

[54] **AIRPORT GROUND AIRCRAFT
AUTOMATIC TAXI ROUTE
SELECTING AND TRAFFIC CONTROL
SYSTEM**

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[21] Appl. No.: **125,372**

Related U.S. Application Data

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abandoned.

[52] U.S. Cl. **340/26**

[51] Int. Cl. **G08g 5/00**

[58] Field of Search **340/23, 24, 25, 26, 35, 40;
343/7 RS, 8**

[56] **References Cited**

UNITED STATES PATENTS

2,892,995 6/1959 Kearney et al. **340/22**

3,254,324 5/1966 Casciato et al. **340/35**

Primary Examiner—**Kathleen H. Claffy**

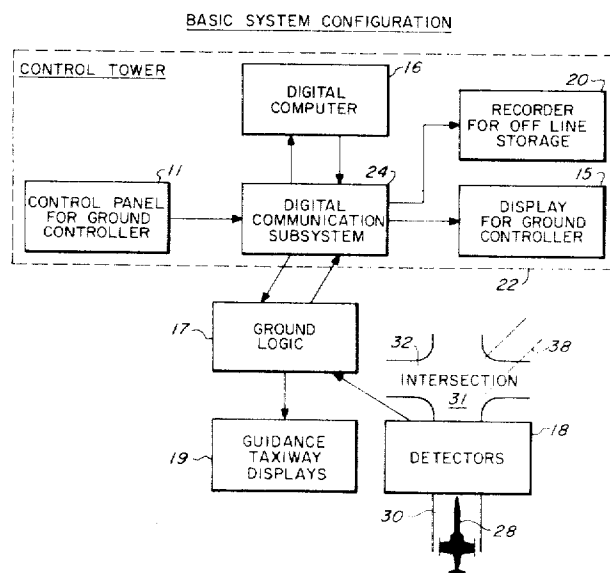
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A. Naigur**

[57] ABSTRACT

As an identified object, such as an aircraft on the ground is scheduled to cross the surface traffic network of certain areas, such as an airport, its identification and point of destination on the ground are fed to an automatic digital computerized controller comprising integrated intersection traffic control and monitoring logic units, which automatically generates a selected route from the point of origin of the object to such destination point, and by appropriate guidance displays including such identification, directs the pilot or driver of the object at each traffic intersection when safely to enter and in which direction to proceed, until the object reaches the desired destination point.

4 Claims, 39 Drawing Figures



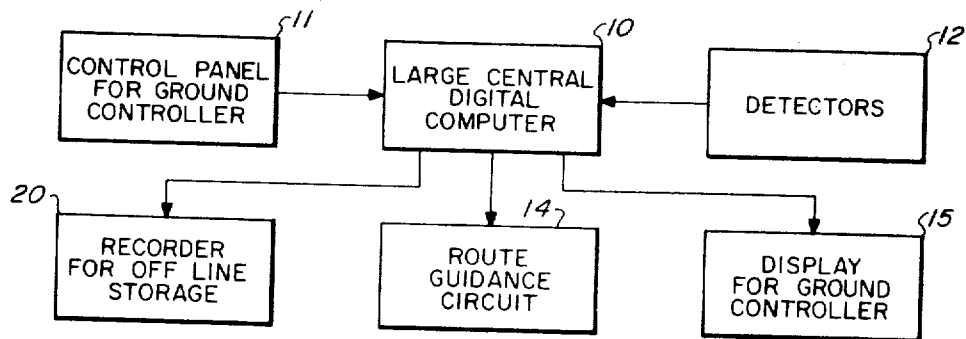


FIG. 1

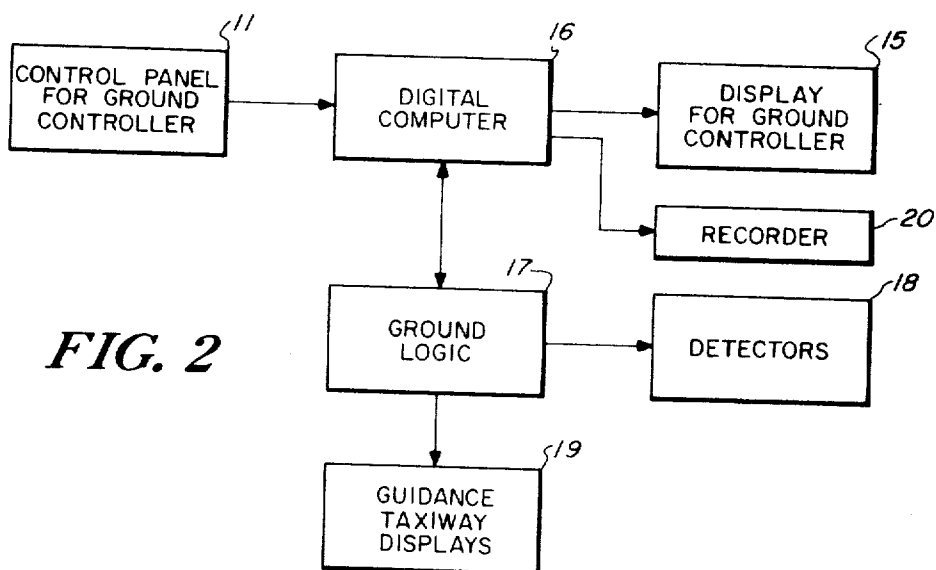


FIG. 2

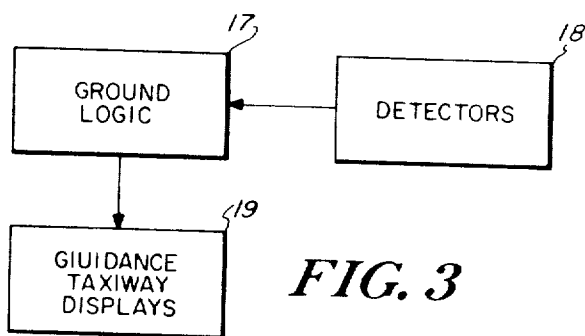


FIG. 3

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BARNWELL RHETT KING
ATTORNEY

BASIC SYSTEM CONFIGURATION

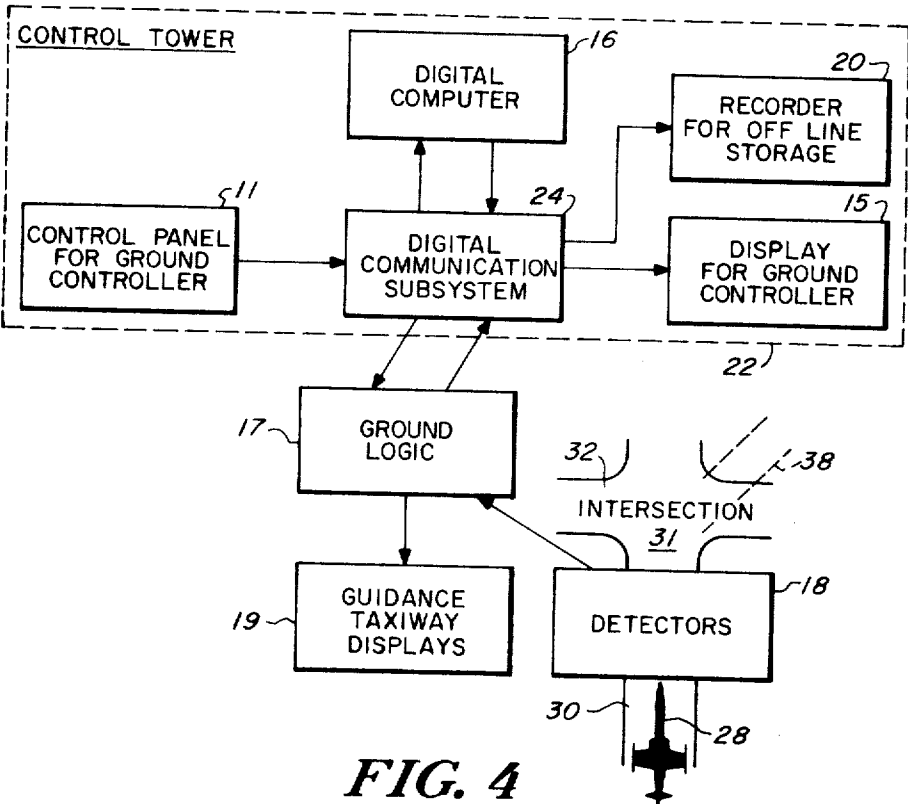


FIG. 4

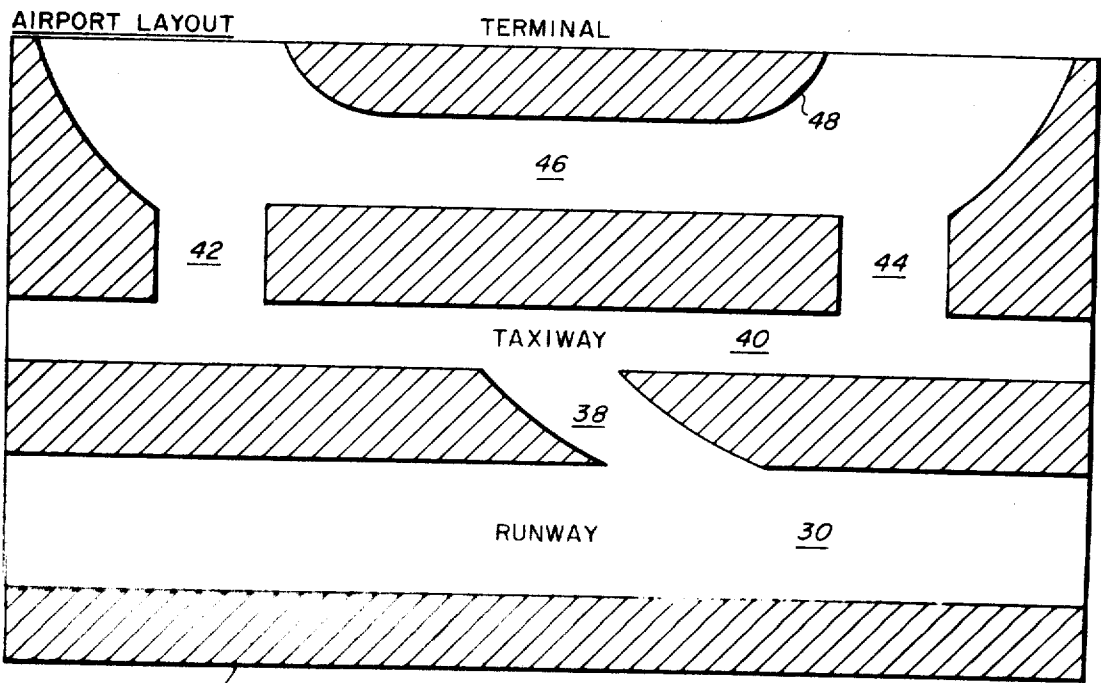


FIG. 5

50

RUNWAY CODE
RUNWAY TURNOFF CODE
"
"
"
⋮

RUNWAY LIST

FIG. 6

52

RUNWAY CODE
RUNWAY DETECTOR CODE
"
"
"
⋮

RUNWAY DETECTOR LIST

FIG. 7

54

TAXIWAY CODE
⋮
RUNWAY TURNOFF CODE
⋮
APRON THROAT CODE
⋮

COORDINATE LIST

FIG. 8

56

TAXIWAY CODE	INTERSECTION CODE	INTERSECTION CODE		
⋮				
INTERSECTION CODE	TAXIWAY CODE	TAXIWAY CODE	TAXIWAY CODE	TAXIWAY CODE
⋮				
RUNWAY TURNOFF CODE	INTERSECTION CODE			
⋮				
APRON THROAT CODE	INTERSECTION CODE			
⋮				

TAXIWAY LIST

FIG. 9

58

AIRCRAFT IDENTIFICATION CODE
TAXIWAY CODE
⋮
TAXIWAY CODE
"
"
POSITION POINTER
POSITION REGISTER

ROUTE ARRAY

FIG. 10

60

AIRCRAFT IDENTIFICATION CODE
RUNWAY DETECTOR CODE
⋮
RUNWAY DETECTOR CODE
"
"
POSITION POINTER
POSITION REGISTER

RUNWAY TRACKING LIST

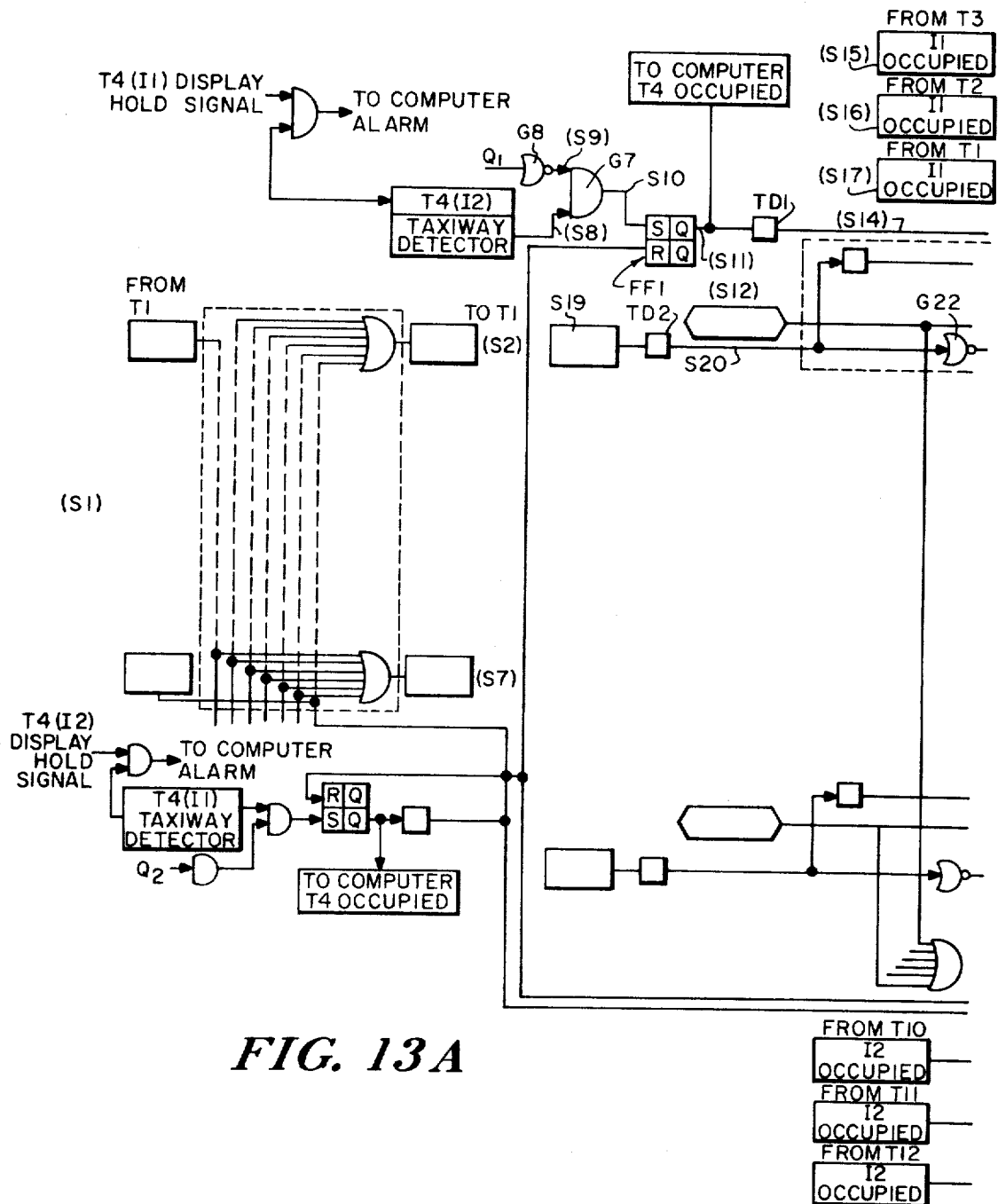
FIG. 11

62

AIRCRAFT IDENTIFICATION CODE
INTERSECTION CODE
TAXIWAY CODE
"
"
"

VIOLATION ARRAY

FIG. 12



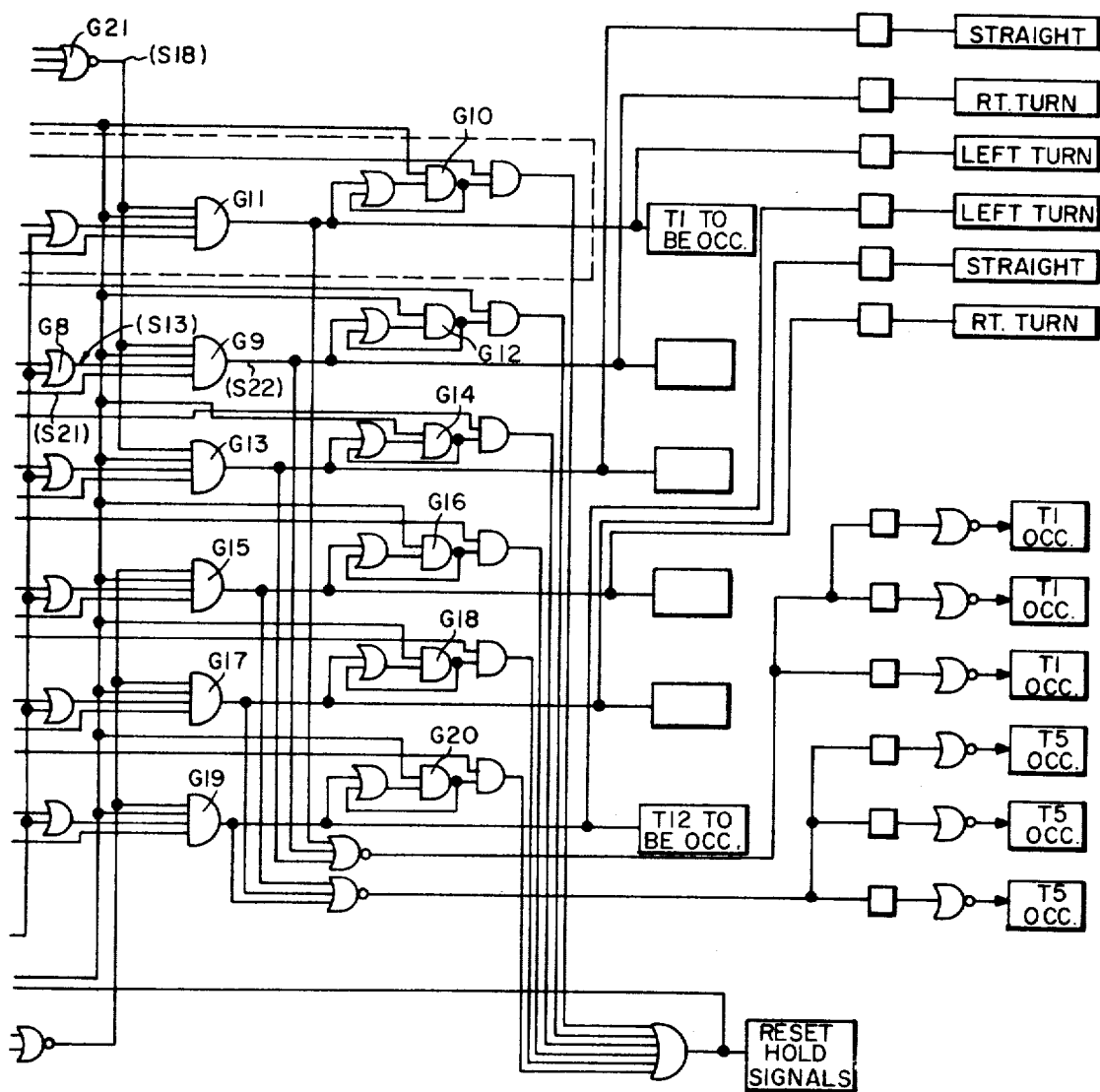
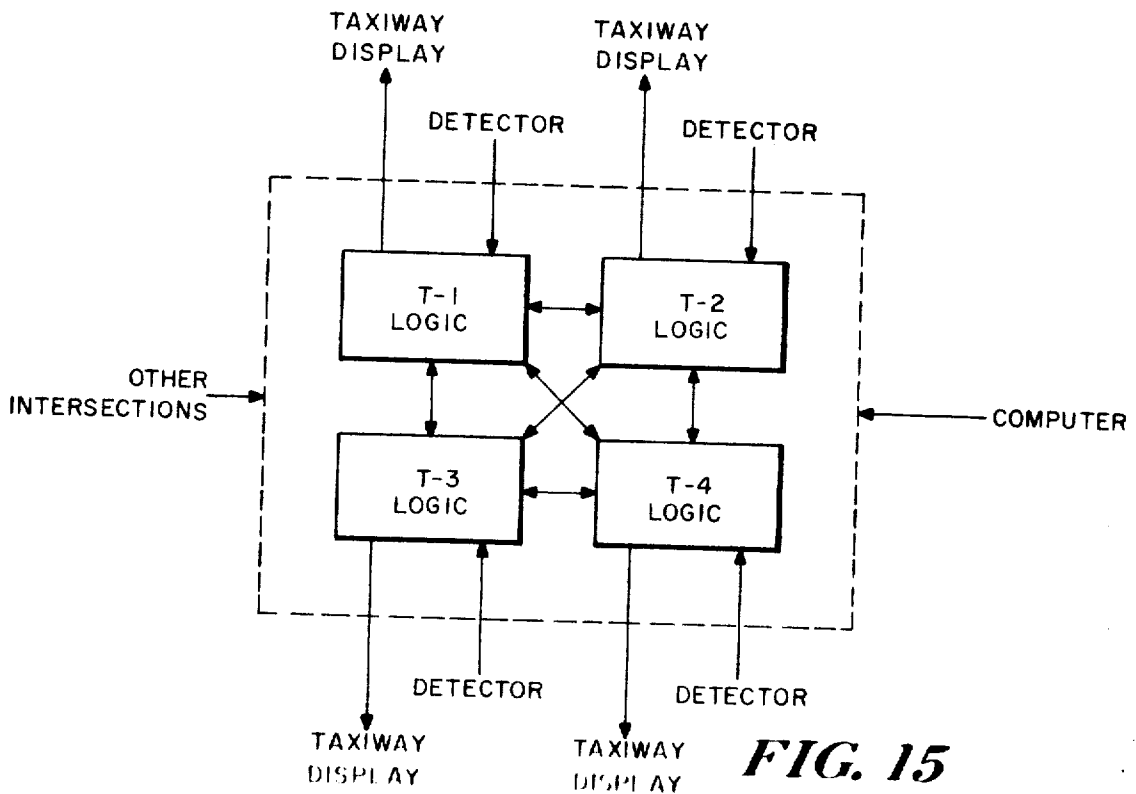
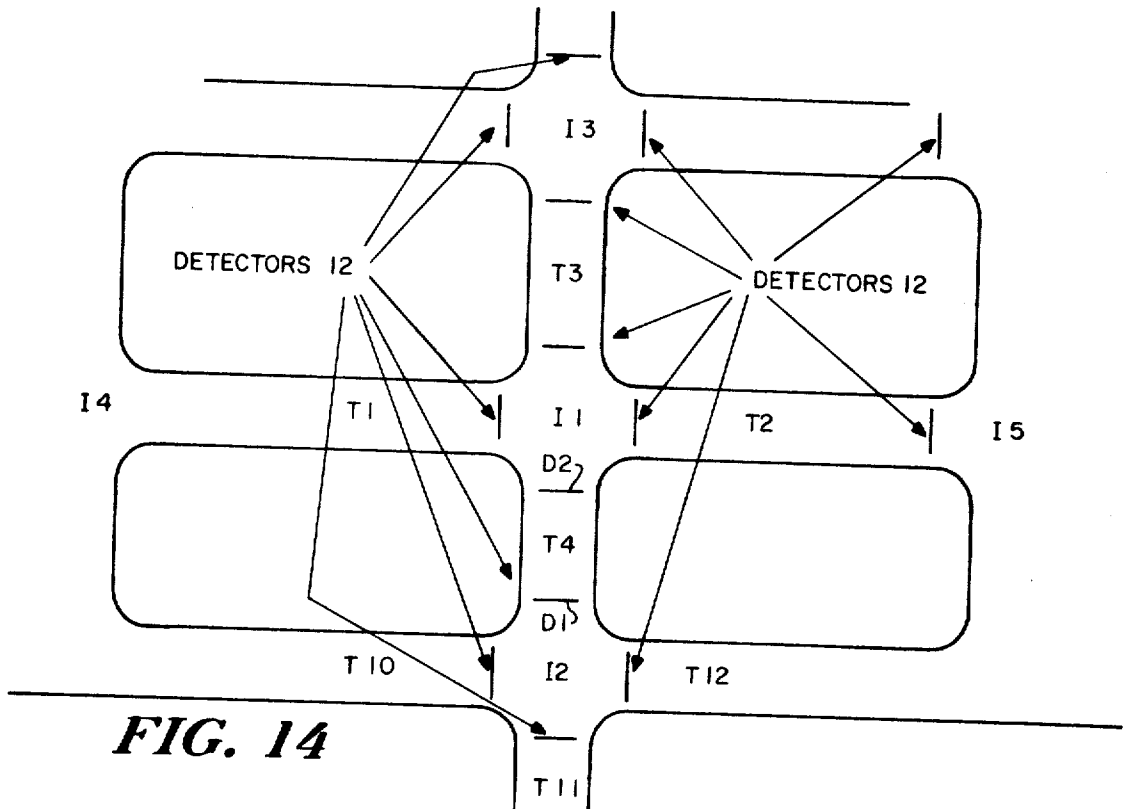


FIG. 13B



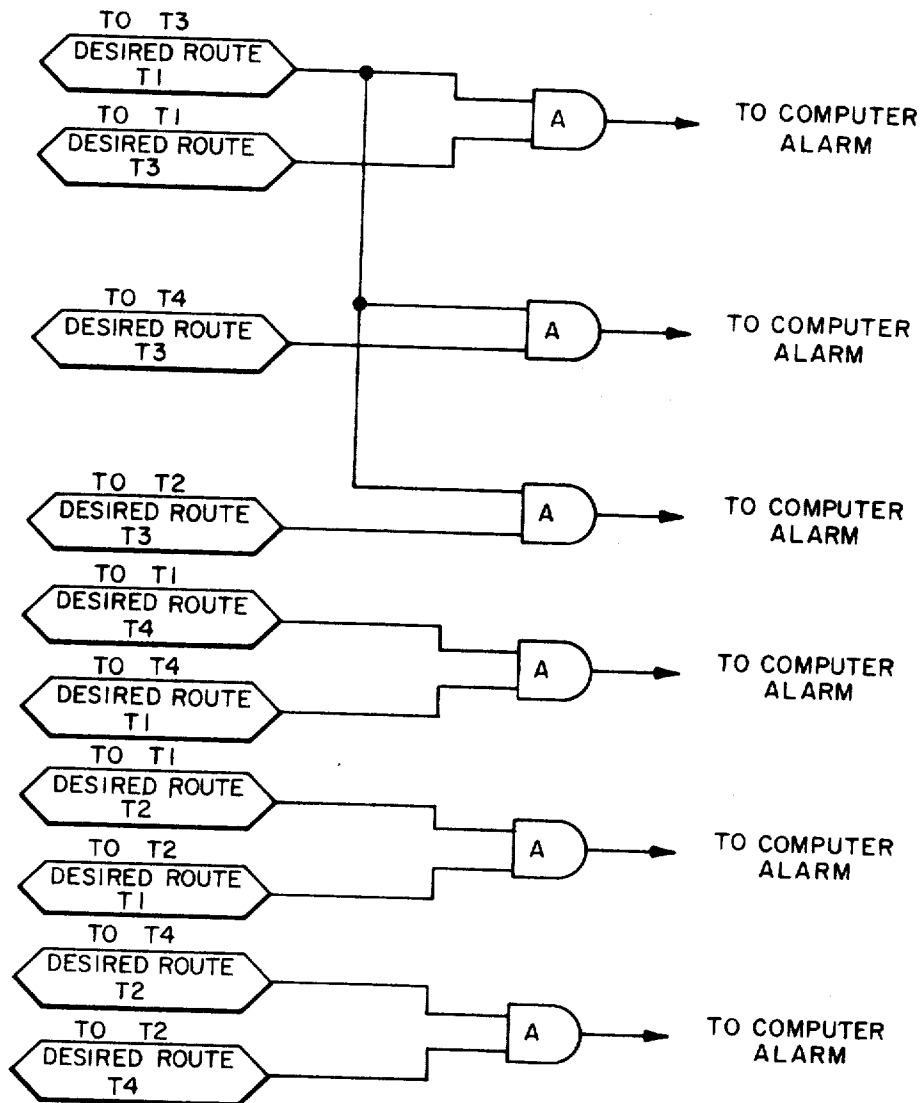
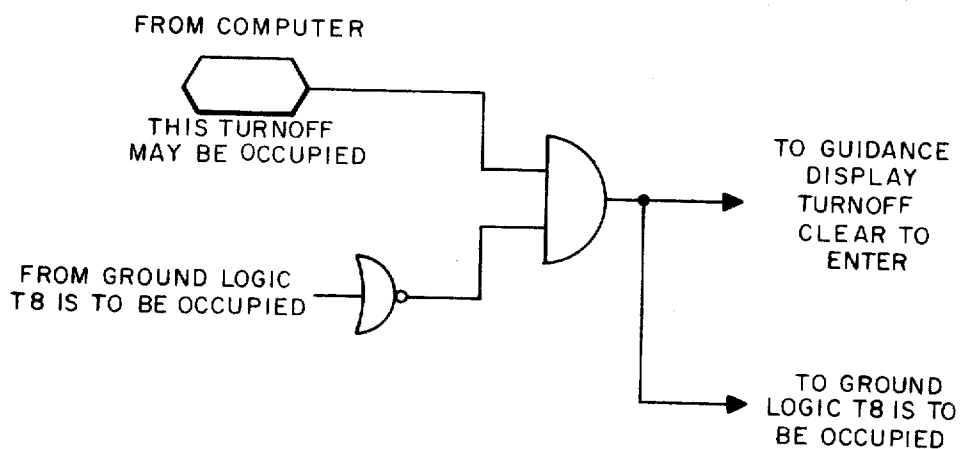
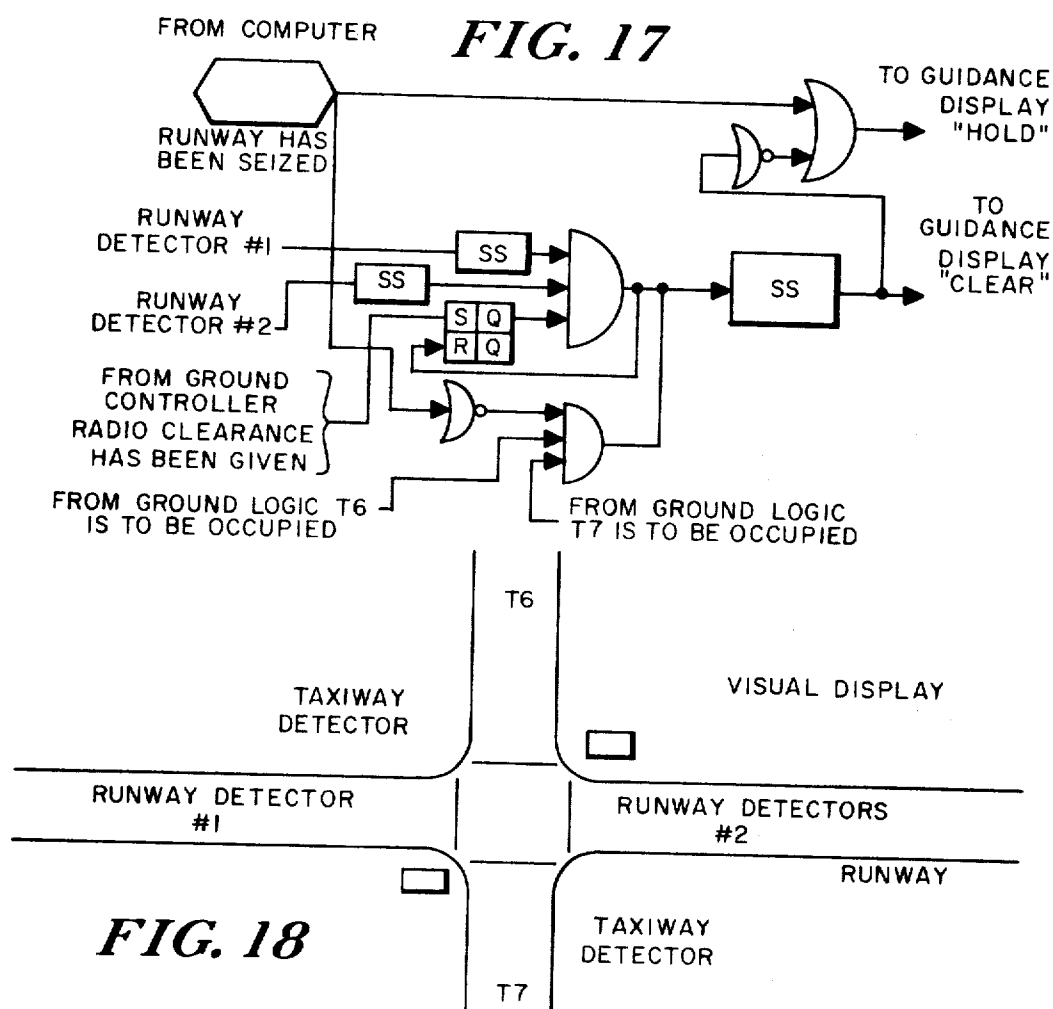


FIG. 16



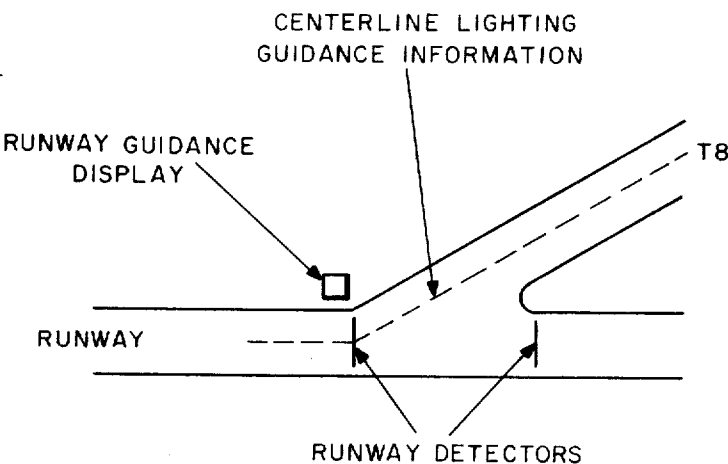


FIG. 20

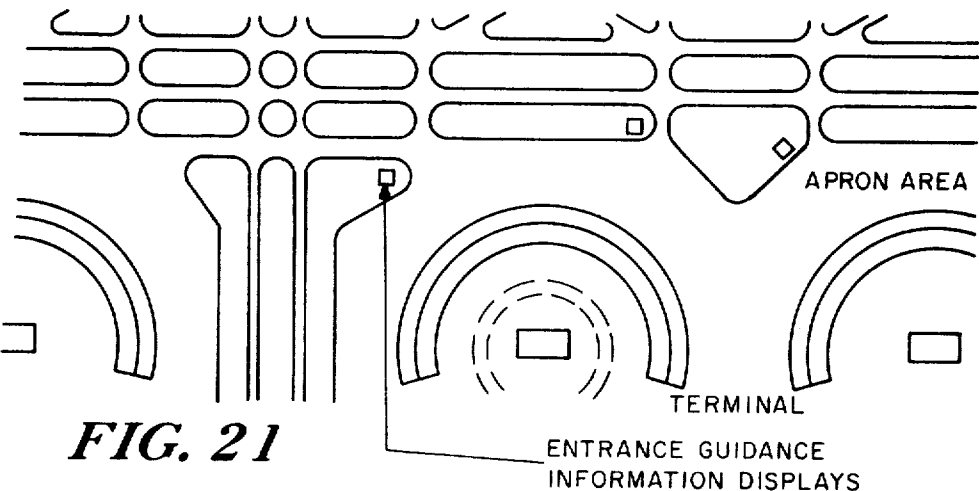


FIG. 21

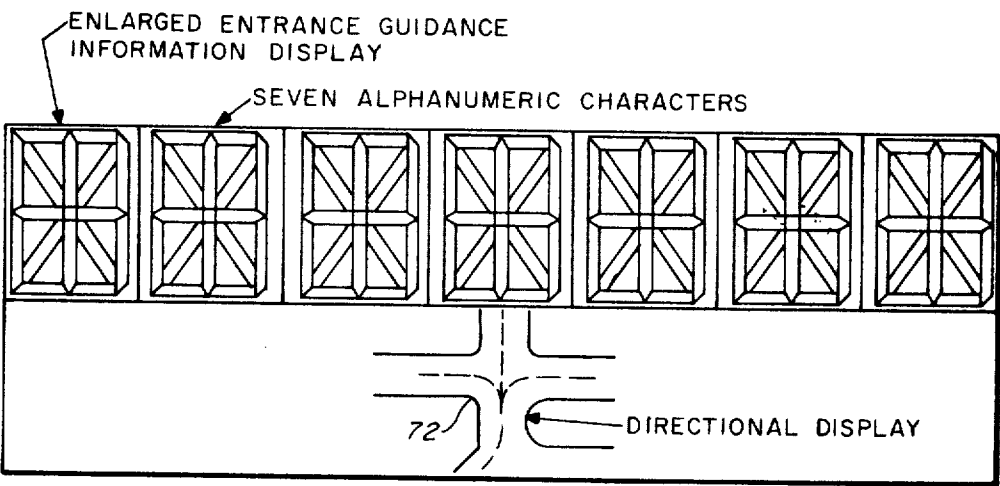


FIG. 22

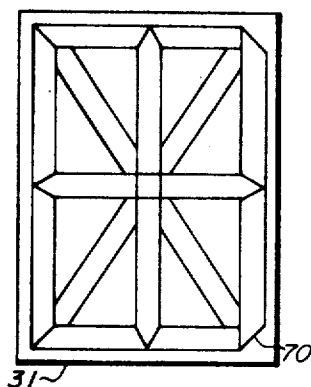


FIG. 23

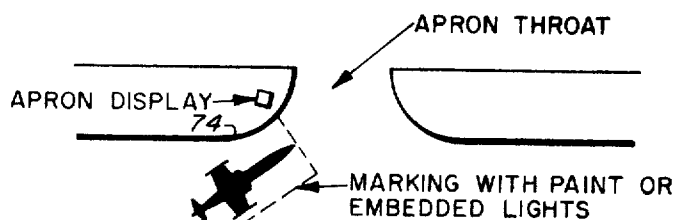


FIG. 24

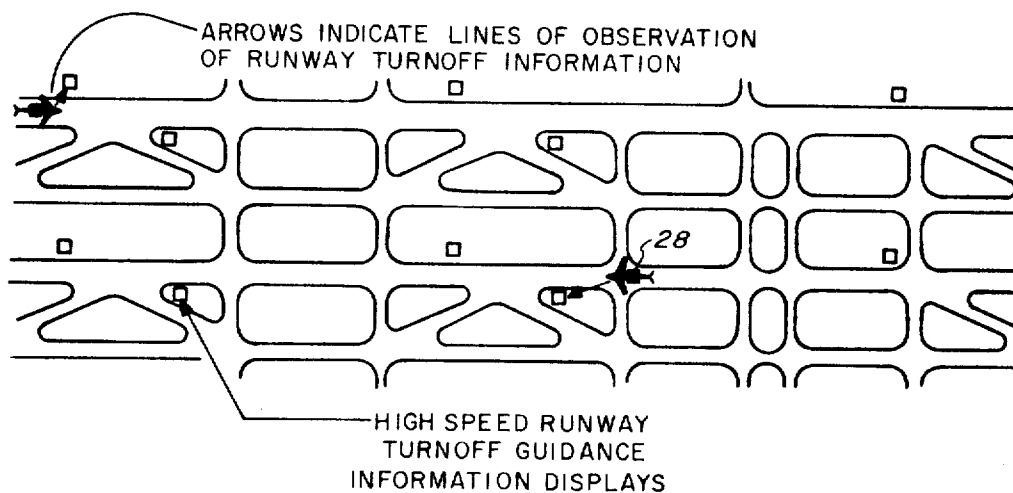


FIG. 25

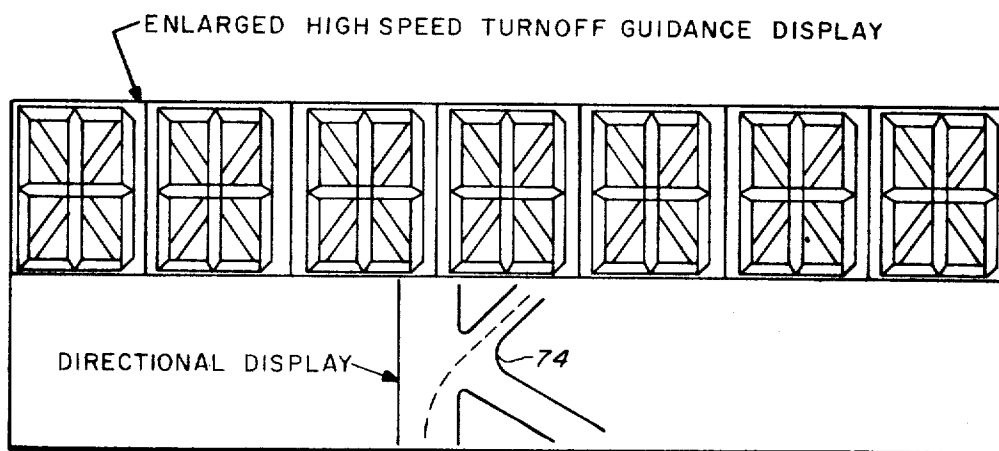


FIG. 26

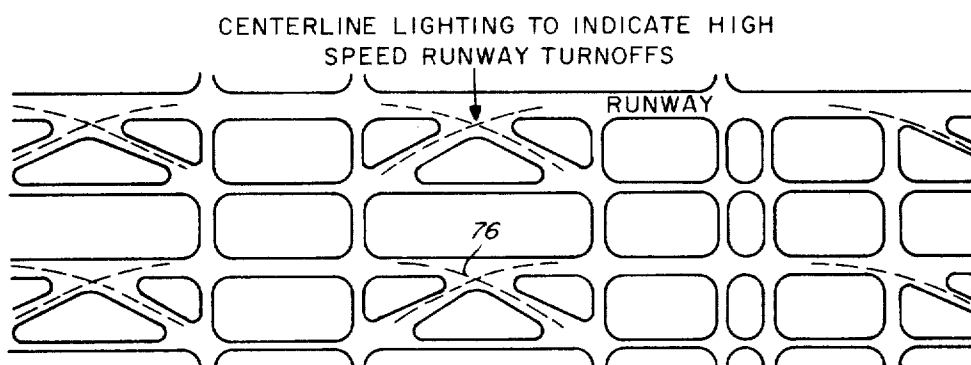


FIG. 27

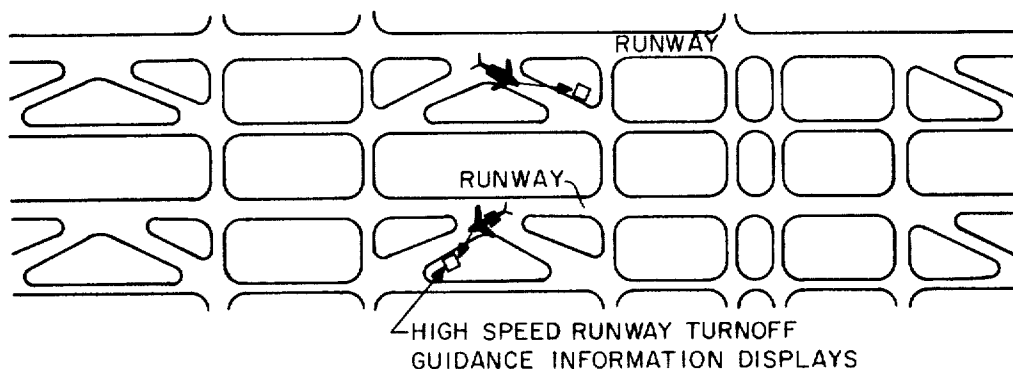


FIG. 28

WHERE TAXIWAY CROSSES RUNWAY THE GUIDANCE DISPLAY WILL BE ON THE SAME SIDE AT THE INTERSECTION AS THE VEHICLE

Diagram illustrating the placement of guidance displays at a taxiway-runway intersection. The layout shows a central runway with multiple taxiways. The guidance displays are positioned on the same side of the intersection as the vehicle, ensuring visibility and guidance. Labels include 'RUNWAY' and 'GUIDANCE INFORMATION DISPLAY'.

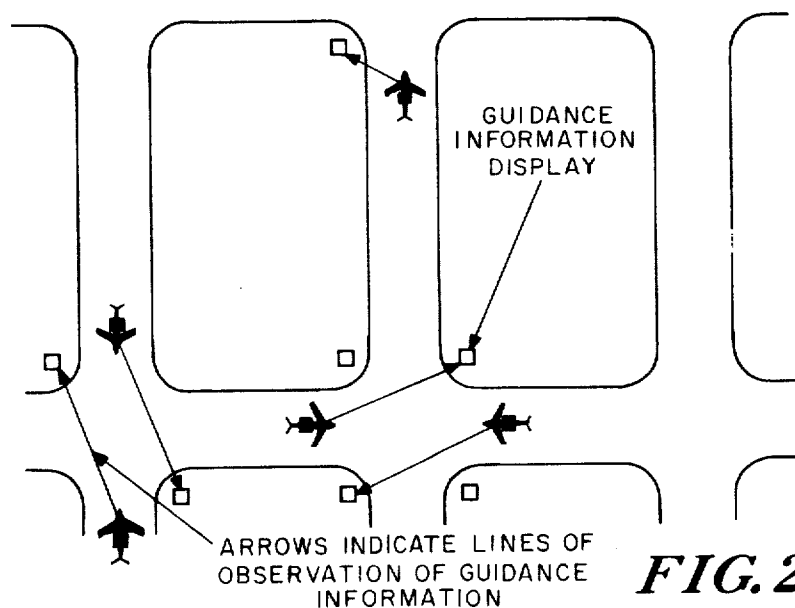
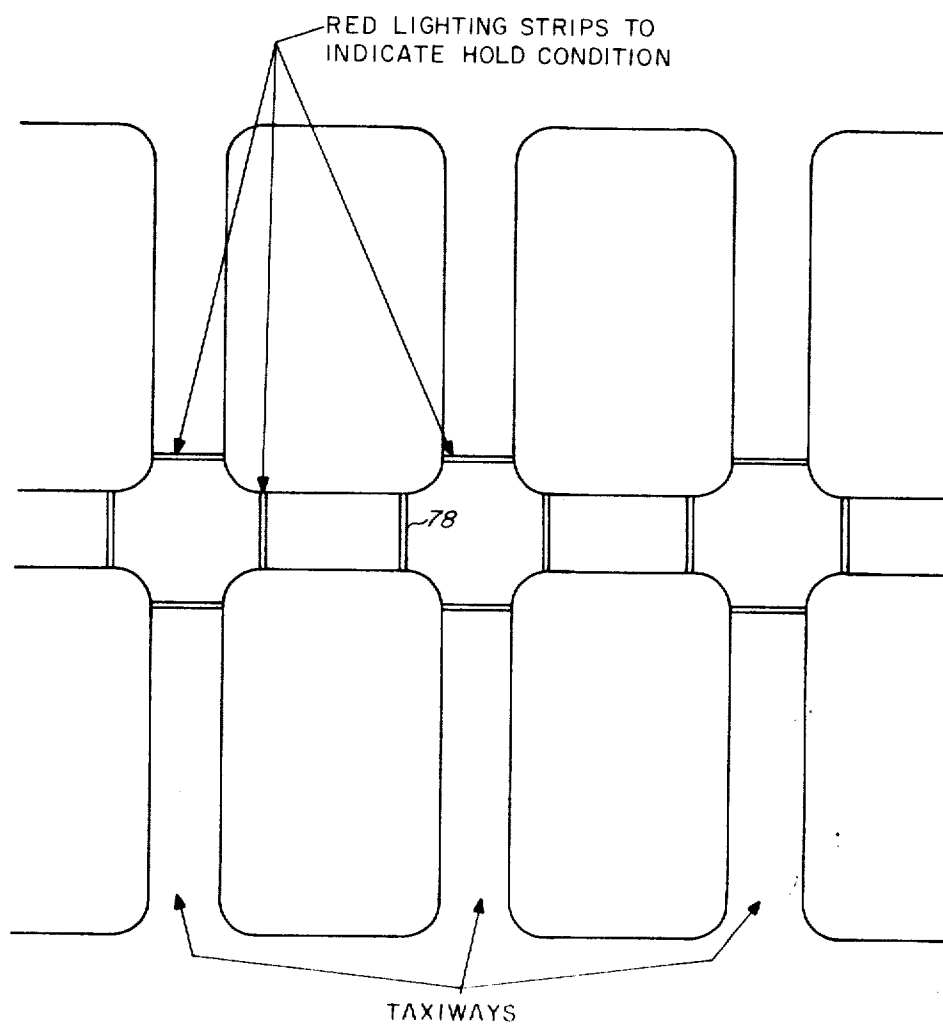
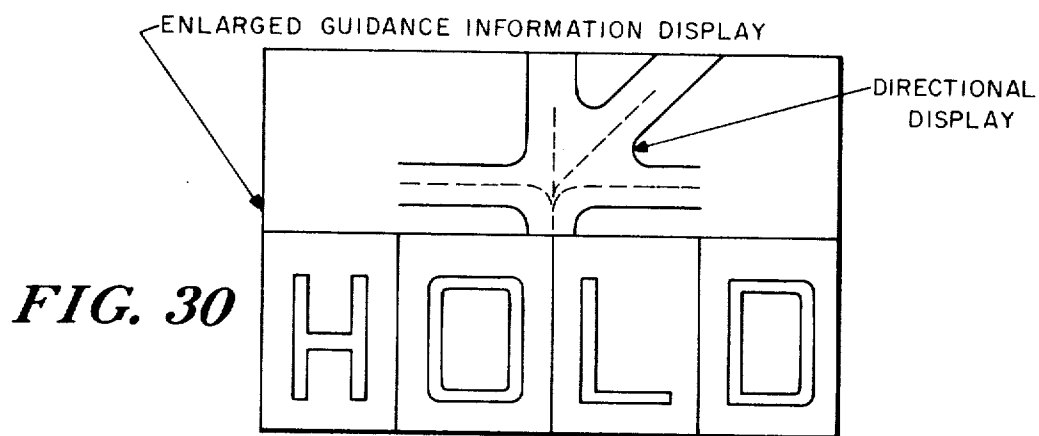


FIG. 29



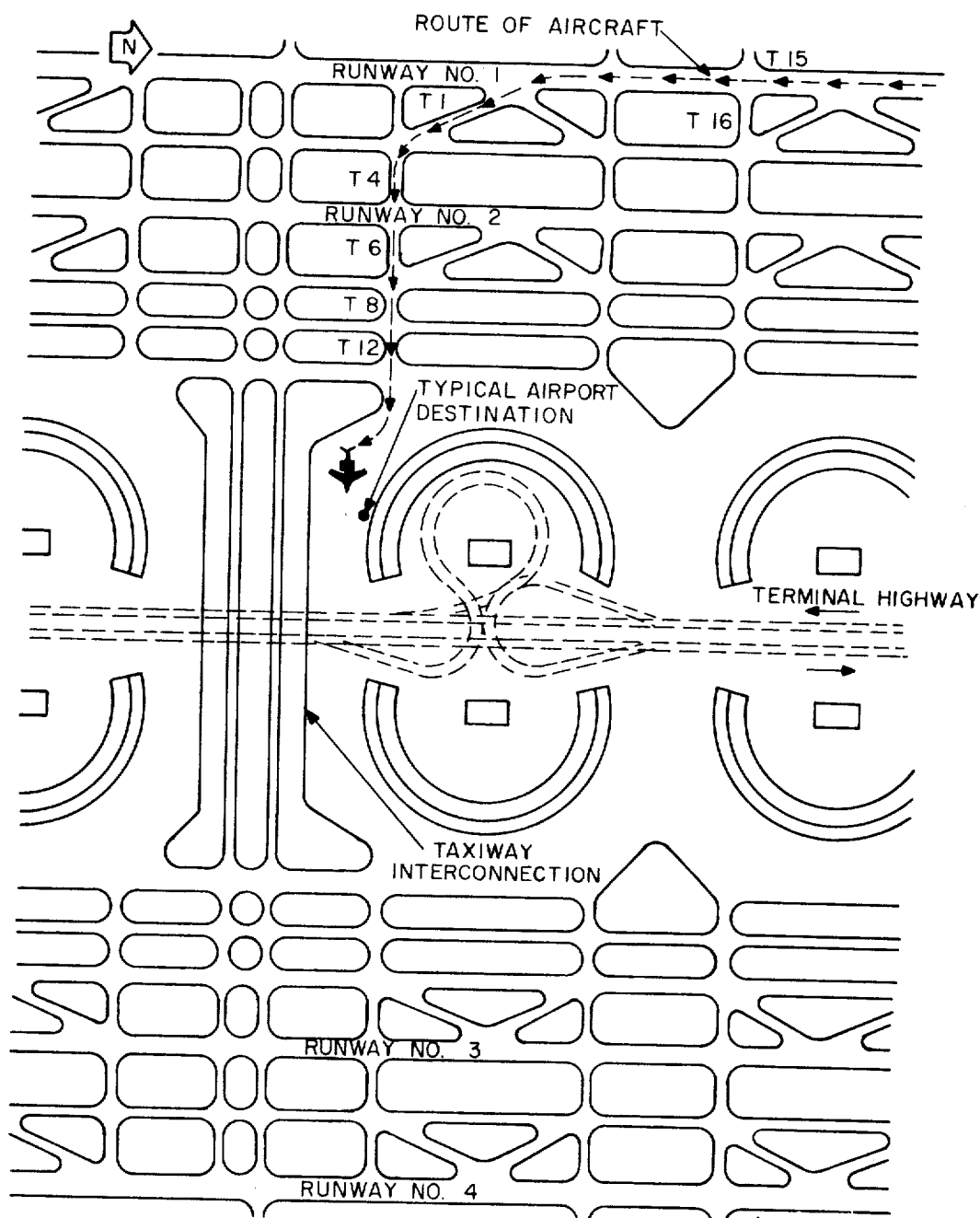


FIG. 32

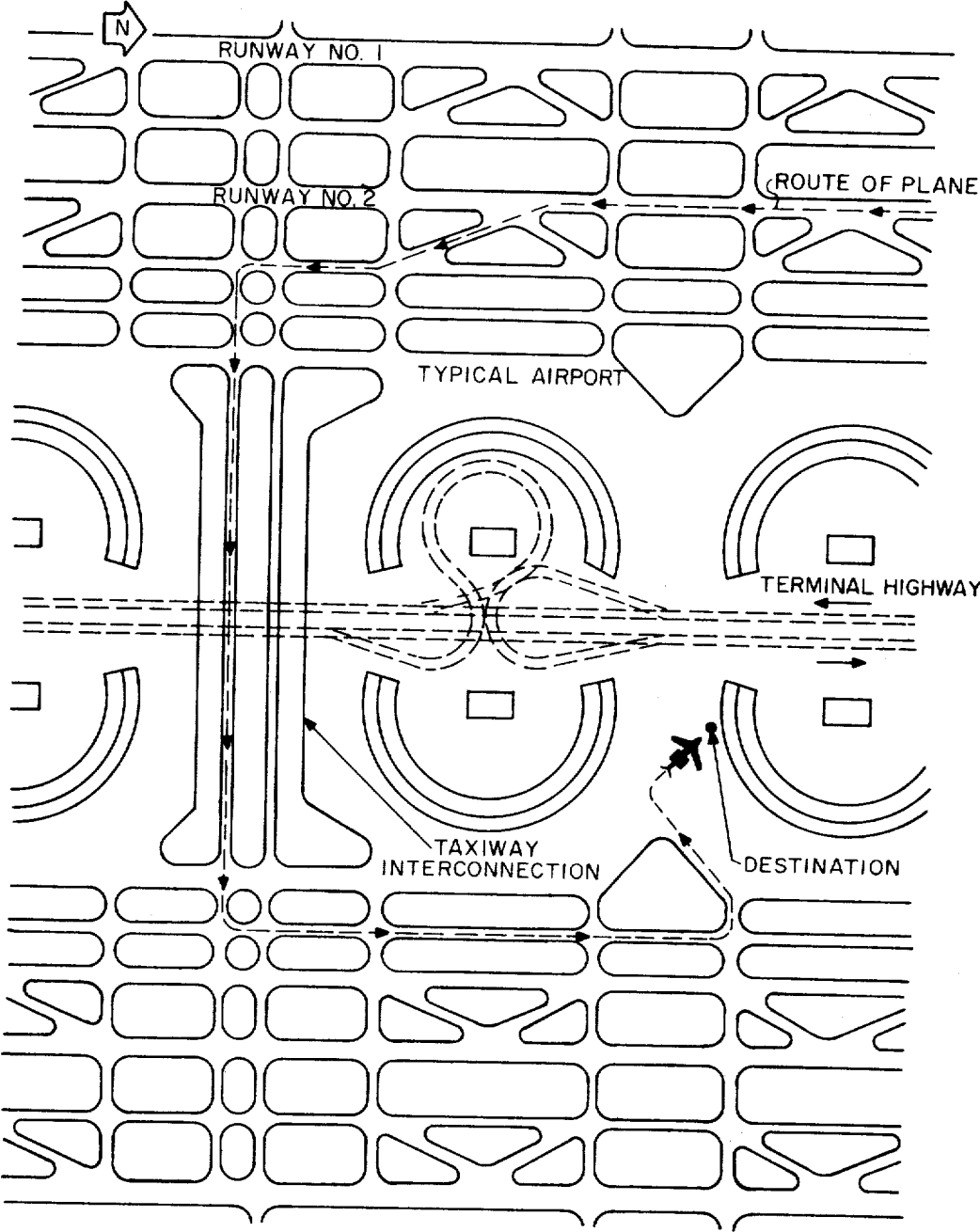


FIG. 33

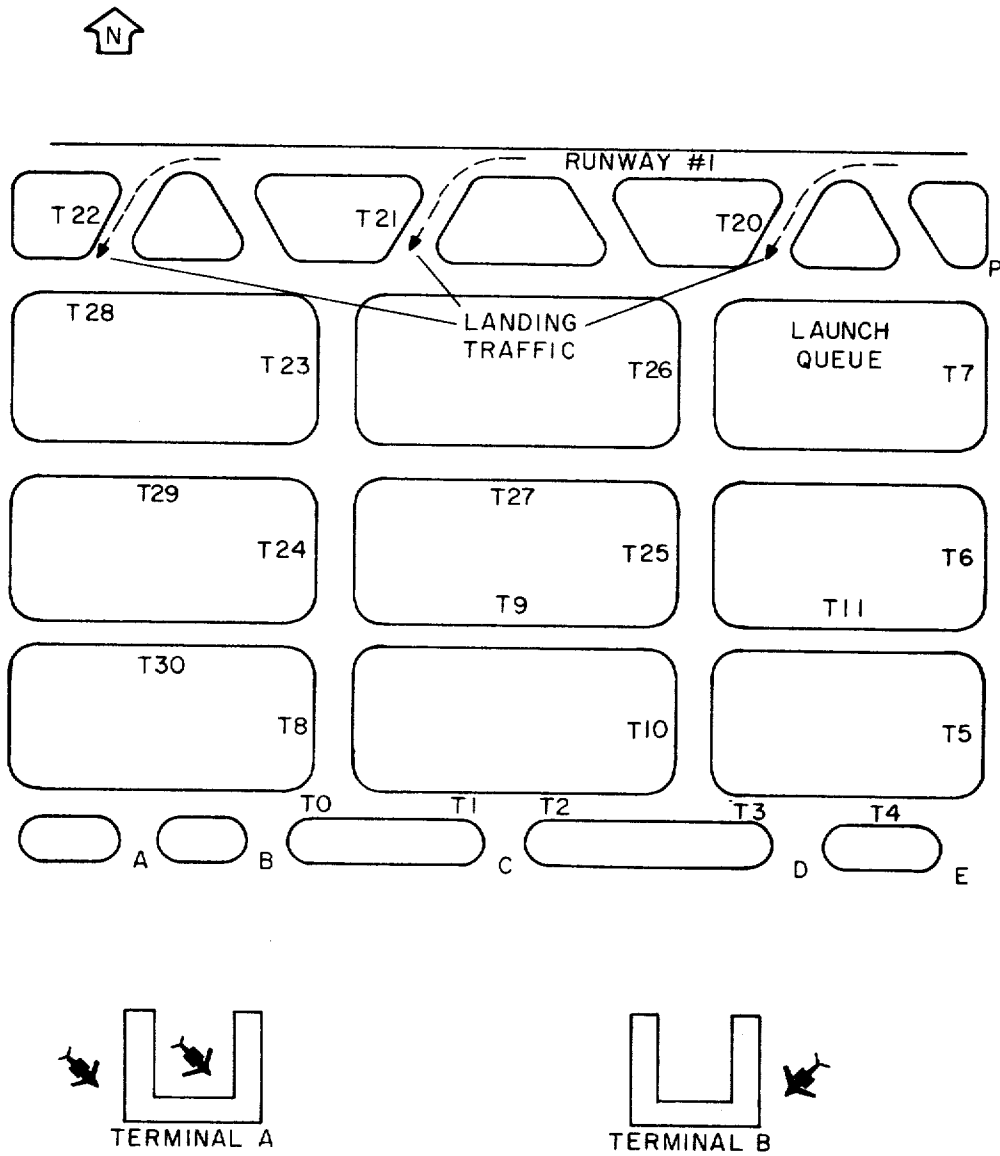


FIG. 34

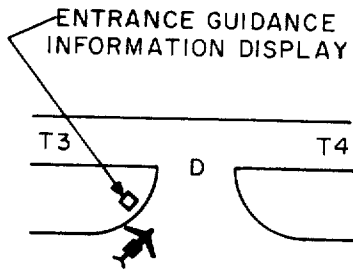


FIG. 35

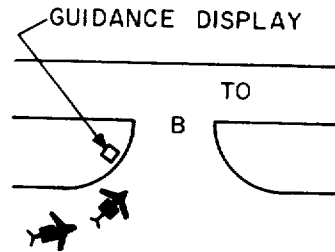
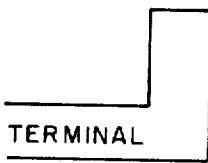


FIG. 36

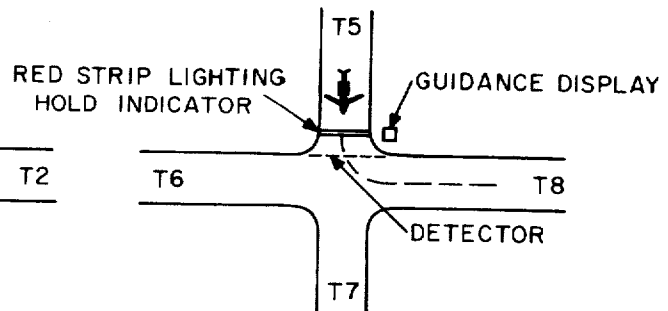
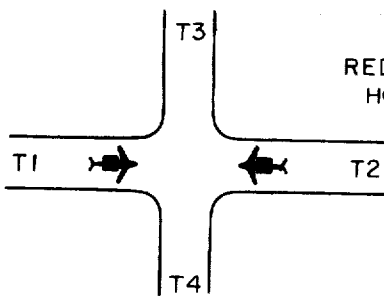
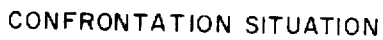


FIG. 37

FIG. 38

AIRPORT GROUND AIRCRAFT AUTOMATIC TAXI ROUTE SELECTING AND TRAFFIC CONTROL SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a continuation of application Ser. No. 827,292, filed May 23, 1969 and now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to surface traffic control systems, and more particularly to the automatic route selection and guidance of an individual vehicles, such as identified aircraft and automotive transports along such route across a network of ground ways of an airport.

In the past, airport ground traffic was managed by a person known as the ground controller who was stationed in the airport control tower. It was the ground controller's responsibility to advise and guide all ground traffic to keep it moving smoothly and safely. To do this effectively, the controller had to be able to see the taxiing planes and vehicular traffic, and constantly be aware of their locations and final destinations. During heavy traffic periods it was difficult for the ground controller to guide all planes; therefore, when a plane landed, he gave the pilot a general route to follow to his destination, and then it was up to the pilot to find his way either from memory or by following a taxiway map.

At night and during periods of low visibility, such personalized traffic control tended to break down. At such times, even pilots familiar with an airport needed guidance to their destination. Under such conditions, though it was difficult or actually impossible for the ground controller to see the planes and taxiways, he was required to guide them to their destinations.

Many air traffic control systems for automatically guiding air traffic in flight and while landing have been proposed in the past, such as that disclosed by U.S. Pat. No. 3,031,658, to Green et al., dated Apr. 24, 1962.

Furthermore, an electrical control system for controlling point-to-point movements of elevated vehicles riding on a rail track has been proposed by Midis et al, U.S. Pat. No. 3,263,625, dated Aug. 2, 1966.

A system for freeway access ramp traffic control is disclosed by U.S. Pat. No. 3,384,869, to Waldron, dated May 21, 1968; and a centralized digital traffic counting system for recording and control is proposed in U.S. Pat. No. 3,322,940 dated May 30, 1967 by Barker et al.

The prior art thus falls into three types: 1) Traffic ground control systems for highways and intersections; 2) Traffic air control for handling aircraft in flight or landing; 3) Traffic rail control of vehicles on tracks.

In the first type no provision was made for controlling any selected individual ground vehicle through a maze of intersections from a point of origin to a point of destination over a preselected route in a network of ways. In the second type, each plane, on landing, was taken over by the ground control personnel as noted above. And in the third type, the vehicles had to remain on the tracks or rails in moving from one station, or siding, to another. Thus, none of such types was concerned with the problems peculiar to ground traffic control in airports.

SUMMARY OF THE INVENTION

The present invention virtually eliminates such problems by locating identified aircraft on the ground by means of detectors on the ways, instead of by visual sightings; automatically keeping track of all ground traffic operating on the airport ways; generating a unique taxi route for each vehicle traveling on the ground across the airport; and directing the pilot by guidance display means at each traffic intersection whether his aircraft may enter and in which direction to proceed to attain his destination on the ground via such route.

The function of the detectors is to detect the presence of aircraft or other vehicles in the taxiways and runways. In most taxiways a detector is located at each end thereof. The detectors located in the runways preferably are positioned just before and just after each runway turnoff and each taxiway crossing. The inputs to the detectors are the presence of an aircraft or vehicles at such locations and the output is an electric signal sent to a ground logic unit associated with the taxiway or runway in which the detector is located.

A novel system is provided by the invention which automatically controls all airport traffic within the ground traffic controller's area of responsibility. The controller oversees the general operation of the system and furnishes it with information regarding each plane's identification (airline and flight number, or registration number), origin, and destination.

The preferred basic system of the invention is composed of at least one programmable digital computer, and a network of digital logic units. The computer generates automatically a selected route for each identified object (an aircraft on ground, for example), keeps track of such object's progress, in cooperation with the logic units which generate an appropriate advisory display at each intersection. The logic units automatically control traffic by such displays at the intersections in a manner somewhat similar to traffic lights at street intersections, but may include identification of the object to be guided so that the driver or pilot thereof is visually notified of the directions being applicable to his particular object. The logic units also act as an interface between the taxiway displays and the computer.

As soon as a plane is cleared to land, the ground traffic controller furnishes the computer with the plane's identification, the runway on which it is to land, and the terminal of destination. The so identified plane is picked up by the system as soon as the first runway detector is tripped and is tracked as the plane moves down the runway. The pilot is directed to turn off wherever he is able to do so. When he chooses a runway turnoff and proceeds onto it, a runway turnoff detector is tripped. Because the system now knows where the plane has turned off the runway, and it already knows the destination of the plane, the computer automatically generates a route, taking into account any restrictions placed on it by the ground controller.

The computer keeps track of the plane's progress by means of detectors on the ground. As the plane approaches an intersection and its presence is detected, information is layed to the computer and the local intersection control (ground logic). If the plane is the only one present at the intersection, the local control allows the computer to display the routing information

and the local control may allow the identification of the plane and an indication as to which direction it may turn.

If more than one plane arrives at an intersection at approximately the same time, the ground logic withholds the computer generated routing information for all but the first plane, while others are given a "Hold" signal. The local control receives information from the computer as to the programmed route (i.e., exit from the intersection) of the first plane, and if that route is clear, it allows the computer display the appropriate routing information to control all surface traffic on the taxiways of the airport with safety, efficiency and speed.

AIRPORT SYSTEM

The invention thus serves to safely manage the movement of all surface traffic within the ground traffic controller's area of responsibility. The latter oversees operation of the entire system and, as pointed out above, furnishes it with information regarding aircraft identification (airline and flight number, or registration number), origin, and destination.

The system preferably comprises the following major elements: (1) detectors in the taxiways and runways to identify the presence of aircraft thereon, (2) guidance information media to convey routing information to pilots or vehicle drivers, (3) a programmable digital computer which generates the route for each aircraft and keeps track of its progress, and includes off-line storage means, (4) digital ground logic units which are the heart of the system and interface with each of the other elements, (5) a ground controller panel which serves as an interface between the ground controller and the rest of the system, (6) a display for providing current status and alarm information to the ground controller, and (7) a digital communications subsystem for interconnecting other subsystems. The ground logic units control each taxiway and intersection by the information they send to the guidance display media. In essence, the ground logic units make "go" "no-go" logical decisions on whether to allow an aircraft to proceed with a programmed maneuver. The decisions are based on routing information from the computer and signals from the detectors indicating aircraft locations.

The ground logic units control the traffic flow through each taxiway and intersection by means of the information that they send to the guidance media. The guidance devices, as their description denotes, are used for providing commands to the pilot of an aircraft on how to proceed to his destination (i.e., turn left, turn right, hold, etc.).

The following is a brief description of the operation:

When an aircraft is cleared to land on a particular runway, this information is passed from the tower controller to the ground traffic controller. The destination (terminal and gate number) is obtained from flight scheduler's controller well in advance of arrival time. The computer locates the aircraft's position after it touches down and crosses the runway detector.

The runway detectors are placed just before and just after each turnoff or taxiway crossing to notify the ground control system immediately of the clearance status of the runway. This is to expedite flow of traffic that is crossing the runway. It should be noted that

the reason for locating a detector just before and just after taxiway crossing or turnoff is to enable the system to determine when the aircraft that is being serviced by the runway has moved past a given taxiway or turnway turnoff. The two detectors allow the system to operate with aircraft moving in either direction along the runway.

As soon as the aircraft leaves the runway and trips a runway turnoff entrance detector, this point of entry along with the destination are used to generate an optimum route for the identified aircraft to follow. When generating the route, any restriction placed by the ground controller are taken into consideration.

The computer keeps track of the aircraft's progress by means of the detectors. As the aircraft approaches an intersection and its presence is detected, information is relayed to the computer and the local intersection control (ground logic). If the aircraft is the only one present at the intersection, the local control allows the display of the routing information and an indication as to which direction to proceed.

If more than one aircraft arrives at an intersection at approximately the same time, the ground logic withholds the computer generated routing information for all but the first aircraft while others are given a "Hold" signal. The local control receives information from the computer as to the programmed route (i.e., exit from the intersection) of the first aircraft, and if that route is clear, allows the routing information to be displayed. As soon as the aircraft clears the intersection, the local control looks at the programmed path of the next aircraft, and if it is clear, allows it to proceed. If the programmed route of the first aircraft is occupied by another aircraft, the local control holds the first aircraft, and allows the second aircraft to proceed first, if its route is clear.

The aircraft proceeds under computer guidance until it reaches the apron area near its destination. At this point, the ramp agent assumes responsibility for directing the aircraft to the proper gate.

The basic procedure is the same for aircraft that are leaving the terminal to take off except that the entrance into the controlled area is the throat of the apron and the destination the takeoff queue.

Regarding movement from terminal to maintenance or between any other two points, the only information the system requires is the entry and exit points of the aircraft.

Vehicular traffic is handled by the system in the same manner as an aircraft (i.e., identification of the vehicle, and its origin and destination are furnished to the computer and the computer guides it through the controlled area) or the computer may just disregard any vehicle which it can not identify. But in either case, a vehicle would still come under the control of the ground logic elements of the system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a digital computerized ground traffic control system illustrative of the invention for a typical airport;

FIG. 2 is a simplified block diagram of a preferred system;

FIG. 3 is a block diagram of a modification;

FIG. 4 is a more complete block diagram of the invention showing the relationship between the circuits in the control tower and field, respectively;

FIG. 5 is a simplified map of a portion of the ground layout of such airport;

FIGS. 6 through 12 are plan views of preferred control instructions for the computer;

FIG. 13(A) is one half of a block diagram of an example of the taxiway logic system of one unit;

FIG. 13(B) is the other half thereof;

FIG. 14 is a plan view of a typical intersection showing the locations of the detectors;

FIG. 15 is a block diagram of interconnected logic units;

FIG. 16 is a diagram of the intersection logic for detecting confrontation situations;

FIG. 17 is a diagram of ground logic for controlling taxiways that intersect runways;

FIG. 18 is a plan view of a taxiway-runway intersection;

FIG. 19 is a diagram illustrating ground logic for controlling high speed runway turnoffs;

FIG. 20 is a plan view of a high speed runway turnoff;

FIG. 21 is a fragmentary plan view of the airport layout;

FIG. 22 is a view in front elevation of a directional display;

FIG. 23 is a view in elevation of an alphanumeric character of such display;

FIG. 24 is a plan view of aircraft parked and waiting to enter an apron throat;

FIG. 25 is a plan view of a high speed runoff layout.

FIG. 26 is a front elevation view of a guidance display for the high speed runoff shown in FIG. 25;

FIG. 27 is a plan view of centerline lighting guidance at runway turnoffs;

FIG. 28 is a similar view of off runway locations of guidance display of aircraft identification;

FIG. 29 is a plan view of a taxiway and guidance displays;

FIG. 30 is a front elevation view of one of the guidance display signs shown in FIG. 29 therefor;

FIG. 31 is a plan view of a layout of taxiway intersections provided with lighting strips to indicate a "Hold" condition;

FIG. 32 is a plan view of a typical airport layout illustrating an example of the operation of the system;

FIG. 33 is a similar view of a modification;

FIG. 34 is a plan view of a portion of the airport layout, illustrating guidance of aircraft to takeoff queue; and

FIGS. 35 through 38 are plan views of several guidance display situations.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fully Computerized System (FIG. 1)

A fully computerized airport ground traffic control system incorporates a single central digital computer 10 having all major responsibilities of the system including management, guidance and safety. Connected to the computer 10 are information supply circuits from a control panel 11 for the ground controller, detectors 12, and outputs to a recorder 20 for off line storage, a route guidance circuit 14 and a display 15 for the

ground controller. Panel 15 is a map of the ground controlled area with each taxiway, runway, intersection, and apron throat marked by lighted segments which are turned off and on by output signals from the computer 10. One modification to this type of panel would be to light each segment while it is seized for use by an aircraft or vehicle. A second modification would be to keep all areas dark except those in which the ground controller has a special interest. Special interest areas might include aircraft crossing a runway, aircraft that has violated a ground signal command, etc. The present system is compatible with either of the above modifications.

The recorder 20 records events, such as identification of each aircraft admitted into the ground control system, the route array associated with such aircraft, and also violations in case the aircraft, for example, violated a guidance signal.

PREFERRED SYSTEM

The preferred concept however, differs from FIG. 1. In lieu of one large central digital computer, the preferred system, FIG. 2, utilizes one or more digital computers 16 interconnected to a separate network of units of ground logic 17. In addition to the control panel 11, each computer 16 is provided with a display 15. The function of the digital computer 16 is to provide traffic flow management.

The local ground logic unit serves to provide guidance and safety through individual detectors 18 and guidance taxiway displays 19. Using this concept, loss of a computer 16 because of a malfunction does not render the total system inoperative. Instead, traffic is still able to move in a safe manner either under the direction of the ground controller himself by information applied through the ground control panel to the ground logic 17, FIG. 3, or by the latter alone. Traffic movement under such circumstances, however, is somewhat less efficient than with the computer operative.

With regard to the use of one or more digital computers 16, in some of the larger airports, the taxiway and runway layout may easily be divided into two or more smaller, interconnected control zones. The present system provides the option of using one digital computer for each one of the smaller control zones. Since the probability of more than one computer malfunctioning at the same time is less than the probability of a signal central computer malfunction, the net effect is to decrease the probability of total computer loss for the entire ground controlled area.

There are numerous devices for detecting the presence of an aircraft, or other vehicle, on the ground. Among these are included the inductive loop, pressure pad and infrared methods. There are also numerous means for supplying route information to the pilot, such as radio, radar, bullhorn, or visual guidance displays; as well as by taxiway lighting, including centerline lighting. The present invention is compatible with any one, or a combination, of such methods, or any other method which may be desired.

Future requirements for airport ground control systems will undoubtedly be very stringent. The only constraints on the present invention will be the state of the art in methods of detection and methods of display of route information.

AIRPORT SYSTEM

Located in the control tower 20, FIG. 4, of the airport 22 is a digital computer 16 which is connected to a buffer unit comprising a digital communication system 24 to which information is fed by an input from the control panel 11 supplied by the ground controller in the form of punched cards, tape or typewritten matter.

Located on the airport traffic arteries and adjacent the intersections thereof are the ground logic circuit units 17, each provided with detectors 18, and traffic control displays 19. For simplicity only one of each is shown in FIG. 4, together with a taxiing plane 28, approaching detector 18 on a runway 30, leading to an intersection 31 with a crossing taxiway 32. The ground logic circuit unit 17 is electrically interconnected to the digital communication subsystem 24.

To eliminate the need for full time human intervention, and also to provide selective automatic routing, an on-line digital computer 16 is preferred. The computer 16 functions: 1) to select automatically a route from entry point into the controlled area to the destination point; 2) to track the aircraft or vehicle as it moves through such area; and 3) to communicate route information to the ground logic. The choice of computers depends largely upon the size of the airport. The computer selected for a particular installation should have adequate capacity to handle present and future needs.

A display 15 for the ground controller of the airport layout and routes selected by the computer 16, is connected to the subsystem 24, as is an off-line storage (recorder) 20, such as a magnetic tape unit, for recording the operation of the system, if desired, as well the entry of each aircraft to the system, its selected route array, and violations, if any.

The digital computer 16 has various criteria stored within its memory so that when it receives information which indicates that a plane has arrived at a particular runway turnoff, it takes this information, together with the required destination information, and with minimal delay automatically "maps out" a selected route for plane to reach its destination. Provisions are also included for the control of vehicular traffic. As an option it is recommended that a continuous record of each designated taxi plan be kept by the recorder 20 for analysis in the event of a plane or vehicle carries out an unauthorized deviation from the planned route.

The computer receives information from taxiway intersections, the control tower, and other related sources. A typical example of the latter type of information is that received from temporary obstructions caused by taxiway or runway maintenance. This information is considered as dynamic because it is always changing.

Other information, which is considered as passive, is related to the layout of the runways, taxiways, terminal area and hanger areas. This information provides the basis for deciding the optimum path for the plane or vehicle along the ground.

OPERATION

The system functions as follows:

1. Landing Aircraft

A. When an aircraft is known to be on final approach, the tower controller provides the ground controller with the aircraft identification (flight

number) and the runway that it is to use for landing. Sometime prior to this, the ground controller will have received the assigned destination (gate number) from the appropriate scheduling authority. The ground controller enters into the computer 16 the flight number, runway number, and the destination. (The destination as far as the ground control system is concerned is the entrance or throat of the apron that services the terminal and gate area to which it is proceeding.) At the apron throat, responsibility for directing the aircraft is yielded to the ramp agent.

B. The digital computer 16 interprets the signal from the first runway detector 18 that is tripped after the aircraft 28 touches down on the runway 30. The aircraft's progress is automatically tracked by the system as it moves down the runway.

C. After completing its rollout, the aircraft 28 turns off the runway 30 at some intersection 31 which is not determined in advance. As the aircraft 28 enters the turnoff 38 from the runway 30, it crosses a runway turnoff detector 18 which immediately and automatically informs associated ground logic 17. The ground logic 28, in turn, notifies the computer 16 by way of the digital communication subsystem as to which runway turnoff is the entrance into the controlled area.

D. Upon receiving this information, the computer 16 analyzes the current taxiway traffic situation and decides the selected path for the aircraft to reach its ground destination.

E. Bidirectional communication between the computer 16 and ground logic 17 enables the computer 16 to track the progress of the aircraft as well as inform the ground logic how to direct the aircraft 28 along the selected path.

2. Aircraft Moving to Takeoff Queue from Terminal

A. When an aircraft is ready for takeoff, a request for clearance is made by voice communication with the ground controller. At this time, the ground controller enters into the digital computer 16 the aircraft number, point of entry into the area supervised by the ground control system, and destination (takeoff queue). The computer then automatically determines the route for the aircraft to follow.

B. When the aircraft has reached the point of entrance into the area supervised by the ground control system (this will be the throat of the apron that services the terminal and gate area from which he has come), the pilot contacts the ground controller.

C. The ground controller inputs an admit command into the computer 16 which signals the ground control system that the aircraft is ready to be admitted.

D. The ground control system via the ground logic 17 and guidance displays 19 admits the aircraft and guides it under the direction of the computer 16 to the takeoff queue.

TYPICAL AIRPORT LAYOUT

A simplified typical airport layout, as shown in FIG. 5, turnoff 38 from runway 30 leads to a taxiway 40 which parallel such runway. Entrance and exit ways 42

and 44 lead to and from apron 46 of terminal 48 and taxiway 40, as shown.

SOFTWARE

The software, FIGS. 6-12, includes subroutines and associated control instructions (lists) that enable the computer to perform specific tasks at the request of various types of inputs.

1. Data Base (Resident)

- A. Runway List - List 50, FIG. 6, contains codes of each runway and the codes of all turnoffs associated with each runway.
- B. Runway Detector List - List 52, FIG. 7, contains codes of each runway, including the codes of detectors located in each runway.
- C. Coordinate List - List 54, FIG. 8, contains codes of all intersections, runway turnoffs, and apron throats.
- D. Taxiway List - List 56, FIG. 9, of codes of all taxiways, intersections, runway turnoffs, and apron throats. Associated with each of the aforementioned sections are the codes of all sections which can be entered from the given section.

2. Data Base (Generated)

- A. Route Arrays 58, FIG. 10.
- B. Runway Tracking Lists 60, FIG. 11.
- C. Violation Arrays 62, FIG. 12.

NOTE: These will be explained in detail later.

3. Subroutines

A. Service Inputs from ground controller including:

- 1. Aircraft Number, Runway Number, Destination.
- 2. Aircraft Number, Apron Throat Number, Destination (Takeoff Queue).
- 3. Admit Command.
- 4. Clearance to Cross Runway.
- 5. Clear Violation Array.

B. Service Inputs from Ground Logic including:

- 1. First runway detector tripped.
- 2. Runway turnoff entrance detector tripped.
- 3. Clear signal from taxiway.
- 4. Taxiway detector tripped.
- 5. Alarm - Hold signal violated.
- 6. Alarm - Confrontation situation.
- 7. Aircraft has entered from apron throat.

C. Other

- (1) Route generator.
- (2) Generate output signals to ground controller display panel. (a) Hold signal violation. (b) Aircraft crossing runway
- (3) Transfer data to magnetic tape unit.

SOFTWARE RESPONSE

The software responds to given inputs, as follows:

1. Input from ground controller containing runway number, flight number, and destination point.

Stored in memory is each runway number and a list of possible points of entry into the controlled area from that particular runway. The computer takes the input runway number and uses it to locate the appropriate list. Signals are sent to the ground logic controlling each runway turnoff included in the list informing them that they may be entry points. The ground logic units control these taxiways and do not allow them to be entered by other aircraft.

The computer receives a signal from the first runway detector that is tripped after the aircraft touches down. A sequential list of the codes of runway detectors as they will be tripped is developed. This list is referred to as Runway Tracking List. Associated with the list will be a position register and position pointer. The code of the runway detector that was first tripped is entered into the position register and the code of the next runway detector to be tripped is loaded into the position pointer. When the aircraft trips the next detector, the position register is updated with the detector code from the position pointer and the next detector code in the list is placed in the position pointer. Thus the position register contains information regarding current position and the information in the position pointer points to the next area to be entered. In this manner, the aircraft is tracked as it moves down the runway.

The detectors are located before and after each taxiway crossing and each runway turnoff; therefore, the system can determine when the landing aircraft has moved past a given runway turnoff. If the turnoff passed is one that was originally seized as a possible exit, the seize signal from the computer is removed. Also, as the aircraft moves past taxiways that cross the runway, the computer signal to the ground logic controlling these taxiways, indicating that the runway is seized is removed.

2. Input from ground logic that an aircraft has tripped the entrance detector in one of the specified runway turnoffs.

If the computer is still sending signals to other runway turnoffs, indicating that they may be possible entry points, then these signals are revoked.

The computer uses this runway turnoff as the origin and calls a subroutine to generate the route for the aircraft to follow to its destination. This subroutine will be discussed later. The route is in the form of a sequential list of taxiway codes. This list, along with the specified flight number, is stored in a designated area of memory and is hereinafter referred to as the Route Array. Associated with the Route Array is a position register and a position pointer. As soon as the Route Array is generated (which is done in a fraction of a second), the position register is loaded with the number of the runway turnoff. The position pointer is loaded with the number of the next taxiway to be entered. A signal is then sent to the ground logic unit associated with the taxiway whose code is in the position pointer (this is the next taxiway in the Route Array sequence) notifying that this taxiway is to be entered.

As will be explained in the ground logic section, the ground logic determines when the next taxiway is available. It then controls the taxiway so that it cannot be occupied by anyone else, notifies the pilot to proceed, and also notifies the computer.

3. Input from ground logic that a certain taxiway is to be cleared.

The computer searches the position registers until it finds the one that contains the same code as the taxiway that has signaled to be cleared. Then the code in the position pointer is shifted into the position register, and the next taxiway code from the Route Array is shifted into the position pointer. The aircraft now proceeds to the next taxiway and upon entrance trips the taxiway detector.

4. Input from ground logic that a specified taxiway detector has been tripped.

The computer searches through the position registers until it finds the one that contains the code of the specified taxiway whose detector has just been tripped. The position pointer is interrogated for the code of the next taxiway, and a signal containing this information is sent back to the ground logic controlling the specified taxiway. Again, the computer time required to do this is only a fraction of a second.

As explained previously, the ground logic determines when the next taxiway is available. It then controls the taxiway so that it cannot be occupied by anyone else, notifies the pilot when and how to proceed, and also notifies the computer. This cycle is repeated until the aircraft reaches its destination. When the code of the point of destination is moved into the position register, the system has finished tracking this particular aircraft, and the Route Array memory locations are opened for use by other aircraft.

5. Input from ground controller containing flight number, point of entry into area supervised by Ground Control System (apron throat), destination (takeoff queue).

A Route Array is generated (with associated position register and position pointer), and the position register is loaded with the particular code of the apron throat through which the aircraft will move. As soon as the aircraft reaches such apron throat, he notifies the ground controller by voice communication that the pilot is in position. The ground controller then inserts an Admit Command.

6. Admit Command input from Ground Controller.

The Admit Command contains the aircraft flight number and a special code which designates it as an Admit Command. The computer accepts this command, interprets the admit code, and sends a signal to the ground logic informing it that the aircraft is cleared to enter the controlled area and which taxiway is to be entered. (This taxiway code is now in the position pointer.)

As soon as the taxiway is clear, it is seized by the ground logic, the pilot is notified to proceed, and the computer is notified.

7. Input from ground logic that an aircraft has moved from a parking position near apron throat into the ground controlled area.

The computer searches until it finds the position register that contains the code of the apron throat from which the aircraft is leaving. The contents of the position pointer are shifted into the position register and the code of the next taxiway from the Route Array is shifted into the position pointer.

When the aircraft trips the detector as it moves into he taxiway, a signal is sent to the computer. The computer services this signal as outlined in Point 4 preceding.

8. Input from ground logic that an aircraft has violated a hold signal.

The computer decodes this input and determines the taxiway and intersection where the violation has occurred. All taxiways which feed this intersection are placed into an array called a Violation Array. An output is sent to the ground controller display designating the specific taxiway in question and related intersec-

tion. Also, override signals are sent to the ground logic controlling each taxiway that is included in the Violation Array. These signals direct the ground logic to cause a hold signal to be displayed at the associated guidance displays.

As soon as the situation has been cleared, the ground controller inputs a command to release the override hold signals.

9. Input from Ground Control to clear the Violation Array.

The command is decoded and override signals to all the taxiways listed in the Violation Array are revoked.

SUBROUTINE TO GENERATE ROUTE

This subroutine develops a sequential list of taxiway codes which defines the shortest path from a given entrance point into the controlled area, and on to a specified exit point. The entrance point and exit points are defined by input information.

Each intersection in the controlled area is given an identification code. The physical relationships between intersections are defined by establishing a reference point and determining the X and Y coordinates of each intersection with respect to this point. The entry and exit points are treated as intersections, and a list is stored in memory which contains the identification code of each intersection, runway turnoff, or apron throat in their associated X, Y coordinates. This list is referred to as the Coordinate List.

A second list, referred to as the Taxiway List, is stored in memory. The first element in each entry of the Taxiway List is the code of a taxiway or intersection. The other elements of the entry are the codes of all taxiways or intersections that can be reached from the taxiway or intersection coded as the first element of the entry.

The code of the point of entrance into the controlled area (hereinafter referred to as A) is input information. The computer searches the Taxiway List to find the entry whose first element has the same code as A. This entry contains the codes of all intersections which can be reached from A. One by one the codes of each of these intersections is used to find its corresponding X, Y coordinates from the Coordinate List. The distance between each of these intersections and exit point is calculated. After all intersections that can be reached from A have been checked, the one closest to the exit point is chosen as the next intersection for the Route Array.

The intersection is then analyzed just as point A was analyzed, and another new addition is made to the Route Array. This procedure is repeated until an intersection is reached that has a taxiway connection to the exit point. As described previously, the sequential list of intersections from entry point to the exit point constitutes the Route Array.

There may be situations where the route generation technique just described may be modified to include some routes which are prefixed. The reason that a prefixed route might be used in lieu of the shortest distance method is in order to cause traffic flow to conform to a specified pattern.

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GROUND LOGIC

The ground logic network is used to (1) detect the presence of an aircraft or vehicle by receiving a signal from the taxiway or runway detector, (2) determine whether it is safe for the aircraft or vehicle to proceed, and to (3) display the appropriate message to the pilot or driver. In essence, the ground logic is used to reduce the workload on the computer.

With respect to the ground logic the following assumptions and definitions apply:

1. Taxiway section (T): Any section of taxiway between two intersections (I).
2. Taxiway Logic: The logic associated with one section (T) of taxiway.
3. Intersection logic: The combination of taxiway logic units for all taxiways T entering an intersection I.
4. Taxiway sections T may handle traffic in both directions, but only one direction at a time.
5. Each taxiway section T is occupied by only one plane at a time.
6. Cases other than defined by items 4 and 5 will be treated as special cases.

Ground logic refers to the interconnected system of all the identical taxiway logic units; a logic diagram of one unit is shown in FIG. 13 (A & B) using the taxiway and intersection detector locations shown in FIG. 14. Several of these taxiway logic units are located at selected intersections to form intersection logic units. This helps to minimize the amount of interconnecting wiring; an example of this is shown in FIG. 15, again with the taxiway and intersection detectors located as shown in FIG. 14.

Each intersection logic unit receives inputs from surrounding taxiway detectors, the computer, and the surrounding intersection logic units. The unit transmits output information to the computer, all surrounding intersection logic units, and the display units.

1. Important Features of Taxiway Ground Logic

- A. The signal from the taxiway detectors is used only to indicate the presence of an aircraft in a taxiway section; therefore, this signal has only one meaning an aircraft is occupying that section.
- B. Each taxiway has a detector located at both ends which enables the ground logic to determine the direction of travel. It does this by setting a memory device associated with the detector which is first tripped as the aircraft enters the taxiway. For example, when a signal is received from a detector (assume this to be Detector No. 1 FIG. 14), the ground logic FIG. 15 checks to see if the detector at the other end of the taxiway (Detector No. 2) has been tripped previously. If not, a memory device associated with Detector No. 1 is set, or the direction may be determined by the detectors themselves.
- C. Clearance to proceed is given only after ascertaining that the section to be entered is not occupied and is not going to be occupied from another direction by an aircraft or vehicle. Once clearance is given, all surrounding logic units are notified that the intersection and taxiway section in question are going to be occupied.
- D. If the computer is not operating, or if a vehicle enters the controlled area without having been en-

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tered in the computer, the ground logic still detects its presence. In this case, it gives clearance to proceed along all unoccupied paths leaving the intersection. If the desired path is not among these and the vehicle does not proceed, clearance is revoked after a time and other taxiway sections around the particular intersection are given clearance.

- E. As an aircraft is cleared from a taxiway section, the logic for that section clears the intersection for use by the other taxiways in rotation. In this manner, traffic is kept moving on all taxiways. In special cases, this can be modified to allow certain taxiways priority in terms of rotation; that is, the ground logic is capable of being programmed to the intersection priority requirements.
- F. In the unlikely event that two aircraft at an intersection were blocking each others' paths (a confrontation situation), the logic notifies the computer so that it can reroute one of the planes. FIG. 16 is a logic diagram of intersection hardware required to perform this function.

TYPICAL TAXIWAY GROUND LOGIC CONTROLLING AN INTERSECTION

Following is a description of the operation of the ground logic for a typical intersection as shown in FIG. 14. Assume that an aircraft has entered taxiway section T4 from intersection I2, and that the computer desires to direct the aircraft to make a right turn into taxiway section T2.

The section T4 logic receives information from section T2 as to whether or not it is occupied, or is going to be occupied from another direction. It also receives information from sections T1, T2, and T3 as to whether any aircraft from those sections are occupying intersection I1. If intersection I1 and taxiway section T2 are clear, the aircraft in section T4 is given the go-ahead to proceed and make a right turn. At the same time, the T4 logic notifies sections T1, T2, and T3 that intersection I1 is occupied and taxiway section T2 that it is going to be occupied.

If section T2 is already occupied or is going to be occupied from some other directions, or if the intersection I1 is occupied from one of the other taxiways, the aircraft in section T4 is given a hold signal. The hold signal is displayed until both the intersection I1 and taxiway section T2 are clear.

It should be noted that the events described in the preceding paragraphs take place in a fraction of a second after the aircraft has crossed the taxiway detector T4 so that the pilot is informed well in advance whether he should stop, go straight, or turn.

Once the pilot is given the signal to make his turn, the aircraft, in effect, occupies the taxiway sections T2 and T4, and intersection I1. This prevents any other aircraft from entering these areas. At the same time the pilot is given the turn signal, the computer is notified that the aircraft is leaving section T4 and, in turn, notifies the logic in section T2 as to the aircraft's next move.

As soon as the aircraft crosses the first detector in taxiway section T2, its presence is cleared from taxiway section T4, and the logic in section T2 goes through the same procedure as described for section T4. The logic

in section T4 sequentially clears intersection I1 to taxiway sections T1, T2, and T3. In this manner the aircraft passes from section to section as directed by the computer.

If the aircraft enters a section and the computer has not indicated a path leaving the intersection, the logic looks at all possible paths and then gives the aircraft the go-ahead for all unoccupied ones. The logic then proceed as described in the preceding paragraphs and notifies the sections involved that an aircraft is going to occupy them. If the path desired by the pilot has not been cleared, he may wait. In this case, the clearance is withdrawn and the other sections are cleared in sequence as described previously. When the sequence again comes to taxiway section T4 the aircraft in that section is again given clearance for all unoccupied paths. This continues until the path desired by the pilot is clear or he proceeds along one of the others.

EXAMPLE GROUND LOGIC SIGNAL FLOW

Assume that an aircraft is entering taxiway T10, FIG. 14. When it enters, a detector will be tripped. The signal from the tripped detector is sent to the computer to be processed. The resulting signal that is sent back from the computer informs the logic associated with T10 that the next taxiway to be entered is T4.

1. If T4 is clear, T10 will send a signal (S1) to T4 logic indicating that T4 is to be entered next, (See FIG. 13A).

2. Signal (S1) is fed into gates. These gates are "OR" gates which means that if a signal is applied to input No. 1, or No. 2, or No. 3, etc., then an output signal will be generated, and thus with (S1) as an input, signals (S6) and (S7) are generated. These signals go to the logic associated with taxiways T1, T2, T3, T10, T11, T12 and inform them that T4 has been seized.

3. When the aircraft turns into taxiway T4, detector D1 will be tripped which creates signal (S8), which feeds into the input of gate G7. At this time, there will be no signal from (S30). This means there will be a signal (S9) from the output of gate G8. The reason for this is because gate G8 is a "NOR" gate with only one input. The gate creates an output of an input signal. When an input signal is applied, then the output signal ceases.

4. Gate G7 is an "AND" gate which means that when signals (S8) and (S9) are applied simultaneously, then the output signal (S10) will be created. (S10) feeds the set (S) input of flip-flop (FF1). When a signal is applied to the (S) input an output signal (S11) is generated from the Q2 side. This signal will remain until a signal is applied to the reset (R) input.

5. The signal (S11) from the Q2 output is sent to the computer and also is input to time delay (TD1).

6. The computer processes signal (S11) and sends back signal (S12) indicating that the desired route is T2.

7. Signal (S12) is fed into "OR" gate G8, FIG. 13(B). This causes signal (S13) to be created which feeds one input of gate G9.

8. At this point, a signal (S14) will be developed at the output of time delay (TD1). This signal will be fed into the inputs of gates G10, G11, G12, G9, G14, G13, G16, G1, G15, G18, G17, G20, G19 FIG. 13B, and also feeds back into gates G1, G2, G3, G4, G5 and G6. If intersection I1, FIG. 14, is not currently occupied then

there will be no signals from T3 (S15) or T2 (S16) or T1 (S17) feeding into gate G21, with no input signals, output signal (S18) will be generated.

10. Signal (S18) feeds into gates G11, G9, G13.

11. If T2 is not occupied, there will be no signal (S19) feeding time delay (TD2) and thus no signal S20 feeding gate G22. G22 is a signal input "NOR" gate and with no input signal this means there will be an output signal (S21).

12. Signal (S21) feeds into gate G9. Now there are signals at all the inputs to gate G9. Since G9 is an "AND" gate, this condition will cause an output signal (S22).

13. Signal (S22) is routed to the logic associated with T2 as well as the computer. The signal indicates that T2 is to be occupied.

14. Signal (S22) also feeds through single shot to the guidance display serving taxiway T4 at intersection

11. This causes a right turn signal to be displayed by the guidance display to the pilot.

TYPICAL SIGNAL FLOW THROUGH LOGIC GATES (FIG. 16)

As can be seen from FIG. 1, an aircraft in taxiway T1 and his desired route is taxiway T3, and at the same time an aircraft is in T3 and his desired route is T1, then an alarm will be generated as follows:

A signal (1) comes from the computer to T3 ground logic indicating that the desired route is T1. Also signal (2) comes from the computer to T1 indicating that the desired route is T3. If both of these signals are input to gate A simultaneously, an output signal (3) will be generated by gate A. The output signal (3) will exist only as long as the two input signals are applied to the input. If either signal (1 or 2) is removed, then the output signal will cease.

NOTE: Gate A is an "AND" gate because it takes signals at inputs 1 "AND" 2 simultaneously to produce an output at 3.

2. Features of Special Ground Logic

A. Typical ground logic operation for control of taxiways that intersect runways.

1. FIG. 17 is a logic diagram of the circuit provided to control a taxiway which intersects with a runway. The control of traffic crossing a runway is different from that in a normal taxiway, and thus, the ground logic is designed differently. FIG. 18 shows a taxiway that crosses a runway. As far as the ground logic is concerned both taxiways T6 and T7 are treated as one taxiway. The reason for this is the only places that an aircraft is supposed to enter a duty runway is from the launch queue or possible intersection takeoff points. Therefore, if an aircraft enters T6, it will cross the runway and exit from T7, or vice versa if it first enters T7. This means aircraft must not be simultaneously admitted into T6 and T7 because it would create confrontation situation. To avoid this, the ground logic seizes and releases both T6 and T7 as if they were one taxiway.

2. If the runway has not been seized for use by either an aircraft taking off or landing, the ground logic allows the aircraft to cross the runway.

3. If the runway has been seized, then the aircraft pilot must request permission to cross from the ground controller by voice communication.
 4. The ground controller grants permission by sending a signal through the computer to the associated ground logic.
 5. The ground logic then directs the aircraft to cross after the aircraft which is taking off or landing has passed the taxiway.
- B. Typical ground logic operation associated with control of high-speed runway turnoffs, is as follows:
1. The ground logic FIGS. 19 and 20 associated with high-speed runway turnoffs notifies the pilot via the guidance displays whether or not the turnoff is available for him to use.
 2. A high-speed turnoff is available for use by a landing aircraft if (1) the computer has sent a signal authorizing it as a possible exit from the runway and (2) the turnoff is not currently seized for use by another aircraft.
 3. When the previously described conditions are met, the ground logic seizes the turnoff so that it cannot be used by any other aircraft and then signals the guidance unit to display that this runway turnoff is available for use by the landed aircraft.

GROUND LOGIC UNITS

The ground logic units make logic-type decisions based on Boolean (yes-no) relationships. The variables in the Boolean relationships are inputs from the computer and detector units. The basic building blocks needed for construction of the ground logic units include, gates (and, or, nand, nor), monostable and bistable multivibrators, and time delays. Such building blocks are available as either discrete components or as integrated circuits.

To increase the total system safety factor, provisions are made for periodic performance checks of each detector unit and each ground logic unit. This is done by sending out diagnostic signals from the computer or the ground control panel and evaluating the response to these signals. The ground logic itself may also generate diagnostic signals to check the status of the guidance displays and detectors. Either or both may be used. In addition, other self-checking features may be employed in the system.

GUIDANCE SUBSYSTEM

The function of the guidance system is to communicate guidance information to aircraft pilots or drivers of vehicles whose routes are being supervised by the ground traffic control system. The guidance system is capable of transmitting the following types of information: 1. Aircraft or vehicle identification and 2. Maneuvering instruction. This is handled in one of the following two ways:

1. Displaying the aircraft or vehicle identification each time maneuvering information is displayed.
2. Displaying the aircraft or vehicle identification only as it has entered the area supervised by the ground traffic control system.

Implementation of the foregoing is accomplished by using either one, or a combination of the following: 1.

Visual guidance displays, 2. Centerline lighting, and 3. Radar. The present system is compatible with all methods of implementation.

For illustrative purposes, consider the following guidance system. Identification of the aircraft or vehicle is only displayed upon entrance thereof into the supervised area. For aircraft or vehicles entering from the apron areas (FIG. 21), a visual display 72 (FIG. 22) should be sufficient. The seven alphanumeric display sections 70 (FIG. 23) are identical and each uses fifteen backlighted segments 31 to generate all letters and numbers. The first three characters 70 from the left, FIG. 22, are for airline identification, and the last four for flight number. The hold signal is developed by using the first four characters. Each segment uses two or more bulbs, not shown, to provide even illumination and also redundancy to prevent loss of a segment as a result of bulb failure. The light is filtered through an orange-yellow filter to provide the same color as is presently being used in taxi guidance signs.

The specifications are actually very similar to those described for taxiway guidance signs in the FAA Advisory Circular AC150/5345-4. To furnish maximum visibility during daylight or low visibility conditions, and yet not exceed the recommended 30-60 foot lambert level of light, a remotely controlled dimming circuit, not shown, is provided. The characters are approximately 10 1/4 inches high by 8 inches wide, and placed on 12-14 inch centers.

The directional display 74, FIG. 24, is a line made of the apron throat as seen from the apron area where the aircraft will be parked awaiting instructions. Each route leaving the apron throat is represented by a line which consists of a series of backlighted segments. To indicate a particular route, the segments making up that route on the display illuminate sequentially starting at the apron throat. When all the segments are lit, they extinguish, and then the sequence is repeated for as long as an aircraft has clearance to enter the ground controlled area. During this period, the pilot sees this as a flashing and extending line along the route he is to take.

When an aircraft 28, FIG. 25, is entering the ground controlled area from a high-speed runway turnoff, a visual display 74, FIG. 26, alone might not be adequate because of the speed of the aircraft; therefore, both a visual display and centerline lighting 76, FIG. 27, could be used to indicate to the pilot those turnoffs open for him to use. The seven alpha-numeric characters and the directional display will be the same as outlined for the entrance guidance display. To shield the lights on the runway turnoff guidance displays from distracting a pilot as he is landing, a hood, not shown, would be included on the top of each display. An alternate method would be to mark the runway turnoffs with centerline lighting and put the visual displays beside the turnoffs as shown in FIG. 26.

Once an aircraft or vehicle has entered the traffic control area (and been identified upon entry), only maneuvering information has to be shown. The maneuvering instructions are displayed via the line map method as outlined for the entrance displays. (See FIGS. 29 and 30)

Since the HOLD signal (FIG. 30) is a very important one, redundant transmission may be very desirable. In

addition to displaying the HOLD signal on a visual display, red strip lighting 78, FIG. 31, may also be placed across the taxiway at the point where the taxiway enters an intersection. The strip 78 would be buried in the taxiway and would be turned on simultaneously with the HOLD signal at the visual display.

EXAMPLES

Following are typical examples of how the present system functions. Also included are the descriptions of a few special cases that could arise and how the system handles them.

EXAMPLE NO. 1

TYPICAL LANDING INCLUDING DUTY RUNWAY CROSSING - FIG. 32

The air traffic controller gives an aircraft clearance to land on runway No. 1. He then passes the flight number and runway number to the ground traffic controller. Prior to this time, the ground controller has received the destination (terminal and gate number) from the commercial airline apron controller. This information is fed into the computer. The computer sends signals to the ground logic associated with all possible turnoffs and taxiways along runway No. 1. If the turnoffs are open, the ground logic seizes them and holds them open as possible exit points. This information is also displayed via the guidance media. All taxiways that cross runway No. 1 are given a hold signal.

Detectors are located along the runway just before and just after all taxiway crossings or turnoff points. This is to expedite the control of traffic crossing the runway as will be pointed out later. It also allows the system to track the aircraft as it moves down the runway. The software then finds a prefixed list of codes of the runway detectors listed sequentially as they will be encountered by the aircraft as it proceeds along the runway. This list is placed into the storage allocated for the aircraft Route Array. By placing the code of the first detector that was tripped into the position register, the aircraft can be tracked as it moves down the runway in a manner similar to its tracking through the taxiway network.

As soon as the aircraft turns into high-speed runway turnoff T1, it is detected by a runway entrance detector. The ground logic associated with this detector notifies the computer which, in turn, revokes the signals to other taxiways that they may become entry points.

The computer takes the entry point and the destination and generates a Route Array (list of taxiways which form the shortest path to the destination). When the Route Array has been completed, a signal is sent from the computer to ground logic associated with taxiways T1 indicating that T4 is the next taxiway to be entered. The T1 ground logic accepts this information, and when T4 is available, the pilot is notified via the display system being used. In addition to notifying the pilot that T4 is clear, the ground logic also notifies the computer. This signal causes the computer position register and position pointer to be updated. Following this a signal is sent to ground logic associated with T4 indicating that T6 is the next taxiway to be entered.

When the aircraft trips the detector in T4, the ground logic releases entry point T1 so it can be used

by other traffic. Also the computer is notified by T4 ground logic that a detector has been tripped.

Notice that the next intersection includes runway No. 2. The control of traffic crossing a runway can be done in at least two ways: (1) the runway can be treated as any other taxiway with the "to be occupied" signal sent to ground logic from the computer instead of from the detector units, or (2) each aircraft will have to get clearance to cross by radio contact with the ground controller. This will have to be interfaced with ground control system. For example, the ground controller tells the pilot that he is clear to go as soon as the ground logic causes the clear signal to be displayed. In addition, the ground logic is prevented from displaying the clear signal until it receives a signal from the ground controller indicating that radio clearance has been given.

If an aircraft were waiting to cross runway No. 1 from T15 to T16 and had received clearance from ground controller by radio, the ground logic would display the clear signal just as soon as the landing aircraft had crossed both runway detectors associated with T15 and T16. In other words, the aircraft in T15 would not have to wait until the landing aircraft had turned into T1 before he was cleared to move.

It is also noteworthy to again point out that the ground logic treats taxiways T4 and T6 as if they were one taxiway. The reason for this as was pointed out before, is that traffic will be allowed to enter the runway from special taxiways referred to in Example No. 3 as take off queues. This means that if an aircraft enters T4, it will then cross the runway into T6 and the same would be true from T6 to T4. Therefore, by treating T4 and T6 as one taxiway, once it has been seized for use, it cannot be entered from the other direction.

Similar sequences to those previously described take place to guide the plane to intersection T8 and finally to intersection T12. Upon leaving intersection T12 the aircraft leaves the area controlled by the ground traffic controller and enters the apron area which is under the control of a ramp agent.

EXAMPLE NO. 2

CONTROL SUBDIVIDED INTO ZONES (FIG. 33)

An aircraft is given clearance to land on runway No. 2. The flight number, runway number, and destination are fed into the computer and the aircraft is tracked as it moves down the runway as described in Example No. 1. A Route Array is generated as soon as the aircraft leaves the runway and trips a runway entrance detector. Notice in FIG. 33 that the destination is a terminal located on the eastern portion of the airport. There is only one taxiway interconnection that connects the western part of the airport with the eastern part. For this physical layout, it would be very easy to split the ground controlled area into two zones -- a western zone and an eastern zone. Instead of one computer administering the guidance and management functions for the total area, each zone could have associated with it a smaller capacity computer for this purpose.

If this is the case, then the western zone control system picks up the aircraft as it leaves the runway and develops a Route Array which guides it to the taxiway interconnection leading to the eastern zone. (The ac-

tual procedure for accomplishing this would be the same as described in Example No. 1). The eastern zone control picks up the aircraft from the taxiway interconnection and generates a Route Array that enables the system to guide the aircraft to its destination.

EXAMPLE NO. 3

GUIDANCE OF AIRCRAFT TO TAKEOFF QUEUE (FIG. 34)

Assume that aircraft are taking off and landing along runway #1. Aircraft touchdown near the east end of the runway, rollout and turnoff at either T20, T21, or T22. Aircraft queue up for takeoff along T7 which has an entry to the east end of runway No. 1. (Note also the penalty box P.)

When an aircraft contacts the ground traffic controller for clearance to move to the takeoff queue, he is assigned a number which indicates his position in the takeoff sequence. These numbers are assigned on a "first come, first serve" basis. In FIG. 34, the aircraft parked at terminals A and B have requested correspond numbers (1, 2 and 3 shown in circles). The authority responsible for getting aircraft from gate to the apron throat is the ramp agent. For orderly entrance into the area supervised by the ground control system, the pilot of aircraft 2 at terminal B receives instructions from the ground controller to move to the apron throat D, FIG. 35, and when aircraft 2 is in that position, the pilot is to call the ground controller. If there is an apron controller, the ground controller would have communicated the clearance to him, and he would have relayed it to aircraft 2.

In the meantime, the ground controller would have input to the computer the aircraft takeoff queue number, flight number, destination, and point of entry into the area supervised by the ground control system.

At terminal A, (FIG. 34) the apron controller (or ground controller as the case may be) advises the pilot of aircraft 1 to move to the apron throat B and then contact ground control. He is also advised to watch for aircraft 3. Then aircraft 3 is contacted and instructed to move to the same apron throat B, line up behind aircraft 1, and contact ground control as soon as aircraft 1 has left, (See FIG. 36). As before, the ground controller would have input to the computer the aircraft takeoff number, flight number, destination and point of entry into the area supervised by the ground control system for both aircraft 1 and 3.

The computer software would have generated a Route Array for each aircraft and loaded the respective position registers with the code of the apron throat through which they are to enter the controlled area. When the ground controller receives voice communication that the respective aircraft have reached the proper position in the apron throat, then he inputs an Admit Command to the computer which causes it to transmit the aircraft number and route information to the ground logic associated with appropriate data display. (Recall that entrance data displays include the aircraft flight number.) He tells the aircraft to proceed as directed by guidance displays and to notify ground control when he reaches the takeoff queue.

This would mean that the Air Route Traffic Center would not assign airspace to an aircraft until it had

reached the takeoff queue. Under present operations this airspace is assigned soon after the pilot requests clearance to leave the loading gate. In some instances last minute shuffling must be done to compensate for unavoidable circumstances that cause an aircraft to become out of sequence to such an extent that it is easier to change the takeoff sequence than to try to rearrange the aircraft. This would eliminate the last minute shuffling and is very compatible with the present system.

Method No. 2 - The ground controller could allow the aircraft to enter the ground control system and proceed to the launch queue in a nonsequential manner. The penalty box could then be used to establish the proper sequence. Method No. 3 - The ground controller could hold aircraft 2 at apron throat D until aircraft 1 had passed, by controlling the time that he input the Admit Command. In the same manner, he would withhold the Admit Command for aircraft 3 to delay it long enough to provide space for aircraft 2 to come in behind aircraft 1. This approach would probably be simplified by requiring that all aircraft moving from the terminals to the takeoff queue follow the same path which would be along the T0, T1, T2, T3, T4, T5, T6, T7 route for this example.

Method No. 4 - The same concept used in Method No. 3 would be employed here except that the computer software would control the sequential admittance of the aircraft into the area supervised by the ground control system.

Method No. 5 - An even more sophisticated computer subroutine could be developed that would guide the aircraft into the taxiway matrix with holding and sequencing handled at intersections between the terminals and the takeoff queue.

For example, the pilot of aircraft 1, FIG. 34, could be directed to move through T0, T1, T2, T10, T11, T6, to T7. The aircraft 2 pilot could be directed to move through T4, T5 and hold at T5 until the aircraft 1 had passed by. Then aircraft 2 could go to T6 and then to T7. In addition, aircraft 3 would be admitted after aircraft 1 and would follow the same route T0 T1, T2, T10, to T11. At T11 it would hold for the passage of aircraft 2 into T6 and could then follow.

The software to implement this method would be much more sophisticated (and thus more costly and error prone) and therefore, it would be much more advantageous to use one or a combination of the previous mentioned methods providing the physical airport layout and other related parameters would allow for it.

EXAMPLE NO. 4

TRAFFIC FLOW AND CONFRONTATION PROBLEMS

A well designed ground control system should be capable of meeting the following requirements to increase the efficiency of traffic management:

1. Near runway turnoffs, aircraft that have been recovered should be given priority so as to clear the runway for use as soon as possible.

2. Near the terminal, aircraft that are to be taking off should be given priority in order to reach the takeoff queue as soon as possible.

3. Minimize the number of points at which takeoff traffic and recovery traffic routes cross.

The present system is not only adaptable to meet such requirements but also it simplifies the software.

The general flow of traffic must be set up in a counterclockwise manner -- takeoff traffic moving left to right and up, and landing traffic moving right to left and down.

The present system is easily adapted to this by:

1. Adapting Methods No. 1 through No. 4 as outlined in Example No. 3. This would direct all takeoff traffic along the T0 T1, T2, T3, T4, T5, T6, to T7 path.
2. Setting up the software to generate routes from runway turnoffs to terminals that would bring all landing traffic down to the T0 T1, T2, T3, T4 path to the left of the apron throat that it is to enter. Then the landing aircraft would move with the stream of takeoff traffic and not against it.

This virtually eliminates confrontation problems but if they were to happen, the following is a description of how the system would respond. As shown in FIG. 37, if aircraft 5 in T1 desires to go to T6 and aircraft 4 in T2 desires to go to T1, (If either desired to go to T3, or T4, there would be no confrontation) the ground logic senses the confrontation situation and notifies the computer which displays an alarm on the ground controller panel. The ground controller then has to reroute one of the aircraft.

EXAMPLE NO. 5

IDENTIFICATION OF TRAFFIC MOVING INTO AND OUT OF THE APRON AREA

As was noted in Example No. 3 an aircraft entering the ground control system's area of supervision from an apron throat is identified by an Admit Command entered into the computer by the ground controller. Recall that the aircraft pilot identified himself and his location to the ground controller via voice communication.

When an aircraft that has landed and been guided to the appropriate throat of the apron that is to be entered, the pilot may use voice communication to identify himself to the apron controller.

An alternate method would be for the ground control system to notify the ground controller via the ground control display that a certain landing aircraft had just entered a certain apron throat. The ground controller could then notify the apron controller. Actually, this method would not only be less efficient but more costly from a hardware and software standpoint.

SPECIAL CASE NO. 1

AIRCRAFT VIOLATES A HOLD SIGNAL (SEE FIG. 38)

Suppose that the aircraft 6 in taxiway T5 has been given a hold signal by its guidance display. Normally, the aircraft 6 would be stopped at a point marked by a painted stripe or, as shown, a red strip light 78 mounted in the runway. Therefore, under normal conditions the detector would not be tripped until the aircraft 6 has been cleared to leave taxiway T5. However, if an aircraft tripped this detector while a hold signal was being displayed, an alarm signal would be sent from the ground logic to the computer which would cause it to be displayed on the ground controller panel. Also, the

flight number and taxiway detector that was erroneously tripped would be output to the ground controller on a typewriter or punched card.

The ground control system could be programmed to respond in different ways to rectify this situation. One method might cause hold signals to be displayed at both ends of all taxiways that feed into the intersection where the violation occurred. These signs would be displayed until the ground controller could clear the situation by either voice communication or by inputting T8 as an origin and generating a new route to the aircraft's destination. The hold signals could only be released by a special input command from the ground controller.

SPECIAL CASE NO. 2

INTERSECTION TAKEOFF

In some cases, the launching of aircraft may be expedited by using intersection takeoffs. As far as the present system is concerned, this would only mean that the destination point as entered by the ground controller would be the queue feeding the intersection takeoff point instead of the queue feeding the normal runway takeoff point.

The decision to use intersection takeoffs would be made by the ground controller based on density of takeoff traffic and also on aircraft weight information obtained from the airline carriers. (Approval would also have to be obtained from the pilot, but all the other factors would have to be assessed first.)

SPECIAL CASE NO. 3

EMERGENCY SITUATION

The system's flexibility can again be seen in the almost unlimited different modes of response to an emergency situation. For example, areas can be blocked off from normal traffic movement, prefixed routes for emergency vehicles can be programmed, and special provisions for guiding aircraft away from the emergency area, to mention a few.

Advantages and outstanding features of the invention include:

1. The ground controller has only to know the identification and point of destination on the airport of each aircraft desiring to taxi across the taxiways of the field in order to handle all planes within his jurisdiction.
- 2.

Automatic response of the system thereafter avoids possible human error in determining the optimum paths of many aircrafts, especially in the case of concentrated airport ground traffic.

3. Once an aircraft has been entered into the system, the next aircraft can be given the individual attention of the ground controller, and enters with a minimum of further attention to the preceding one; reducing his work load.
4. The system solves prior problems due to fog and darkness at the airport.

As used in the claims the term "vehicle" means taxiing aircraft or plane, as well as automobile, truck, etc. that may be used at an airport, or other surface area. Furthermore, while the invention is primarily concerned with airport ground traffic control, it is not limited thereto, but is applicable to the control of city

traffic, especially in emergencies, as when an ambulance, or police car, or fire fighting vehicles must cross a traffic area with safety and dispatch. The invention also is applicable to the traffic control of boats, or ships within a predetermined surface area of water, such as a boat basin. Thus, "object" includes any aircraft, vehicle, boat, which moves over a surface, under the control of a pilot, driver, etc.

A latitude of modification, change and substitution is intended in the foregoing disclosure and in some instances some features of the invention will be employed without a corresponding use of other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the spirit and scope of the invention herein.

What is claimed is:

1. A surface traffic control system for controlling the movement of vehicles including automotive transports and taxiing aircraft over a network of surface ways and intersections for the automatic generation of a current optimum route for use by selected individual operator driven vehicles over said network of surface ways, comprising:

detector means located at said intersections for sensing the presence and absence of vehicles at said intersections;

a plurality of individual digital logic means for each of said intersections operatively connected to each other and to each of said detector means to respond to the existing traffic at such intersection detected by said detector means for defining a traffic pattern at such intersection and for safely controlling the flow of traffic at such intersection;

a central digital computer operatively connected to said digital logic means for generating an optimum route in relation to existing traffic conditions on said network of surface ways for use by each of said vehicles on said network, said optimum route passing through a plurality of said intersections at each of which said optimum route may take a plurality of paths;

route guidance means operatively connected to said digital logic means for indicating to the operator of each selected vehicle the optimum route generated by said central digital computer.

2. A surface traffic control system according to claim 1 in which said network includes intersections of tax-
iways and runways, and individual digital logic means are comprised of individual satellite digital computers located at each of said intersections.

3. A surface traffic control system according to claim 1 in which said route guidance means include visual displays located at said traffic control stations for indicating to the operator of said vehicles the correct instructions for traversing said optimum route.

4. A surface traffic control system according to claim 1 in which said digital computer is under the supervision of the ground controller of the airport, such that when the identification of a particular vehicle is supplied to said computer along with the desired destination and point of origin thereof, said optimum route is automatically selected by the computer which thereupon in cooperation with said logic means guides said particular vehicle over said optimum route.

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