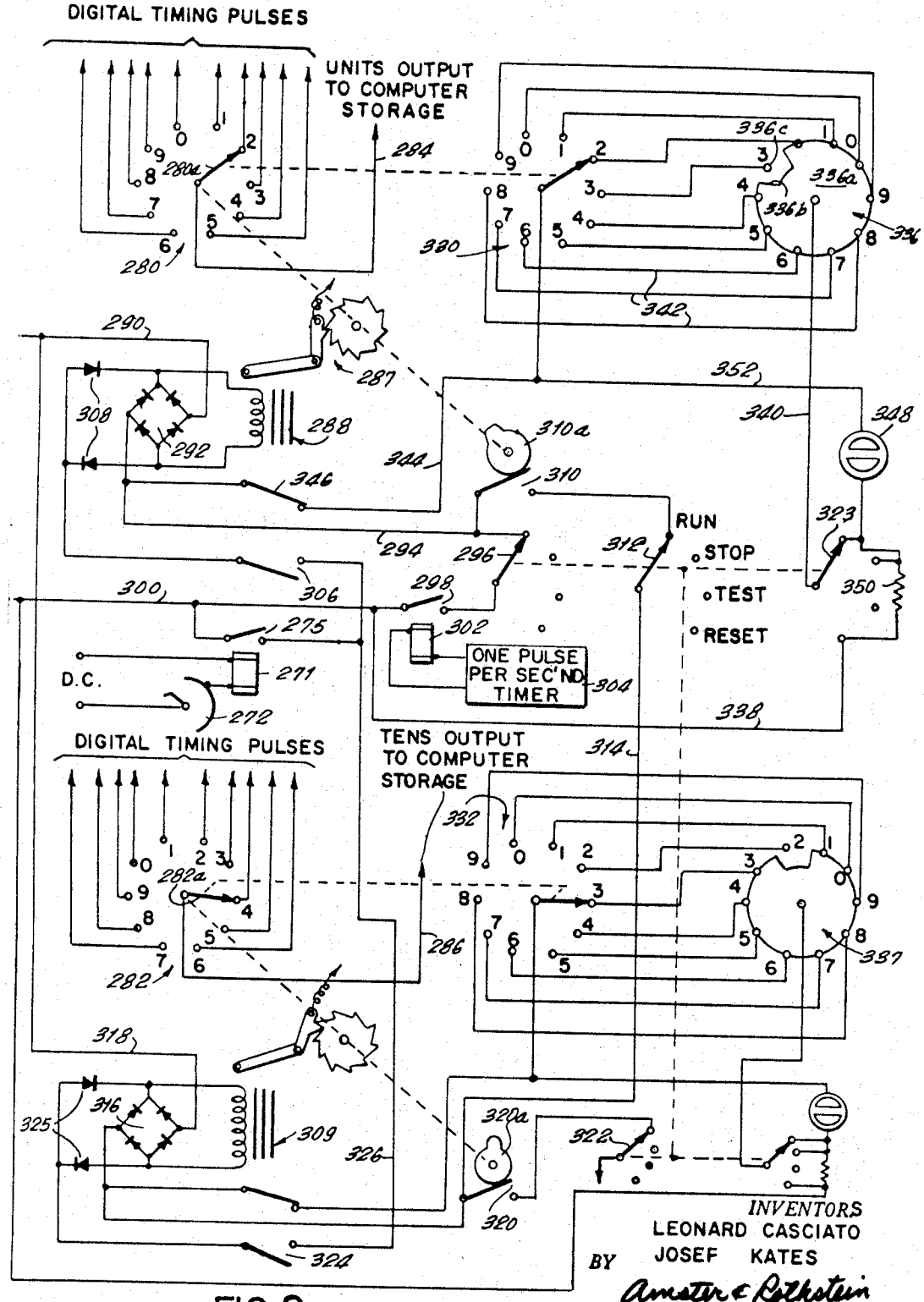


FIG. 8

United States Patent Office 3,328,791 Patented June 27, 1967

3,328,791

TRAFFIC MONITORING SYSTEMS

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Original application Jan. 13, 1961, Ser. No. 82,580. Divided and this application July 9, 1965, Ser. No. 478,518

3 Claims. (Cl. 340—324)

This is a division of application Serial No. 82,580 now Patent No. 3,254,324.

The present invention relates to methods and apparatus for controlling traffic signals.

In large cities, with ever-increasing traffic and traffic congestion, there has been a rapid rise in the number of signal-controlled intersections. In a typical modern city, the concentration of traffic signal installations varies at different parts of the city, and may often exceed a density of 100 per square mile. The traffic patterns which these signals are intended to control result from an intricate relationship between business, industrial and residential factors. The concentration of vehicles varies from a low level at night to a maximum during rush hour conditions. The morning rush hour traffic is usually drastically different from the evening rush-hour traffic, and traffic patterns within a given rush hour period may change considerably. Furthermore, acute problems develop when the otherwise normal traffic pattern for any given time of the day is disturbed locally. This may result from routing of emergency vehicles past the rest of the traffic or, in the case of accidents, traffic may be stopped entirely at certain spots of the city.

Considerable progress has been made in the past towards improving the control of traffic signals with more versatile control methods and equipment. For example, the isolated fixed-time traffic signal controller has been provided with synchronizing devices so that a series of traffic signals distributed along a thoroughfare may be variously coordinated for special advantages. The signals may be offset in time so that traffic moving in one direction may proceed at a predetermined constant speed without stopping. In the extreme case, when the time offsets are made zero, the signals will change indications simultaneously. Further improvements involve a choice of several fixed-time settings, the change from one timing schedule to another being governed usually by some form of time clock.

This fixed-time class of signal equipment is insensitive to traffic movements and operates satisfactorily mainly in those situations where traffic patterns are uniform and fairly predictable. Greater improvement has been made in the control of traffic signals by the development of equipment which *does* respond in some manner or other to actual traffic movements. For example, at an individual intersection the signals can be operated so that the right-of-way time will be divided between intersecting streets in proportion to the volumes of traffic moving along these streets. In the extreme case, right-of-way may remain continuously with one street in the absence of traffic on the cross street. A network of traffic signals may be operated in a traffic-responsive or traffic-actuated manner in the following way: a group of signals may be operated with a short time cycle when traffic volumes are low and longer time cycles when traffic volumes are high. This has the advantage on the one hand of allowing low-volume traffic to move quickly without undue waiting time for cross street traffic, and on the other hand of minimizing the time lost in starting and stopping heavy traffic. In coordinated traffic-actuated systems such as these, pre-set cycle times and offset adjustments are selected automatically on the basis of measured traffic volumes rather than by a time clock. The operation of any form of traffic-actuated signal equipment depends upon vehicle detectors which may be required on some or all approaches to an individually controlled intersection or at certain strategic locations within a system of controlled intersections.

Such equipment has recently been finding widespread usage throughout a number of cities of all sizes, and in spite of its relatively high cost has in some cases been installed on a city-wide basis involving the expenditure of several millions of dollars. The reason for the great emphasis on improving traffic signal systems is that even a small improvement in street utilization brought about through the better regulation of vehicular traffic flow can be worth the equivalent of many miles of new road facilities while costing only a fraction of the amount required for building new or widening existing roads.

However, in spite of the improvements brought about through the use of these modern forms of traffic signal equipment, the increasing complexity of traffic movements tends to render even the most up to date traffic signal controllers less and less effective. In spite of their mechanical and electronic complexity, existing forms of traffic control equipment can respond only in a very limited way to changes in traffic. Equipment which performs best at an individual intersection cannot in general be coordinated into a system of traffic signals except in a very loose manner. Equipment which is used for coordinating a system of traffic signals in general operates according to average traffic conditions within the system and does not adjust to suit local emergencies. Very frequently automatic traffic signal equipment labouring within its limitations, will systematically generate traffic troubles rather than alleviate them. For example, if for any reason traffic congestion should occur in the vicinity of a traffic detector, traffic may become stationary and the counter will receive no further indications of the movement of vehicles. This can cause the automatic equipment to resond as if there were no vehicles at all at a time when the street may be full of vehicles. Similarly, vehicles may be expedited into a trouble area at a time when restraints should be imposed to prevent congestion from becoming widespread. Even the best of currently available equipment is not sufficiently flexible to deal with situations such as these.

A further drawback to the operation of this traffic signal equipment is that experience plays no part in its overall operation. No record is kept as to how the system reacted relative to a given traffic configuration and there is no way of evaluating the effectiveness of the control system other than by direct observation and qualitative evaluation. The traffic engineer has at most a daily record of counts from certain detectors which he must evaluate manually in making empirical adjustments to the settings of the automatic equipment. A large number (if not all) of the fixed settings must be made at the controller box at the intersection. To change, even in a minor way, the choice of settings available to the automatic equipment involves a great deal of time and a lot of work. For example, one widely used automatic traffic-actuated controller has over thirty adjustments which must be made manually. Additionally, these automatic systems require complicated equipment at the street corners which is not only expensive and complicated to adjust, but also very costly to maintain.

The present invention describes a traffic signal control system which is generally free of the above limitations. It permits, in a very flexible manner, timing of traffic signals to best suit both the requirements of the individual inter-

section and the performance of the traffic signal system as a whole. It is capable not only of controlling traffic in a very versatile manner but also of evaluating the quality of the results and of using accumulated experience in automatically optimizing its performance.

An object of the invention resides broadly in the provision of novel methods and apparatus for controlling the timing of traffic signals. An important feature of the invention resides in the use of a modern digital electronic computer for controlling multiple signallized intersections in a completely automatic traffic-responsive manner. This electronic computer, located at a suitable remote control center, is connected, as by multi-conductor cable, to the traffic signal equipment at the various intersections. A modification-unit attached to each of the individual traffic signal controllers permits the computer to remotely take over control of the signals or to release them back to local operation.

Traffic detectors, of which a variety of types are available, are suitably located throughout the network of streets. These detectors are arranged to send traffic counts directly, as by multiple conductor cable, to the computer. In one embodiment, traffic counts only are transmitted, but additional traffic information such as speed, volumes, density, etc., could advantageously be used. Additionally, indications of the signals showing at each intersection are transmitted directly to the central computer. At the central control location, a special time clock is connected to the computer to provide exact information on the time of day and to provide a real time base to allow the computer to calculate, for example, rates of flow of traffic from the traffic counts.

Apparatus is provided at the central location for translating indications from the traffic signal equipment and from the traffic detectors into input signals in suitable form to be utilized by the computer, and for translating output signals from the computer into control signals suitable for actuating the traffic signal equipment.

With the above arrangement of equipment, the electronic computer at all times has a continuous external supply of information on vehicle movements, signal indications and time. When automatic control is in effect, the computer takes over direct control of the signals. The local controller timing mechanisms are made inoperative and no change of any of the signals can occur unless the computer transmits the appropriate electrical impulse. The timing of each phase of the signals is under the complete control of the computer and is independent of any adjustments at the local signal controller. If for any reason central control should fail, or if the communications link between the computer and the remote equipment should become inoperative, control of the signals will automatically revert back to the local signal control mechanism, thus providing fail-safe standby operation of traffic signals in the event of system malfunction. Traffic signals can be brought under or released from central control individually, in groups, or altogether, depending upon requirements. The central control in the form illustrated below also includes provision for manually controlling the signals from the remote control center, but this feature is only rarely used as a test feature in conjunction with initial installation.

In controlling the traffic signals, the computer is guided by what is called the Master Control Program which is a set of coded instructions supplied in program form as by the computer programming personnel and stored electronically within the computer. This Master Control Program is made up of many subsets or subroutiness of instructions, each subroutine containing up to several hundred individual instructions. Each subroutine describes a particular maneuver which the computer must perform. For example, one subroutine instructs the computer how to read in traffic data and where to store it for immediate or future use. Another subroutine instructs the computer

how to take over control of a traffic signal. Still another subroutine instructs the computer how to detect traffic congestion, and so on. By means of these subroutines, the computer is able to control the traffic signals according to a great variety of traffic control concepts, and is able to evalute the results that are produced.

In addition to these subroutines, there are stored within the computer tables of data which describe the local conditions at each intersection. For example, the data table for a particular intersection would list such information as the number of lanes on each approach, whether or not parking is allowed at any time of day, how far the detectors are located back from the cross walks, and so on. When the computer is applying a certain concept of control (control mode) to a traffic signal, it automatically specializes the general control principles to suit the particular location.

It is to be noted that the computer is not restricted to following the same repetitive path of computation in converting information on traffic movements into timed signal actuations. The computer can not only be programmed to carry out computations and follow exceedingly complex trains of logic at very high speed, it can also be programmed to make changes in the list of instructions it is carrying out. It is this very powerful feature of the computer which makes it so versatile. Given a suitable starting point for controlling traffic, the computer can be programmed to learn from experience and to continuously optimize the effect that signal actuations are producing on traffic.

In the illustrative embodiment of the invention, the Master Control Program comprises a large number of preselected groups of subroutines called Control Plans. Each Control Plan specifies the control subroutine (or control mode) which is to be applied to each intersection. Parameter tables for each intersection accompany each Control Plan and serve the purpose previously described. Each Control Plan corresponds to a completely different traffic-actuated signal system. The number of Control Plans which can be stored within the computer is virtually unlimited. For example, up to fifty different Control Plans, each of which would be suitable for controlling a network of one thousand traffic signals, could be stored on a single reel of magnetic tape associated with the computer. To add to or make changes in the programs or plans stored within the computer requires no mechanical changes, either at the central control area or at the individual signals.

The change from one control plan to another may be made at the computer console or it may be made automatically by the computer. In the latter case, the computer uses certain computer information on current traffic behaviour, coupled perhaps with information based on time of day, and on certain information acquired through experience in dealing with other traffic situations. For this purpose the Master Control Program includes one or more subroutines which enables the computer to determine which of the various control plans is to be put into effect at any given time. One refinement is to have a single completely generalized Control Plan which the Computer modifies from time to time to suit the changing traffic picture.

It is accordingly an important object of the present invention to adapt traffic-signal controllers to control by an electronic computer, and it is a further and related object to create an integrated system comprising a large number of traffic signals, each having its individual local control apparatus, and a centrally located electronic computer. Further objects relate to the methods of controlling the selection of the mode of operation of coordinated traffic signals, as well as the character and control of the timing cycle of any individual traffic signal, separately, or as part of a larger system.

Among the more specific objects of the invention are the following:

To provide an attachment for a traffic signal unit by

means of which a central computer can assume control and suppress local control of the traffic signals;

To provide a monitoring system for remote indication of the phase of operation of each local traffic signal or synchronized group of local traffic signals;

To translate the transmitted indication of the phase of signal operation of each key local traffic signal into digital data form recognizable by a computer;

To provide a phase monitor of minimum complexity which is nonetheless capable of providing an indication of many different control conditions that prevail, from time to time, at the local traffic signal, and in this way to provide practical apparatus that can be utilized economically in a large system;

To provide apparatus for transmitting vehicle counts detected at intersections to a central location and to provide apparatus of minimum complexity for supplying vehicle-count information in digital form useful in the computer, thereby making practical a system that can economically utilize large numbers of vehicle detectors and count indicators;

To provide a mode of surveillance of the pattern of traffic signals in effect at the computer, such that during the individual portions of each cycle of traffic-signal operation, the computer can make repeated evaluations of the local conditions and, in individual instances, modify the duration of the current phase;

To transform the information developed in the computer into signal form effective to exercise the requisite control over the remote traffic signal control units;

To establish initially any phase relationship between the traffic signals of a coordinated group, as required by the selected plan, whether synchronized or staggered; and

To provide an integrated traffic control system utilizing a central digital computer wherein a common source of calendar and time-of-day information is effective to measure time intervals in evaluating traffic density, to provide a common time base for the entire coordinated traffic signal control system, and to provide calendar and time-of-day information in a form useful to the digital computer in calling into effect any of the stored predetermined plans of traffic signal control.

The nature of the invention and various further objects and features of novelty will be apparent from the following detailed description of an illustrative embodiment of the invention in its various aspects. Reference is made in this description to the accompanying drawings which constitute part of the disclosure. In the accompanying drawings:

FIG. 1 is a diagram illustrating one of a large number of traffic signal installations connected to the central control equipment;

FIG. 2 is a perspective view of a portion of the central control equipment for coordinating the digital computer at the central location with a number of traffic signal installations at various locations of the system;

FIG. 3 is a wiring diagram of a local traffic-signal controller forming part of the local traffic signal installation in FIG. 1;

FIG. 4 is the wiring diagram of the monitor shown in FIG. 1 for providing information at the central control equipment to indicate the phase in the cycle of operations of a distant traffic signal controller;

FIG. 5 is the wiring diagram of the output unit in the central control equipment, shown in FIG. 1, for enabling the computer to control and actuate the controller of a local traffic signal unit remote from the computer;

FIG. 6 is the timing diagram of certain portions of the apparatus in FIGS. 4, 5 and 7;

FIG. 7 is the wiring diagram of the stepping-switch continuous counter, shown in FIG. 1, for relaying vehicle-counts from the remote vehicle detector to the digital computer shown in FIG. 1;

FIG. 8 is the wiring diagram of a portion of a digital clock that forms part of the central control equipment of FIG. 1; and

FIG. 9 is a block diagram of a digital computer forming part of the central control equipment.

Referring now to the drawings, FIG. 1 represents, diagrammatically, an elemental portion of an integrated traffic control system, the apparatus in FIG. 1 including central control equipment **10**, a single remote or local traffic signal unit **12**, and a single vehicle detector **14** associated with traffic along one of the routes controlled by signal unit **12**. Units **12** and **14** have wired connections to the central control equipment, represented by single lines in FIG. 1. The connections here provided (FIGS. 3, 4, 5 and 7) are pairs of wires such as are used in telephone circuits, but it will be appreciated that other communications links may be substituted for providing the necessary interconnection between the central and the remote or local equipments.

As shown, three pairs of wires **16A**, **16B** and **16C** are represented in FIG. 1 by three single lines, these three pairs of wires extending between traffic signal controller **18** at the local installation and monitor **20** of the central control equipment. This monitor provides an indication at the central location in both visual form and in a form that can be utilized in a digital computer, representing the phase of the traffic signal control cycle at the local installation.

At the local traffic signal installation, there is an adapter **22** which is added to the traffic signal controller that enables the central control equipment **10** to seize control of and to actuate the local traffic-signal controller **18**. Adapter **22** is connected by two pairs of wires **24** and **26** to an output unit **28** in the central control equipment **10**.

The single vehicle detector **14** that forms part of the local traffic signal installation illustrated in FIG. 1 is connected by a pair of wires **30** to an input counter unit **32** in the central control equipment. It will be appreciated that each local traffic signal installation will include a number of vehicle detectors **14**, suitably located to indicate the flow of traffic. Thus, there may be two traffic detectors **14** in a north-south street at opposite sides of the intersection and in opposite lanes, northbound and southbound, respectively; and there may be two similarly located vehicle detectors **14** in the cross-traffic route for providing an eastbound traffic count and a westbound traffic count. More elaborate installations may involve multiple counters along each route, including a first vehicle detector at a point of approach to a signalized intersection for counting vehicles approaching the intersection, and another detector in the same route close to the intersection in order to provide information as to number of detected approaching vehicles that may be assumed to have actually entered the intersection, the difference in these counts representing the number of vehicles waiting. Each time a vehicle passes detector **14**, an impulse is transmitted along line **30** to the input counter unit **32** at the central control equipment **10**. If detector **14** is in the form of a simple wheel-actuated pressure switch, the number of two-axle vehicles can be derived by a scale-of-two counter (not shown) that provides one impulse in response to each pair of switch actuations, or this conversion can be programmed in the computer.

Each local traffic signal installation **12** includes its own traffic controller **18** and its own adapter **22**, complemented by an appropriate number of vehicle detectors **14**; and these units transmit information to the central control equipment **10** and receive control impulses from the central control equipment. In the complete system there are as many monitors **20** and output units **28** as there are separately controlled traffic signal installations or synchronized groups of traffic installations in the system. Similarly, there are as many input counter units **32** in the complete system as there are vehicle detectors **14** in the system.

A digital clock **36** forms part of the central control equipment, and provides numerical input in a form useable by the computer, being in the form of the number of seconds elapsed since some arbitrarily chosen starting time, e.g. noon or midnight.

All of the monitors **20**, the output units **28**, the input counter units **32**, and the digital clock **36** have appropriate connections to the digital computer **34**. The internal wiring and operation of the local traffic signal controller **18** and adapter **22** which are shown diagrammatically in FIG. 1, are discussed in detail below in connection with FIG. 3. Similarly, monitor **20**, output unit **28**, input counter unit **32** and digital clock **36** of FIG. 1 have circuits shown in FIGS. 4, 5, 7 and 8, respectively, and are discussed in detail below. A block diagram of computer **34** appears in FIG. 9 and is similarly discussed in some detail below.

The central control installation, in addition to the computer and digital clock, involves as many monitors **20**, output units **28**, input counter units **32** as are required by the number of differently controlled remote traffic-signal installations. The monitors, output units and counter units may be physically assembled in the manner indicated in FIG. 2. Six monitor units **20** are illustrated, as are the corresponding six output units **28** for six remote traffic-signal installations. A large member of counter units **32** are shown in the same installation. A common chassis **38** is provided for containing the circuit equipment used in common by all of the monitors, the output units and the counter units; and a common power supply **40** is included for the foregoing equipment.

Traffic signal controller and remote indicating and control adapter

The internal wiring of traffic signal controller **18** and the adapter **22**, forming part of the local traffic signal unit **12** in FIG. 1, is shown in FIG. 3. The traffic-signal controller includes a continuously running A-C synchronous dial motor **42** having an electromagnet **44** and a combined armature and brake **44***a*, and three dial cams **46**, **48** and **50**. In practice the cams are constituted of a single axially grooved cylinder in which so-called keys **51** are inserted. The keys **51** have radial projections and act as cams that cooperate, respectively, with normally open cam-actuated switches or contacts **52**, **54** and **56**. The projections of the inserted keys are located at different axial positions on their supporting cylinder, so that each key cooperates with its corresponding switch. A number of keys cooperate with switch **52**, while only one key is provided for actuating switches **54** and **56**.

A drum-advance solenoid **58** is provided for operating a "drum" by means of a ratchet-and-pawl indexing mechanism. This indexing mechanism includes armature **73**, pawl **74**, and a spring **76** that normally holds the pawl **74** in the position illustrated. Pawl **74** cooperates with a ratchet **78** that is secured to a common drum shaft. When solenoid **58** is energized, it tensions spring **76** and withdraws the pawl **74** into position for engaging the next tooth of ratchet **78**. Upon deenergization of solenoid **58**, tensioned spring **76** advances the ratchet one step.

The "drum" that is operated by ratchet **78** consists of a series of drum cams **80**, **82** and **84** having a plurality of distinctive signal-changing positions. Cam **80** operates normally closed drum-lock contacts **62**. A series of cams **82** are provided (only three being shown) for actuating contact pairs **83** that constitute a sequencing switch for the traffic lights **85** or other traffic signals at the local traffic intersection. Three cams **84** are used for actuating respective switches for providing a remote representation of the drum position or phase.

The operation of the apparatus thus far described may be briefly reviewed. Each time one of the keys **51** closes drum-advance contacts **52**, solenoid **58** is usually energized. An energizing circuit for solenoid **58** may be traced as follows: from A-C supply line **60** through normally closed drum-lock contacts **62**, through solenoid-actuating drum-advance contacts **52**, wire **64**, selector switch **66** in its automatic-advance position, through lead **68**, the normally closed pair of relay contacts **90A** and lead **70**, through solenoid **58**, to the opposite alternating current supply line **72**. When the dial motor **42** carries key **51** beyond switch or drum-advance contacts **52**, and allows the switch **52** to open, solenoid **58** is deenergized. Spring **76** then drives pawl **74** and indexes ratchet **78**, and the drum with its various cams **80**, **82**, **84** advances one step.

It is possible for the dial, represented by the dial cams **46**, **48** and **50**, to get out of step with the drum cams **80**, **82** and **84**. In order to assure and to restore the proper relationship between the dial and the drum, normally closed drum-lock contacts **62** are included in series with drum-advance contacts **52**. When the drum has been indexed to the position where contacts **62** are opened by cam **80**, subsequent closure of drum-advance contacts **52** will have no effect. The dial will continue to rotate and switch **52** will close, but the pulse transmitting circuit to the solenoid **58** is broken. When the dial cams **46**, **48** and **50** come into proper relationship with the drum, dial cam **48** closes drum-release contacts **54**. These contacts provide a circuit that bypasses drum-lock contacts **62**, thereby energizing solenoid **58**, and indexing the drum so as to advance cam **80** and to allow drum-lock contact **62** to close once again. The drum and the dial resume operation, properly synchronized. In a normal, synchronized cycle of operation, drum-lock contacts **62** open at the same time that drum-release contacts **54** close. In normal operation, the drum-lock contacts **62** do not cause a halt in the drum-advance sequence.

Selector switch **66** is illustrated as having an automatic position and a manual position. The automatic position has just been described. When selector switch **66** is shifted to the manual position, the circuit from the various dial-actuated switches or contacts is broken and, instead, solenoid **58** is in a circuit that may be energized by operating manual switch **86**. The dial continues to rotate without affecting the drum. Selector switch **66** and push-button switch **86** are normally operated by a policeman under special circumstances.

At the end of an interval of manual operation, the dial and the drum may very well be out of synchronism. When switch **66** is returned to its "automatic" position, restoration of the dial cams and the drum into proper synchronism is effected automatically, as described.

Cams **84** form part of the drum advanced by the ratchet-and-pawl mechanism **73**, **74**, **78**. These cams operate respective switches **88A**, **88B** and **88C**. Switches **88A**, **88B** and **88C** are normally open, and they close when the spring-biased contact arm of each switch finds a cut-out in its related cam. Cams **84** have portions broken away so that unique combinations are provided for representing the different drum positions. In this illustrative embodiment, there are eight different possible combinations of "closed" conditions of these switches, so that eight different conditions of the traffic-signal sequencing switch can be represented by the combinational condition of switches **88A**, **88B** and **88C**. These switches are connected by pairs of wires **16A**, **16B** and **16C** to a corresponding remote monitor **20** at the central control equipment **10**.

By means of the apparatus in adapter unit **22**, the drum-advance solenoid **58** can be removed from control by both the solenoid-advance contacts **52** and the manual switch **86**. This apparatus includes a "hold" solenoid or relay **90** having a single-pole double-throw set of contacts **90A** and a normally open pair of contacts **90B**. The moving arm of contacts **90A** is connected to drum-advance solenoid **58**. In the position illustrated (relay coil **90** not energized), contacts **90A** connect wires **68** and **70** so that the circuit from solenoid **58** to "auto-manual" selector switch **66** is unbroken. It is possible to energize

"hold" relay **90** from the central control equipment, by means including wires **24**. When this is done, single-pole double-throw contacts **90A** reverse their condition and the circuit from drum-advance solenoid **58** to selective switch **66** is broken. At the same time, contacts **90B** are closed, producing two effects. First, a neon indicator lamp **92** is energized via wires **94** and **96**, showing that the traffic-signal sequencing switch is under remote control. Second, a circuit is completed from the alternating current supply wire **94** through contact **90B** and wire **98** to cam contacts **56** and (when the latter close) to brake electromagnet **44**. Synchronous dial motor **42** continues to drive cam **50** until contacts **56** close. When this occurs, brake solenoid **44** is energized and the dial motor **42** is arrested in its position where contacts **56** are held closed by the key on dial cam **50**. The dial therefore remains in the fixed position determined by the key on cam **50** so long as drum-advance solenoid **58** remains under remote control. Other traffic signals in the area having previously coordinated operating cycles and equipped with remote-control adapters may be similarly placed under remote control. All of those coordinated but individually timed traffic signals are arrested under remote control and they are held against operation by their respective brakes during the period of remote control. When remote control of one or more traffic signals is discontinued, they are restored to local control; and when this occurs the respective brakes release the timing dials and the controllers of each of the traffic signals of this group will resume operation in the same relationship that previously prevailed, provided the drums are in this relationship at dropout, which can be accomplished by the computer program.

It has been shown that energization of hold relay **90** establishes control over drum-advance relay **58** from the remote point. Actuation of this drum-advance relay is also accomplished from the remote point, as previously indicated, by energizing wires **26**. These wires are connected to remote-control actuating relay **100**, and when this is energized, relay contacts **100A** close. This completes a circuit from alternating current supply line **72** through drum-advance relay **58**, wire **70**, through the normally open pair of relay contacts **90A** which are now closed, wire **102**, relay contacts **100A**, and alternating current supply line **94**.

The foregoing description of the local traffic signal controller **18** indicates three changes made at the controller in order to establish remote indication and remote control of the operation. One change involves the utilization of a series of spare cams and cam contacts **84** and **88** for remote indication, such cams being commonly available; and another change involves interposing a pair of relay contacts **90A** between wires **68** and **70** which were previously an unbroken lead in the local-control apparatus. A third change is the connection of the brake circuit as described and illustrated. Operation of the traffic signal controller is completely normal when hold relay **90** is not energized. When hold relay **90** is energized, the drum-advance relay or electromagnet **58** is placed under control of the remote-control actuating relay **100**. After central control is no longer desired, the hold relay **90** is de-energized and drum-advance relay **58** is restored to its previous control by the motor-operated dial cams **46** and **48**. The dial is locked by brake **44** during remote operation; and when local operation is restored, the dial resumes its advance immediately, in synchronism with all other traffic signal controllers that were placed under remote control and restored to local control, provided the drums are in synchronism at dropout.

Monitor 20

In FIG. 3, contact **88A**, **88B** and **88C**, which are operated by the cams **84**, have leads **16A**, B and C (FIG. 1) to a monitor **20** of the central control equipment **10**. The details of monitor **20** are shown in FIG. 4. The main purpose of this apparatus is to provide information for the computer to recognize the position of the local traffic-signal cams and sequencing switches **82**, **83** (FIG. 3) and to provide a display representation at the central control equipment **10** corresponding to the traffic signals monitored.

In FIG. 4, a pairs of lines **16A**, **16B** and **16C** are shown connected to respective relays **104A**, **104B** and **104C**. These relays are energized by direct current from terminals **110** and **112** through normally closed contacts **106** of relay **108**. For example, a circuit may be traced from the negative direct-current supply terminal **110** through contacts **106**, along common negative line **114**, along one of a pair of wires **16A**, to cam contact **88A** (FIG. 3), returning along the other wire of the pair **16A**, through isolating diode **118A**, to energize relay **104A**, the other terminal of this relay extending to the positive direct-current supply terminal **112**.

Relay **104A** has two groups of contacts, including a set of single-pole double-throw contacts **120**, and four more sets of double-throw contacts **120**, and four more sets of double-throw contacts **122***a*, **122***b*, **122***c* and **122***d*. Similarly, relay **104B** has two groups of contacts, including a group having two sets of double-throw contacts **124***a* and **124***b*, and another group having two sets of double-throw contacts **126***a* and **126***b*. Relay **104C** has one group of four double-throw contacts **128***a*, **128***b*, **128***c* and **128***d*, and another set of double-throw contacts **130**.

Relay contacts **120** are connected in cascade with contact group **124***a* and **124***b*, and contact group **128***a*, **128***b*, **128***c* and **128***d*, so that terminal **134** at one end of the cascade of the contacts is connected through the various double-throw contacts mentioned to one and only one of eight output terminals **132**, depending upon the particular combination of relays **104A**, **104B** and **104C**, that are energized at the time. Terminals **132** have respective leads designated **1**, **2** . . . **8** in FIG. 4, these designations representing the eight sequential positions of the signal-sequencing switch **82**, **83** in FIG. 3. The leads extending from terminals **132** are connected to corresponding contacts of a motor-driven rotary switch **136**, whose moving contact arm **136***a* extends to a direct current supply.

Rotary switch **136** is a normal part of the card-reading apparatus in a standard computer, and this switch produces timed "read" digit pulses. The timing of such pulses in the computer is illustrated in the lower half of FIG. 6. A pulse will be delivered at terminal **134**, which is connected to the computer storage entry portion of the computer of FIG. 1 at a time in the "read" cycle which corresponds to the circuit from terminal **134** to the particular terminal **132** that is completed by contacts **120**, **124***a* and *b*, and **128***a*, *b*, *c* and *d*. In this way, relays **104A**, **104B** and **104C**, which are connected to lines **16A**, **16B** and **16C** and cam contacts **88A**, **88B**, **88C** (FIG. 3), provide read-in information in a form that is useable by the computer. For example, the eight significant positions of the signal-sequencing switch **82**, **83** in the local traffic-signal unit can be translated into corresponding timed pulses supplied to the computer in a "read" cycle, to represent the following local traffic signal phases:

Monitor Relays			Number	Interpretation
A	B	C		
O	O	X	1	Southbound advance green.
O	X	X	2	Northbound advance green.
O	X	O	3	North-South green.
X	X	O	4	North-South green-amber.
X	X	X	5	Westbound advance green.
X	O	X	6	Eastbound advance green.
X	O	O	7	East-West green.
O	O	O	8	East-West green-amber.

There are some conditions when the traffic signal for both the North-bound and the South-bound directions are green. At such times both East-bound and West-bound

commonly have red signals. There is another condition when both East and West have green signals, the North-South signals are red. Additionally, the North and South can both be amber (or amber and green) while the East and West are red; and conversely, the East and West can both be amber (or green and amber) while the North and South are red. Finally, there are four conditions when the green light is allowed in only one direction at any one time, that is, South-bound, North-bound, West-bound or East-bound. These are the signal combinations in the tabulation above. Other signals and signal combinations may of course be substituted, and any number of positions may be accommodated by circuit adaptation if the 8-position arrangement is not suitable.

An additional function of the monitor is to provide a visual indication at the central control location which represents the phase of the local traffic signals at remote installations. For this purpose, relays **104**A, **104**B and **104**C are equipped with the groups of double-throw contacts **122***a*, *b*, *c* and *d*, **126***a* and *b*, and **130**, connected in cascade, as previously described. These contacts are arranged to energize one of the monitor display relays **138***a*, **138***b*, **138***c* . . . **138***h*. Only one of these relays **138** will be energized by the cascaded contacts, as determined by the particular combination of relays **104**A, **104**B, **104**C that are energized. Relays **138** are energized by alternating current from terminals **140**.

It would be feasible to arrange circuits energized by each energized relay **138** to represent the North, South, East and West "green," "amber" and "red" lights, but to do so would involve relatively complex display apparatus in the central control equipment. Such display apparatus is duplicated for each of the local traffic signal controllers in the system, and so simplication of the display is of importance. The illustrative embodiment shown in the drawing provides the display information without requiring as many indicator lights as there are separately controlled lights at the traffic controller site.

The display control circuit in FIG. 4 includes a first series of normally open relay contacts **142***a*, **142***b* . . . **142***h* and a second set of normally open relay contacts **144***a*, **144***b* . . . **144***h*, selectively operable by the particular relays **138** having corresponding alphabetic characters. Additionally, a normally open pair of contacts **146***a* is arranged to be operated by relay **138***e* and a pair of relay contacts **146***b* is operable by relay **138***h*. All of the contacts **144** and **146** extend to an alternating current supply line **150**, as do contacts **142***a*, **142***b*, **142***c*, and **142***d*. Contacts **142***e*, **142***f*, **142***g* and **142***h* extend to alternating current supply line **150** by way of continuously operating flasher contacts **148**. The other alternating current supply line **152** extends to a series of North-South indicator lamps **154**R, **154**Y, **154**G, and to East-West indicator lamps **156**R, **156**Y, and **156**G. A set of terminals **160** is provided, connected to the respective lamps **154** and **156**, for auxiliary display or for test purposes.

With the set of contacts **130**, **126** and **122** operated in various combinations depending upon the energized combination of relays **104**A, **104**B and **104**C, various conditions will be displayed by lamps **154** and **156**. Thus, for position number 3 in the table, the local traffic signals for both North and South are green, and the local signals for East and West are red. Only relay **104**B is energized, so that only relay **138***c* will be selected. This will be represented by a single green light **154**G and a single red light **156**R being turned on in the display unit **158**. For advance to condition #4, relays **104**A and **104**B are energized, monitor relay **138***d* is selected, and contacts **142***d* and **144***d* are closed. As a result the East-West red lamp **156**R remains on, while the North-South green lamp **154**G, which was on, is turned off and North-South yellow lamp **154**Y is turned on.

For the purpose of representing Advance Green for one direction while red is set for the opposite direction at the local controller, the circuit including flasher **148** is used. There are four such conditions, where only North, only South, only East or only West has an Advance Green indication, represented in the above table by "1," "2," "5" and "6." We may consider that condition #1 in the tabulation is in effect at the local traffic signal installation, and only relay **104**C is energized. Under these conditions, monitor display relay **138***e* is energized, closing contacts **142***e*, **144***e* and **146***a*. The red light **156**R for East-West is energized through contact **146***a* and the red light **154**R for North-South is energized through contacts **144***e*; and the green light **154**G is energized through contacts **142***e* and through flasher contacts **148**. The North-South lights include a steady red light and a flashing green light, and this display in the monitor signifies a green light at the local traffic controller for the southbound traffic only. By like token, when relays **104**B and **104**C are energized, East-West red lamp **156**R is on steadily and North-South green lamp **154**G is energized through the flasher, but the North-South red lamp **154**R is off. The flashing North-South green lamp **154**G at the monitor, with lamp **154**R turned off, signifies "North-bound green only" at the local traffic controller. Similarly, in position #6, relays **104**A and **104**C are energized with the result that relay **138***f* is selected, and North-South red lamp **154**R is steadily on and East-West green lamp **156**G flashes, signifying "East-bound advance only" at the local traffic signal installation. West-bound advance only is represented by steady illumination of North-South red lamp **154**R and East-West red lamp **156**R and flashing East-West green lamp **156**G. This condition prevails at the monitor when all three of relays **104**A, **104**B and **104**C are energized.

The foregoing display apparatus in the monitor uses six lamps to represent twice as many lamps that would otherwise be needed to duplicate the lights at the local traffic signal controller, considering red, green and amber in each of four directions that may be used in various combinations. This represents a substantial saving, which is particularly important because a separate monitor with the necessary complement of lights is provided at the central control equipment for each of the local traffic signal installations in the system.

An appreciable interval of time (⅕ second) elapses during a "read" cycle of operation of the switch **136**. It is desirable that any particular combination of energized relays **104**A, **104**B and **104**C should not change during this "read" cycle. Otherwise the computer might receive ambiguous information. For this purpose a circuit is provided that disconnects relays **104**A, **104**B and **104**C from lines **16**A, **16**B and **16**C during the "read" time interval. This circuit additionally holds the relays in their condition prevailing just before disconnection occurred. This circuit includes relay **108** and a "read-hold" timing switch or cam contact **162** through which relay **108** is connected to the D-C supply terminals **110** and **112**. The closing of contacts **162** is represented by the "read-hold" part of the timing diagram in FIG. 6. Relay **108** is thus energized for a period somewhat longer than that required for the "digit pulse generator" contact arm **136***a* to complete its sweep past all of the contents of switch **136**. During this "read-hold" time, relay **108** causes contact **163** to be connected to D-C supply terminal **110**.

Each of the relays **104**A, **104**B and **104**C has a corresponding holding contact **164**A, **164**B and **164**C, and an isolating diode **166** connected in series with each hold contact. During a "read" interval, a circuit may be traced from terminal **110** through relay contacts **163**, through any one or more of the holding contacts **164**A, **164**B and **164**C that were closed before closing of contacts **163**, and through the corresponding relays **104**A, **104**B and/or **104**C to D-C terminal **112**. Any relay that was energized before contacts **106** are opened remains energized when contact **163** is connected to D-C supply terminal **110**, and for this purpose these relays

104A, 104B and 104C have a suitably retarded opening characteristic. Correspondingly, the connection of lines 16A, 16B and 16C to the supply terminal 110 is broken when contact 106 is opened. As soon as the "read" interval is over, contact 163 opens and contact 106 recloses, thereby restoring lines 16A, B and C, and the remote cam switches 88A, B and C into their control relation with respect to relays 104A, B and C.

The apparatus in FIG. 4 converts the information represented by the combinations of closed switches at the local traffic signals into timed pulses, and thus provides the computer with input information in useful form, indicating to the computer the phase of the traffic-signal sequence that prevails at any given time. This is particularly useful when the computer initially assumes control of the local traffic signal controller. The phases of the computer signal-control cycle and of the local traffic signal control cycle should initially be brought into agreement and this agreement should be verified repeatedly. The apparatus of FIG. 5 utilizes the output from the computer in causing operation of the local traffic signal controllers, acting through adapter units 22 in each of the local traffic signal controllers (FIG. 3). The function of the isolating diodes 118 and 166 is to eliminate feedback paths that would produce undesired cross-coupling between circuits.

Output unit 28

The circuit of the output unit 28 is shown in FIG. 5. This includes three principal relays, an "actuate" relay 170, a "hold" relay 172, and an "interlock" relay 174. When "hold" relay 172 is energized, a circuit is completed that extends from the positive direct-circuit supply line 175, through normally closed switch contacts 186*a* and relay contacts 180, to the pair of lines 24 which extend to "hold" relay 90 (FIG. 3), and thence to the negative return line 177 of the direct current supply. Toggle switch 186 is interposed in this line for manually interrupting the "hold" circuit at the central control equipment. When "actuate" relay 170 is energized, another control circuit extends from line 175 through switch contacts 186*a* and contacts 176 of the "actuate" relay, to "actuate" control line 26 for energizing "actuate" relay 100 in FIG. 3, thence to the negative return line 177 of the direct current supply.

Supplementing contacts 176 and 180 for energizing "hold" line 24 and "actuate" line 26 are a pair of additional push-button switches 188 and 190. Push-button switch 188 includes two sets of normally open contacts 188*a* and 188*b*. Contacts 188*a*, when closed, provide a circuit bypassing relay contacts 180 and switch contacts 186*a* and thus energize the "hold" relay 90 (FIG. 3) when the push-button 188 is manually operated at the central control equipment. Similarly, if both push-buttons 188 and 190 are operated at the central control equipment, then a bridging circuit extends not only through contacts 188*a* to the "hold" line 24, but also another bridging circuit extends from D-C supply line 175 through contacts 190 and 188*b* to "actuate" line 26.

Operation of a local traffic controller under control of push-buttons 188 and 190 at the central control station is only rarely undertaken, being primarily for test purposes.

Relays 170, 172 and 174 are operated by signals from the "punch" or read-out line 192 from the output of the computer, this output being applied to these relays through isolating diodes 194, 196 and 198. This output appears in the form of pulses which may occur at any one of twelve parts of an operating cycle, as indicated by the dashes along the "output digit pulses" line in FIG. 6.

Rotary switches 204 and 210, which are actually the same switch and are part of the computer's standard output equipment, operate relay 202, thereby closing relay contacts 200 and operate relay 208, thereby closing relay contacts 206 at times of the output cycle shown in the chart in FIG. 6. Rotary switch 226, which is also part of the computer's standard output equipment, operates relay 224, thereby closing relay contacts 222 as shown in the line "output hold" of the timing chart in FIG. 6. Only certain combinations of the 12 available output pulses are actually used. The actuate relay may be operated by either a 12 pulse, a 3 pulse or an 8 pulse as shown in the line "actuate relay" of the timing chart in FIG. 6, through a circuit consisting of line 192, switch contacts 186*b*, isolating diode 194, relay 170, relay contacts 200, and line 177 to the negative side of the DC supply. The timing of relay contacts 200 will prevent any other impulses from operating actuate relay 170. While 12, 3 and 8 impulses will always operate actuate relay 170 and consequently relay 100 (FIG. 3), they will only be effective in operating the traffic signals when hold relay 172, and consequently hold relay 90 (FIG. 3), are operated, as can be seen from FIG. 3. The hold relay 172 is normally picked up by either a zero or a five impulse through a circuit consisting of line 192, switch contacts 186*b*, isolating diode 196, relay 172, line 214, isolating diode 199, relay contacts 206, master dropout control 218, and line 177 to the negative side of the direct current supply.

Once picked up, the hold relay is self-holding through a circuit running from the positive side of the D.C supply through line 175, switch contacts 186*a*, dropping resistor 212, relay contacts 178, relay 172, line 214, isolating diode 199, relay contacts 206, master dropout control 218, and line 177 to the negative side of the D.C. supply.

Once energized, the hold relay 172 will be deenergized only by the opening of relay contacts 206, which occurs regularly at a late stage of the output cycle, as shown in the timing chart of FIG. 6.

However, a bridging path is provided, to bypass relay contacts 206, this path consisting of line 216 and interlock relay contacts 184. This path will be effective whenever the interlock relay is operated, and will prevent the hold relay 172 from being de-energized.

The interlock relay 174 is normally picked up by either a 12, 0, 3 or 5 impulse through a circuit running through line 192, switch contacts 186*b*, isolating diode 198, relay 174, isolating diode 199, relay contacts 206, master dropout control 218, and line 177 to the negative side of the D.C. supply.

Once picked up, the interlock relay 174 remains operated through the remainder of the cycle in which it was picked up through a circuit running from the positive side of the supply through line 175, line 179, relay contacts 222, dropping resistor 220, relay contacts 182, relay 174, line 214, line 216, interlock relay contacts 184, master dropout control 218, and line 177 to the negative side of the D.C. supply. It releases near the end of the output cycle through the opening of relay contacts 222 as previously described.

On most output cycles, it is desired to keep the hold relay 170 energized without causing any actuation. This is accomplished by outputting a 5 impulse which operates the interlock relay 174 and thus prevents the hold relay 172 from being dropped out on that cycle.

A 12, a zero or a 3 impulse will also prevent the hold relay 172 from dropping out on the cycle in which it occurs, but these impulses will produce actuations as well. (The computer output is so wired that a zero impulse is always followed by a 3 impulse).

Several combinations of output impulses are used to obtain the desired results at the controller. The absence of an impulse during any cycle will cause the hold relay 172 to drop out, if it is energized. A 5 impulse will pick up the hold relay 172 if it is not energized and will cause it to remain held if it is already energized. A zero and a 3 impulse combination will pick up or hold the hold relay 172 and produce a single actuation. A zero, 3 and 8 impulse combination will pick up or hold the hold relay 172 and produce two actuations in quick succession. A 12, 3,

and 8 impulse combination may be used only if the hold relay **172** is already picked up, and will produce three actuations in succession.

It will be appreciated that the stepwise advance of the drum cams **80**, **82**, **84** in the sequencing switch contained in unit **18** in some cases will not effect a phase change, by reason of the number of teeth in the ratchet **78** being greater than the number of distinct phases provided in the sequencing switch by the rise and dwell portions of the respective cams **80**, **82**, **84**. In such situation, for some actuations of the pawl **74**, the stepwise advance of the ratchet **78** may not be sufficient to change the condition of the sequencing switch. Therefore, in order to change from one phase to the next, it may be necessary in some cases to provide more than one actuating pulse from the central control equipment to the drum solenoid **58**. The provision of plural actuating pulses as described above is one way of effecting desired phase change in this illustrative situation.

Relays **202**, **224** and **208** as well as the master drop out control **218** are common to all the output units. The hold circuits for all the output units pass through the master drop out control. If the master drop out control receives no "read hold" pulse during a pre-determined period of time (say 10 seconds) then it will disconnect all the output units and thus release all the controllers to local control. This is a fail-safe feature in case the computer stops for any reason. The master drop out control **218** may, for example, be a thyratron operated relay which opens the circuit after the prescribed time period.

The "hold" and the "actuate" relays can be operated as described above in response to properly timed pulses from the computer. Thus a "5" pulse will cause pick-up and holding of the relays **172** and **174**, and of the "hold" relay **90** at the local traffic signal controller (FIG. 3). Pulses at the "0" and "3" times in the cycle will cause pick-up and a single momentary actuation of relay **170**, and of the "actuate" relay **100** at the corresponding local traffic signal controller. Pulses at "0", "3" and "8" times in the cycle will cause pick-up of the "hold" relay **90** and two actuations of the "actuate" relay **100**. Pulses at the "12," "3" and "8" times in the cycle will cause three actuations of the relay **100** in the local traffic signal controller, provided the "hold" relay is in the energized state. The "master drop-out control" **218** is arranged so as to de-energize the interlock and hold relays **174** and **172** in the event that no pulses are detected during a preset period, thus indicating malfunction or stoppage of the computer.

From the foregoing description of the output control, it appears that in the absence of signals from the computer, the remote local traffic controllers will operate according to their individual or interconnected cycles; or, in the event that the computer at the central control station indicates that control is to be assumed, the central control equipment can take over control of the local traffic signal controllers. When this is to be done, the computer compares the numerical representation of the position of the cam contacts **88A**, **88B** and **88C** in the local traffic signal controller as provided by the monitor (FIG. 4) and the number supplied by the computer to represent the phase in its signal-control sequence and waits until the desired phase comes into effect before assuming control. This is effected by suitable programming of the computer.

Vehicle counters

In connection with FIG. 1, vehicle detector **14** was described with its wired connection **30** extending to a counter unit **32**, there being a sizeable number of vehicle detectors **14** and counter units **32** in the system. The internal details of an illustrative input counter unit contained in the central control equipment is illustrated in FIG. 7. Line **30** extends to a vehicle detector, being in its simplest form a pressure switch **14** actuated by a vehicle. Pressure switch **14** (FIG. 1) completes a circuit from the positive lead **230** of the D–C supply (FIG. 7) through relay **232**, and via leads **30** and detector **14**, to the negative return lead **234** of the direct current supply. Momentary energization of relay **232** causes closing of its holding contacts **236**, these contacts being in a circuit which bypasses the line **30** and the remote pressure switch **14**. The holding circuit extends from the negative terminal of relay **232**, through holding contacts **236**, through lead **238** and through a pair of contacts **240** (to be described), and thence to the negative terminal of the D–C supply.

Energization of relay **232** additionally causes closing of its operating contacts **242**. These contacts complete a circuit from the alternating current supply terminal **244**, through the contacts **242**, through counter **246**, to the opposite terminal **248** of the alternating-current supply. Counter **246** is an ordinary odometer-wheel counter actuated by an electromagnet of conventional construction, useful for maintaining a running total of vehicles passing each detector at the central control equipment. Closing of contacts **242** also applies alternating current to a neon indicator lamp **250** with its series-resistor **252**. Contacts **242** additionally apply alternating current across the input terminals of bridge rectifier **254**. The direct current output terminals of this bridge rectifier energize electromagnet **256** of a stepping switch. This stepping switch includes ten contacts **258** which occupy a sector of one-third of a revolution of the wiping contacts **260**, there being three such wiping contact arms **260** so that one of the arms is always in contact with one of the contacts **258**. A full forward stroke of the electromagnet shifts a pawl and tensions a pawl-return spring (see parts **73**, **74**, **76**, **78** in FIG. 3), and when the electromagnet is deenergized, the pawl operates a ratchet to advance the three contact arms **260** as a unit through a one-step range. In this way, one of the wiping contact arms **260** advances from one of the stationary contacts **258** to the next one each time the electromagnet is energized and deenergized.

Electromagnet **256** of the stepping switch is suitably arranged to open normally closed contacts **240** when the indexing mechanism approaches the end of its indexing stroke. As soon as this occurs, the holding circuit for relay **232** is broken. The relay is then deenergized, unless the vehicle that initially actuated the remote pressure switch **14** is still on the pressure switch. In that event, relay **232** would remain energized and, correspondingly electromagnet **256** would remain energized until the vehicle releases the pressure switch **14**.

Each of the contacts **258** extends along a respective lead **262** to a corresponding stationary contact **264** of a read digit pulse emitter **264**, **266**. Wiping contact arm **266** is connected to a direct current source and applies D-C to the emitter terminals **0** to **9** in proper timed relation to the computer operation. Consequently, when a pulse is applied to the particular line **262** and contact **258** that is connected to contact arm **260**, a pulse is emitted at the computer input line **268**. Rotary switch **264**, **266** is part of the computer's standard input equipment.

It is possible that the sweep of contact arm **266** for effecting a "read" operation might occur during the time that relay **232** is being energized. It will be recalled that the active stroke of the electromagnet **256** does not have any direct relation to the stepping switch arms **260**, for it is the spring-return stroke that effects a one-step advance of the contact arms **260**. This occurs upon deenergization of electromagnet **256**. It may happen that the "read" cycle is initiated just prior to the energization of relay **232** or it may be that the "read" interval occurs during the time that relay **232** is being energized. If this should occur, then it is conceivable that the relay **232** and electromagnet **256** might be deenergized and the contact arm **260** would advance during the "read" interval. Conceivably

an ambiguous read-out condition could result. To avoid this, the following circuit is provided:

A "hold" relay **270** is provided, energized by a "read hold" wiping contact switch **272** which is part of the computer's standard input equipment. Closing of the wiping contact **272** occurs at a time prior to the sweep of contact **266** along the active stationary contacts **264** of the read digit pulse emitter, and contacts **272** remain closed until just after contact arm **266** passes the last active contact **264**, as illustrated in the "read hold" portion of FIG. 6.

Energization of relay **270** causes closing of relay contacts **274**. This completes a circuit through isolating diode **276** that bypasses contacts **240**. Thus, when relay **232** has once been energized by a detected vehicle, and holding contacts **236** are closed during a "read" interval, it makes no difference that electromagnet **256** might complete its forward stroke and open contact **240**. If that should occur, the holding circuit for the negative return of relay **232** would still be complete, extending through contacts **236**, diode **276**, contacts **274**, to the negative direct-current terminal, and both relay **232** and electromagnet **256** would still be energized. Upon completion of the "read" time interval, relay **270** is deenergized and this permits the holding circuit of relay **232** through contacts **274** to be opened. Electromagnet **256** presumably has completed its forward stroke and therefore contacts **240** have been opened, breaking the other possible negative return of the relay holding contacts **236**. It follows that a vehicle detected during the ⅛ second "read" interval is not registered until after the "read" interval, when the electromagnet is deenergized and the contact arm advanced thereby one step.

The normal count frequency that may be expected is of the order of one-per-second, or slower; and because the "read" time interval is of the order of ⅛ of a second, there will be no loss of a count as a result of the holding operation of relay **270**.

The counter advances continuously, stepping from one contact **258** to the next, without reset occurring. The frequency of recycling of the computer by internal programming means to "inspect" the counter in FIG. 7 may be anything found desirable. For example, this may occur once every two seconds. The internal program of the computer will then compare the count registered by the digital pulse emitted at line **268** with the previous count stored in the computer corresponding to this particular counter. If the new count is higher than the previous one, then the number of vehicles detected in that particular interval is simply the difference between the two counts, and this difference is stored. However, if the previous registered count were higher than the new count, then presumably the new count is the digit represented by the impulse transmitted by lead **268**, plus 10. The previous count is substracted from this adjusted value, and this gives the number of actuations of the vehicle detector during the computer recycling time interval. The full cycle capacity of 10 steps in the illustrated counter **258–260** is sufficient for practical purposes, it being only required that the interval between each computer evaluation of the counter and the next one shall be short enough to keep the count difference at a value of 9 or less, this being the differential count capacity of the continuous stepping switch counter **258, 260**. This comparing and count adjusting procedure is carried out through programming of the computer.

The digital clock

Calendar data concerning the month, day-of-the-month, the day-of-the-week and "holiday" indication is all pertinent information useful to the computer in automatic selection of an appropriate traffic-signal sequencing plan or succession of different plans that may be used during a given day. Such information may be represented by digits, manually set up on the computer plugboard or by means of selector switches. The digital clock **36** that appears in FIG. 1 performs a number of functions including that of providing time-of-day information used by the computer in calling into operation various traffic-signal sequencing plans appropriate to different times of the day. The digital clock serves also in the precise measurement of the elapsed time during each phase of each traffic-signal sequence. Finally, the clock can act as a common time reference for synchronous or properly staggered operation of all the traffic-signal controllers in the system when controlled by the computer. The wiring diagram of an illustrative digital clock effective for the purpose of the described traffic-signal control system appears in FIG. 8.

The time as measured by the digital clock is an accumulation of seconds, registered in a decimal system so that the clock can reach a count of 99,999 seconds (for example) by employing a five-stage counter with ten counts per stage. This takes care of a 24-hour period, which is 86,400 seconds.

In FIG. 8 only two stages are illustrated, the units and the tens stage. These include respective ten-position stepping switches **280** and **282**. The time in seconds is entered into the computer in the manner discussed in connection with FIG. 7. Each of the ten terminals of stepping switch **280** is connected to a respective contact of a "read" digit pulse emitter, which may be the same one illustrated in FIG. 7. The position of the moving contact **280***a* determines at what time in the cycle of the digit pulse emitter a pulse will be transmitted from stepping switch **280** of the units stage along wire **284** to the computer storage entry. Similarly, an impulse is delivered to wire **286** by stepping switch **282** of the tens stage at a time in the "read" cycle which depends upon the position of its wiping contact **282***a*, thus representing the tens-of-seconds count in that stage. Three more orders of decimal stages (not shown) build up a second-counter capacity of 99,999 seconds. Time of day is specified in computer storage in terms of total number of seconds elapsed past midnight, for example. At midnight the clock may be reset to zero or at some other convenient time it may be set to the appropriate reading in seconds.

The operation of stepping switch **280** is quite similar to the operation of stepping switch **258–260** in FIG. 7. Contact arm **280***a* is coupled by a ratchet-and-pawl stepping mechanism **287** to the armature of electromagnet **288**. The contact arm is advanced one step for each cycle of energization and deenergization of electromagnet **288**. An energizing impulse is supplied once each second in a circuit that includes alternating current supply line **290**, bridge rectifier **292**, line **294**, operation selector switch **296**, relay contacts **298**, and the opposite line **300** of the alternating current supply. Electromagnet **288** gets D.-C. pulses from the bridge rectifier. Relay contacts **298** are closed once each second by relay **302** having a suitable source of impulses **304** for delivering precisely one impulse per second.

At times the computer may call for a readout operation at a moment before the counter is to be indexed or while it is in the process of being indexed. To avoid possible ambiguity in the input to the computer, the same "hold" timing contacts **272** are used here that appear in FIG. 7, as well as a relay **271** which contacts **275**. Contacts **272** close and energize relay **271** shortly before the "read" timed pulses are impressed on the stationary contacts of stepping switch **280** and relay **271** is maintained energized until after a complete "read" cycle has taken place. Energization of relay **271** closes relay contacts **275**. Stepping switch electromagnet **288** includes a pair of normally open contacts **306** that are in series with contacts **275** and with rectifiers **308**. Contacts **306** close shortly after the start of the energized forward stroke of electromagnet **288**. Consequently, once operation of electromagnet **288** has commenced during a "read" interval by virtue of the closing of contacts **298**, the electromagnet

288 is maintained energized during that "read" interval. The holding circuit for this "read" cycle includes alternating current line 300, relay contacts 275, contacts 306 actuated by electromagnet 288, and a pair of rectifiers 308 which parallel two of the bridge rectifiers and energize electromagnet 288. At the end of a "read" interval of approximately 1/5 of a second, contacts 275 open, and unless contacts 298 are still closed at that time (as would occur if relay 302 is operated late in the "read" cycle) electromagnet 288 becomes deenergized, and contact arm 280*a* is advanced one step .

Stepping switch 282 of the tens order of the seconds counter operates exactly in the same manner as the circuit described in connection with stepping switch 280 with one slight exception. Electromagnet 309 of stepping switch 282 is to receive only one "advance" impulse for each ten impulses supplied to electromagnet 288. For this purpose, cam 310*a* is mechanically ganged to moving contact arm 280*a* of the units stage and closes cam contacts 310 once in each complete rotation, when contact arm 280*a* reaches the "9" position. When this occurs, an energizing circuit is established for electromagnet 309, as follows: Starting with alternating current line 300, the circuit extends through relay contacts 298 and selector switch 296, cam contacts 310, operation selector switch 312, line 314 extending to bridge rectifier 316, thence along line 318 to the opposite alternating current supply line 290. When stepping switch arm 280*a* is in the "9" position and the next impulse closes contacts 298, electromagnet 288 is energized for advancing stepping switch 280 to the zero position. At the same time, electromagnet 309 is energized for advancing stepping switch 282 one step.

The tens order has a cam 320*a* and a cam switch 320 which is effective to transmit an impulse to the actuating electromagnet of the next higher order stepping switch once each time that moving contact arm 282*a* is in its "9" position. This "carry" arrangement extends from each order, via manual selector switch section 322 and others ganged with it, to the next higher order, up to the highest stage.

By virtue of contacts 324 of the tens stage (comparable to contacts 306 already described) and rectifiers 325 and line 326, the position of contact arm 282*a* is prevented from change during a "read" time interval. By means of this circuit, electromagnet 309 is energized when it should receive an advancing impulse; but actual advance of contact arm 282*a* by its spring, ratchet and pawl mechanism 311 cannot occur during the "read" operation of the computer.

The digital clock which counts seconds is capable of running continuously with manual selector switches 296, 312 and 322 set as illustrated. Provision is also made to stop the clock, simply by moving these selector switches one step clockwise, thereby breaking the operating circuits. It is also possible to test the circuit in a "test" position of the manual selector switches 296 and 312, and a "reset" position is also provided.

For "test" and "reset" operations, a second selector deck 330 is ganged to units-order 10-position switch 280, and a like 10-position selector switch 332 is ganged to selector switch 282. A manual switch 323 is ganged to switches 296 and 312. A further ten-position manual switch 336 is included in the units stage, and a corresponding switch 337 is provided in the tens stage of this seconds counter or digital clock. The moving selector member 336*a* is conductive and interconnects nine of its ten stationary contacts, only one stationary contact 336*a* being out of contact with selector 336*a* at any one time, by virtue of its cut-out 336*b*. Selector member 336*a* can be adjusted to any desired selection from "0" to "9."

With the switches of the units order in FIG. 8 set as shown, except for adjustment of ganged switches 296, 312 and 323 to the lowermost or "reset" position, a circuit may be traced as follows: Starting with alternating-current supply line 300, and continuing along line 338, the circuit extends through selector switch 323 and line 340 to conductive selector 336*a*; and this selector connects all line 342 together—except for contact 336*c* at cut-out 336*b* —to energize the selector contact arm of switch 330 in all positions except that corresponding to the position of cut-out 336*b*; and the circuit continues along line 344 and through normally closed contacts 346 of the stepping-switch electromagnet 288, thence via rectifiers 292 to the opposite alternating-current line.

Completion of the above circuit with energization of electromagnet 288 by rectifier 292 causes an energized stroke of the electromagnet. This opens contacts 346 and deenergizes the electromagnet so as to produce a spring-energized advancing stroke of switch decks 280 and 330. This cycle is repeated until the selector arm of switch 330 finds the wire 342 that extends to a stationary contact of switch 336 opposite cut-out 336*b*. By manually setting switch 336 at zero, or any other position, the digital clock can be set at zero or any other indication.

A neon lamp 348 is connected in series with resistor 350 between line 338 and manual selector switch 336. When switch 323 is in the "reset" position, and when the positions of switches 330 and 336 agree, all of the lines 342 extending from selector disc 336*a* are open-circuited at switch 330. However, a circuit extends from lines 300 and 338, through resistor 350 and lamp 348, along wire 352 and lead 344 through normally closed contacts 346, to rectifier 292 and supply line 290. Consequently, when the stepping switch 280 has reached the position called for by manual selector switch 336, neon lamp 348 lights.

In the foregoing manner, the units order of the clock can be set to provide any desired digital input for the computer. The higher-order stages are constructed likewise and each stage can thus be set manually to produce any desired initial time digits for the computer, or this provision for resetting can be carried out once daily. Other digital input to the computer is similarly provided by like apparatus (not shown) for providing month, day-of-the-month, day-of-the-week and any other set information for the computer.

When the selector switch 323 is in the "reset," "stop" or in the "run" position, neon lamp 348 is generally short-circuited by a circuit including selectors switches 323, 336 and 330, one of the lines 342 and line 352. Only by rotating switch 336 into agreement with the numerical position corresponding to that of switch 280 can neon lamp light. This occurs through a circuit including lines 300 and 338, resistor 350, neon lamp 348, lines 352 and 344, switch 346, rectifier 292 and supply line 290. In this way, the manual switches of all the stages of the clock corresponding to switch 336 can be manipulated with ganged switch decks 298, 312, 323, 322 etc. in the "stop" or the "run" position, until the neon lamps light, in order to ascertain the clock reading. In the "stop" position as shown, the circuit through switch 296 is broken and so the one-second advance impulses are suppressed. In the "test" position of the switches all the neon lamps light, and this provides a test of their being operative.

The computer

A typical digital computer suitable for purposes of the present invention is that described in a booklet entitled "Type 650 Magnetic Drum Data-Processing Machine Manual of Operation" Form 22–6060–1, published by International Business Machines, copyright 1955. A brief discussion of some elemental characteristics and capabilities of this machine follows, as an illustrative form of the computer in the system of FIG. 1. However, the present invention is not dependent upon this particular machine nor on its specific internal details, and since such detailed information is widely known and available, the following description of this machine is deliberately general in content and is primarily intended to provide an orientation and a basis for certain terminology useful in connection with the traffic signal control system.

This type 650 IBM data processing machine as shown in FIG. 9 includes a magnetic drum **360** for general storage or memory. The general-storage surface of the drum is subdivided into a series of equal-width "bands" **362**, each band extending around the drum and including fifty "word" locations **354**. Assuming a 40-band drum is used, the drum has a general storage capacity of 2,000 words. Each word contains ten digit areas.

Each word location is assigned a four-digit identification code from 0000 to 1,999. This code includes a two-digit portion from 00 to 49 or from 50 to 99 to locate a word position in any pair of the bands, and the code includes an initial two-digit portion from 00 to 19 to identify a particular one of the twenty pairs of bands.

Each ten-digit word can represent any value from minus 9,999,999,999 to zero to plus 9,999,999,999; and the digits can be used separately or in groups to relate to different quantities or to different codes.

The successive individual bands along the drum are provided with a series of magnetic read-write heads, for sensing the recorded digits and for re-recording new digits and thereby erasing the previous ones. The drum rotates to carry the successive locally magnetized digit areas past these heads at high speed. Suitable control circuits suppress or divert the signals induced in the heads at all locations except at a particular, selected word location, as identified by any particular "storage address" between 0000 and 1,999. These address codes identify a particular band and a particular one of the 50 areas within the selected band.

Information for entry into this general storage is supplied from various external information sources or internal sources, in various ways. It is supplied from external sources such as punch-cards or magnetic tape storage apparatus; and it also originates externally in the present traffic-signal control system at the monitor, the counters, and the digital clock. The externally derived information is not recorded directly into the general storage, but instead it is first recorded in a portion **368** of the drum called "read buffer storage." Each time the "read buffer storage" is to receive new information, it is first cleared, its entries being transferred to the general storage. The input channels for entry of information can handle 100 digits during a single "read" cycle. These input digits are divided into ten words of ten digits each; and ten words of ten digits each are transferred into general storage each time the read buffer storage is cleared.

Information delivered from the machine is also handled indirectly, being first recorded in a portion of the drum **370** called the "punch buffer storage"; and from this, it is delivered to the external utilization apparatus. This output apparatus, like the "read" portion already described, has the capacity to handle 100 digits concurrently.

Much of the matter recorded on the general storage is not information in the sense of numerical data, but it is in the nature of instructions. A stored instruction includes ten digits and a sign. The first two digits are an operation code. This may represent "add" or "multiply" or any one of many other functions or combinations of functions, the Type 650 IBM machine having the capacity to execute approximately 90 such functions. The next four digits of this instruction "word" represent the "data address," or the drum location to be selected for use in the particular operation, or the location in which information is to be stored by the operation, or other locations, or shifts of digits in the accumulator. The last four of the ten digits represent the address or location where the instruction word is to be found for the ensuing operation, which takes place after completion of any given operation. The sequence of instructions is called a program, and causes automatic operation of the computer to utilize stored data and externally supplied information, usually by punch-card read-in apparatus.

The data address and the instruction address for the next operation relate to the drum if the code is between 0000 and 1,999. In addition to the storage drum **360**, the machine includes a 20-digit accumulator **372**, divided into a 10-digit Upper accumulator and a 10-digit Lower accumulator plus sign; and it includes a Distributor **374**. The struction address may be 8001 if the distributor is to be the source of the data to be used in the ensuing operation; and the instruction address may be 8002 or 8003 when the lower accumulator or the upper accumulator contains the data to be used in the operation next following any given operation in progress.

A on-digit adder **376** is provided for performing all necessary computations, including addition, substraction, multiplication and division. It uses information from the distributor and one half of the accumulator; and it includes a "carry"loop **378**.

A program register **380** is included which obtains addresses and operation codes from the general storage or the distributor or the accumulator, and it transfers such codes to an operation register **382** and to an address register **384**, the Arithmetical and logical operations of the machine are performed by the accumulator, the distributor and the adder. These operations are controlled by the program, operation and address registers. Validity checking units **386** are provided at the output of the program register, the distriblutor and the accumulator.

The arrangement is such that as each operation is being performed, the next instruction is being located. Magnetic tape units (not shown) may be connected to the computer to provide rapidly available auxiliary sources of stored information.

General mode of operation of the system

Initial setup consists of storing in the computer the necessary program instructions, as well as tables of parameters and pre-established data pertaining to the system. This information may be kept on decks of punched cards in which case it must be read into the computer's general storage through the puched card read-in unit, or it may be kept on magnetic tapes in which case these tapes must be mounted on the tape units connected to the computer. The program consists of sequences of instructions in the computer's code language, including those required to effect the computation of the formulas referred to hereinafter. The tables of parameters and pre-established data may include such information for each intersection as: the detectors associated with that intersection, their distances from the intersection, the digit positions of input where the input data for the intersection will appear, the digit positions of output where the output data for the intersection must be sored, the normal local control sequence for the intersection, data relating to expected volumes of turning movements at the intersection, predetermined maximum and minimum limits for traffic signal phase durations, values of fixed phase times (e.g. amber times), test criteria for changing control formulas, and any other such information as may be required by the formulas used to determine the computer controlled sequence of the traffic signals.

In operation with the signals under computer control a repetitive cycle of operations is performed under the direction of the computer program. We shall refer to this cycle as the computation cycle. It begins with a read operation which causes the current values of all the counters and monitor units in the system as well as the clock information to be read simultaneously into a designated set of storage locations within the computer's general storage. This is accomplished by suitable wiring of the computer's control panel to the external units.

Let us consider the signallized street intersections in the system as being numbered from 1 to N. The order of numbering is immaterial. The computer then takes the input information and the initially stored data pertaining to intersection No. 1 and by means of an appropriate formula or algorithm which would be determined by the engineer or the programmer, ascertains whether any

change in the indication of the signals at intersection No. 1 is called for at this particular time. This might, for example, be done by comparing the elapsed time since the beginning of the current phase of the signal, such time being ascertained by a comparison of the current clock reading with that recorded at the last detected phase change of the signal, with a desired or limiting phase duration obtained from a stored table or calculated by a formula referred to above. If the elasped time were found to equal or exceed the desired or limiting time so desired, a phase change would be called for; otherwise no change would be called for. Depending on the results of this calculation, the computer stores in a particular output area of storage an appropriate code to effect the required change or no change. No actual output, however, takes place at this time.

The program then proceeds to intersection No. 2 and, using the input information and initially stored data pertaining to intersection No. 2 and applying again an appropriate formula or algorithm, which is not necessarily the same as that used for intersection No. 1, ascertains whether any change of signal indication is called for at this time for intersection No. 2, and again stores the apropriate output code. This procedure is gone through for each of the N intersections in turn. Because the computer performs arithmetic operations very quickly these calculations can be accomplished for the whole set of intersections within a short interval, for example a little less than two seconds.

When the Nth or last intersection has been processed in this way, an output order is given by the computer program which causes all the output codes which have been stored during the processing to be converted to sequences of timed impulses which are sent to the output units described elsewhere in the application, thus causing each traffic signal to maintain its current indication or to change to a subsequent indication. This represents the end of the control cycle and the cycle immediately repeats with another read instruction. This control cycle may take a total of approximately two seconds and will continue to repeat in this way so long as the computer is in control of the signals.

In initially assuming control of the system and in finally relinquishing control of the system, an essentially similar sequence of cycles is gone through, except that the formulas used for these phases of the operation are designed to ascertain for each signal the proper time to bring it under or to release it from control of the computer. Output codes are provided to effect this pickup and dropout, as described elsewhere in the application. At a given time, any part of the system might be under computer control with the remainder operating in its normal locally controlled mode. Pickup and dropout programs are designed to effect a smooth transition between these two states.

The formulas used for computing the proper traffic signal change times may be as simple, or as complex and sophisticated, as desired, within the limits imposed by the speed of the computer. That is, all of the intersections must be processed within the time allowed for one computation cycle.

A simple program, in computing the change time for a given intersection, may for example use as data for that intersection only the particular values associated directly with that intersection, that is the values from the counters which are associated with the detectors on the approaches to that one intersection, the monitor value for that intersection, the clock data, and the initially stored data for that intersection. Even with this restriction, there can be considerable variation in the degree of complexity of the formula used. For example, the formula could take into consideration the density of the traffic on the different approaches, the number of cars waiting on the red light, and even the speed of traffic if this information were available from specialized detectors or could be deduced in some way from the information available. Another factor that could be used in the formula is the time of day, day of week, etc., which information is available from the clock input.

Now it will be seen that there is no reason for the information used in the formula for determining the changes for a given intersection to be restricted to the data from the detectors and controller at that intersection only. The formula might well utilize information from detectors and controllers 1, 2, 3 or more blocks away in any direction. In this way coordination of various degrees may be achieved. In fact, information from any part of the system may in principle be used in determining the control changes for any given intersection since all of this information is simultaneously available to the program. The complexity of the formulas used is limited only by the capacity of the machine to do the requisite calculations in the time available and by the ingenuity of the engineers and programmers. The amount of storage available within the computer might also be considered to be a limitation, but this restriction is largely obviated by the availability of magnetic tapes which provide a large amount of auxiliary storage which is rapidly accessible to the computer. Thus, at any time during the calculations, as a result of criteria built into the program it is currently using, the program can automatically make a decision to call in a new set of formulas from the magnetic tapes, and proceed with these new formulas. For example, certain criteria might indicate an emergency situation, such as blockage of a particular intersection, in which case the computer could call into action a special program which would facilitate rerouting of traffic around the blocked area. It is quite conceivable that the machine could be programmed to improve its own formulas on the basis of experience. This is similar to the idea of machine learning which has been investigated with computers in other fields.

With the advent of computers with higher and higher speeds, this invention gives the traffic engineer a tool which he may not yet be able to fully exploit due to lack of sufficient understanding of the ways of traffic. In this connection it may be noted that one of the merits of this system is that a complete log of all data recorded, as well as all operations performed can be kept on magnetic tape and analysis of this data may provide the basis for further improved methods of control.

When the data processing machine described is connected in the system of FIG. 1, it is prepared for operation by initially entering the program instructions, and by entry of information to be stored in the form of tables. These tables contain numbers describing physical characteristics of the system as well as traffic characteristics based upon the experience, calculations and surveys of traffic engineers. In preparing for the entries, a number of desirable plans of traffic signal coordination are worked out, without being limited to one, two or three sets of schedules. Punch cards may be used for entering the initial information and program of instructions, or magnetic tape read-in apparatus or both may be used.

In the operation of the computer for control of traffic signals, the 100-digit read-in channels usually connected to the punch-card reader are instead connected to the above-described traffic-signal read-in apparatus, including the digital clock and the monitors and the stepping-switch continuous counters actuated by vehicle detectors (FIG. 1). The output channels from the computer that would ordinarily go to a card-punch unit are here connected to the respective output units (FIGS. 1 and 5).

The monitor of each traffic signal in the computer-controlled system provides a single digit that represents its phase, such as "east-west green and north-south red." One read-in digit serves for the phase of a single traffic signal. One digit also represents the position of each stepping-switch continuous-counter (FIG. 7) so that, if there are four vehicle detectors **14** related to a particular inter-

section, four digits will convey to the computer the vehicle-count information pertaining to the related intersection. For example, the first four digits of a ten-digit word in the "read" buffer may represent the respective positions of the North, South, East and West stepping-switch counters related to a particular traffic signal, and a fifth digit may represent the phase of that traffic signal, e.g., 4096700000. The zeros in this word indicate that there is a capacity for receiving five more digits of like information from another traffic signal having four counters and a phase-representing monitor. With a total capacity of 100 digits, the "read" buffer could accommodate 20 traffic signals represented by five digits each. One word space is reserved for the digital clock and calendar information, and so the number of 4-detector-and-traffic-signal units supervised in this example is reduced to 18. The input data need not be in the arrangement shown in this example since the location of each digit of input information is identified by stored tables within the computer.

A word of read-in information comprising ten digits is sufficient for the digital clock and associated calendar information provided by panelboard connections or switches (not shown). The first two digits may represent the month, the next two the day of the month, the fifth may represent the day of the week, and the next five digits may represent the time of day in seconds. Using this form, the number 1026451466, for example, represents October 26, Wednesday, 51466 seconds past mindnight.

The computer may be programmed to have a read-in cycle every two seconds, each lasting about ⅕ second. The time between "read" cycles is available for data processing. The buffer storage is emptied by transferring its information to general storage during the first part of each "read" interval, and then the new information is registered in the "read" buffer. The above representation of a particular traffic signal and its counters, 4096700000, may be routed into the read buffer, and then by proper instructions in the computer program to general storage location 1951. At the same time, the above time-and-date 10-digit word 1026451466 may similarly be routed by computer programming to general storage address 1960. Concurrently, at these two-second "read" intervals, corresponding information concerning a second traffic signal and its counters (represented by the second five digits of the above word) would be routed to the same location 1951 of general storage. The 5-digit representations of two more traffic signals and their counters may be routed to general storage location 1952. In this way, the five-digit representations of 18 traffic signals and their counters can be registered concurrently in general storage locations 1951, 1952 . . . 1959. Location 1960 may be reserved for the time-and-date 10-digit code word.

In a sequence of nine two-second computation cycles, considering only one traffic signal and a 10-digit time-and-date word, the digits in locations 1951 and 1960 may be:

Cycle	Location 1951	Location 1960
1	4096700000	1026451466
2	5196700000	1026451468
3	5216700000	1026451470
4	5226700000	1026451472
5	7227700000	1026451474
6	7327800000	1026451476
7	9347800000	1026451478
8	0357300000	1026451480
9	0458300000	1026451482
10	1758300000	1026451484
etc.	etc.	etc.

Numbering the digit positions in the above codes from 1 to 10, starting at the left, the digits refer to the following:

Location 1951, Digit 1—North Counter
Location 1952, Digit 2—South Counter
Location 1951, Digit 3—East Counter
Location 1951, Digit 4—West Counter
Location 1951, Digit 5—Monitor
Location 1960, Digits 1 and 2—Month (October)
Location 1960, Digits 3 and 4—Day of Month (26th)
Location 1960, Digit 5—Day of Week (Wednesday)
Location 1960, Digits 6 to 10, incl.—Time of Day in Seconds

The following information may be deduced from the tabulation (above) of 10 "read" cycles:

(a) Total elapsed time—18 seconds
(b) Total north counts received—7
(c) Total south counts received—7
(d) Total east counts received—6
(e) Total west counts received—2
(f) The traffic signals changed from East-West green through a 4-second East-West amber phase into the North-South green phase.

Between each ⅕-second read-in operation and the next, the machine performs logical and computing operations utilizing the information from each digit of the digital clock and of each traffic-signal group of five digits, as well as information from pre-recorded tables. During the time between each ⅕-second read-in operation and the next, two seconds later in this example, the computer programming causes successive computations to be made relative to one traffic signal after another. If there are 18 differently controlled traffic signals, then the computer performs 18 complete sequences of computations in succession within the time between each "read" operation and the next. At the end of the computation interval, concurrent read-out operation to all the controlled signals occurs, each with its own control channel.

As a measure of traffic density during a particular phase of a traffic signal, the computer may be programmed to ascertain the maximum number of vehicles detected in any 10-second interval. By suitably programming the computer, the information in location 1951 may be transferred to location 1971; and in the next 2-second interval the information in location 1951 may be routed to location 1972, and in four more cycles the information in location 1951 may be transferred to locations 1973, 1974, 1975 and 1976. The programmed computer subtracts the stored, fixed digits in location 1971 representing the initial state of the counters from the value in location 1976 and records the difference in another coded location, e.g. 1981. In this example, if the initial counter readings are 4096700000 in location 1971 and if the counters step along progressively to reach 7327800000 ten seconds later, the first counter has advanced from 4 to 7, and so has advanced 3 counts. This value can be registered in location 1981. The second counter, having advanced from 0 to 3 will have detected 3 counts and the second counter-representing digit recorded in location 1981 as a result of the programmed computer operation will also be 3. The third counter has advanced from 9 to 2; and since the computer recognizes "2" as less than "9" it adds "10" to "2" and substracts the "9" from "12," giving 3 counts for the third counter. The fourth counter has advanced only one.

The first four digits stored in location 1981 on the basis of the above computations are 3331, representing the actual number of vehicles that were detected approaching a certain intersection from four directions during the 10-second interval, assuming placement of four vehicle detectors **14** (FIG. 1) to detect vehicles along these approaches.

At the seventh read-in cycle following the above phase change, the new count reading can be transferred from location 1951 to location 1971, erasing the first one in location 1971; at the eighth cycle the new information can be transferred to location 1972; and so on. During each computation cycle that follows each read-in opera-

tion, the computer subtracts the earliest stored number from the latest, and thereby obtains the 10-second traffic rate. If it exceeds the value previously registered in location 1981 (as determined by a programmed comparison) the new, higher value can then be registered there.

During times when traffic is light, it may well be advisable to leave control of the local traffic signals to their local sequencing controllers, according to a useful application of the disclosed system. When a rush-hour arrives, at a preset time stored in the computer program and checked against the digital clock automatically, the computer then assumes control of some parts or all of the supervised signal control system. This is achieved by sending a "hold" impulse via the circuit of FIG. 5 to that of FIG. 3.

Traffic-responsive control of individual traffic signals has been discussed, in which it appears that only one digit is involved in phase representation while four more digits are involved (in an example) in registering counts of vehicle detectors. Traffic density may not be of particular interest in a system where accurate traffic flow can be predicted with reasonable accuracy. In that event, a number of time cycles can be recorded as parts of a plan stored in the computer, each signal to be monitored and controlled by only one read-in and one read-out digit. A system of 90 differently controlled traffic signals could then be accommodated in this manner by the illustrative computer, changes from one plan to another being dictated by read-out from the digital clock as compared with stored clock readings at which each plan is to be called into effect. Also, detectors at key locations may be used to contribute to plan selection for a large system of traffic signals.

The capacity of the general storage of drum **360** in the illustrative computer is limited, and may not be enough to accommodate the number of different plans required by the central traffic control system. In that event, additional plans and program instruction may be made available to the computer in the form of quick-access magnetic tape storage units. Manually in advance or automatically at programmed times of day, which may differ depending on the day of the week and on certain dates of the year, the computer may cause substitution in its general storage or memory of a program available in an auxiliary tape storage unit in place of that currently in its general storage. In this way a large number of different plans of traffic signal coordination that have been found desirable at different times may be brought into effect as desired.

Each plan may be modified at the central location, without tedious on-the-scene adjustment of each individual traffic-signal controller, as is required with usual locally controlled units. The total elapsed time of the complete sequence of phases in each control cycle can readily be changed, making it long or short as may be desired. Multiple signals may be coordinated, for example staggered or offset in a predetermined relationship, and the direction and speed of traffic flow favored by staggered signals may be changed at different times, automatically or at will, using readily available previously prepared signal control plans and computer programs.

The adaptation of traffic signals to digital control by means of a central digital data processing machine is seen to be of great advantage from many points of view. Large numbers of control plans for traffic-signal systems can be quickly and automatically put into effect on the basis of predicted times, traffic density, or other criteria. Changes in any plan can be made with comparative ease, at a central location and without resort to mechanical changes for large numbers of individual sequence-timing units. The vast flexibility and new possibilities of the system disclosed are of particular importance in relation to the growth and complexity of signal-controlled traffic networks.

A broad range of modification and varied application of the novel features described above will occur to those skilled in the art, and therefore this invention should be broadly construed in accordance with its full spirit and scope.

What we claim is:

1. Apparatus for remotely evidencing the selective positioning of a rotary multi-pole selective switch in a local traffic signal control, comprising a transmitter at a first station location, said transmitter including a plurality of rotary coaxial cams, a plurality of switches cooperating with said cams respectively and operable thereby to open and closed conditions, coordinating means connecting said cams to said selective switch, said cams having related contours such that each selective position of said selective switch has a corresponding unique combination of open and closed cam-operated switches, signalling means at a second station location remote from said first station location, said signalling means including a plurality of terminals corresponding to the predetermined positions of said cams, energizing means, a plurality of switching relays equal in number to the number of said cam-operated switches and having energizing circuits connecting the coils of said switching relays to respective ones of said cam-operated switches, a plurality of display-actuating relays equal to the number of predetermined positions of said cams, means connecting said switching relays and said display-actuating relays to said energizing means, each of said display-actuating relays including first and second contact pairs, a plurality of phase-representing lamps connected to said contact pairs for displaying the phases of a traffic signal in response to the switching of said display-actuating relays, including means connecting said lamps to said energizing means, each of said switching relays having first and second sets of double-throw contacts, the contacts of said first set being connected in cascade to said plurality of terminals, the contacts of said second set being connected in cascade to the coils of said display-actuating relays, said terminals being adapted for connection to a digital "read" pulse emitter of a digital computer, said first contact pairs of said display-actuating relays and said second contact pairs of a group of said display-actuating relays being connected to said lamps and to said energizing means for selectively energizing the connected lamp, and a flasher switch, said second contact pairs of another group of said display-actuating relays being connected in a circuit to said energizing means, said flasher switch being interposed in said circuit in control thereof.

2. Apparatus for remotely evidencing the phase of a local traffic signal, including signal display control means proximate to said signal for establishing said phase, and further including a remote monitoring system including a plurality of display relays equal to the number of the traffic signal to be represented, energizing means, switching means for energizing said display relays selectively in accordance with the selected phase of the local traffic signal, including means connecting said switching means to the coils of said display relays, means connecting said display relays and said switching means to said energizing means, each of said display relays having first and second contact pairs, a plurality of indicator lamps, means connecting each of said first contact pairs and each of said second contact pairs of a first group of said relays in series with a predetermined lamp and said energizing means, a flasher switch, and means connecting said second contact pairs of a second group of said relays in series with said flasher switch, said energizing means and predetermined ones of said lamps.

3. Apparatus in accordance with claim **2**, including third contact pairs for predetermined ones of said display relays of said second group, said third contact pairs being connected to predetermined ones of said lamps and to said energizing means.

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