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SURFACE MOVEMENT GUIDANCE AND CONTROL SYSTEMS

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FOREWORD

Discussions concerning requirements for surface movement guidance and control extend far back in ICAO's history. The most recent world-wide meeting at which discussions on this subject took place was the Eighth Air Navigation Conference (Montreal, 1974) and it was these discussions which led to the writing of this Circular.

Two parts of the Conference record deserve particular attention. The first is the declaration of the need for a system of taxiing guidance and control; the second is the recognition of the multi-disciplinary nature of the problem. ICAO Annexes and other documents contain many aids and procedures which are currently used for surface movement guidance and control; however, in the past no review of the over-all requirements has been undertaken. This Circular presents such a review together with details of systems recommended to meet various requirements. In regard to the multi-disciplinary nature of the problem, it is most important that work is not always conducted in isolation within the various specialities involved. The ultimate aim is to develop an integrated system which is compatible with the requirements of all associated disciplines.

The purpose of this Circular is to assist States in assessing the types of surface movement guidance and control systems required at their various aerodromes. As all aerodromes require a surface movement guidance and control system of one kind or another the main question is the extent of the system required. This Circular attempts to provide States with the best information available at the present time.

The Circular has been developed by the ICAO Secretariat working with the assistance of a study group composed of members nominated by Australia, France, United Kingdom, United States, Airport Associations Coordinating Council, International Air Transport Association, International Federation of Air Line Pilots' Associations, and International Federation of Air Traffic Controllers' Associations. It is the first step in carrying out the recommendations of the Eighth Air Navigation Conference. Work will continue in ICAO on this subject, to define related requirements for Standards, Recommended Practices and Procedures.

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CHAPTER 1 - INTRODUCTION

1.1 What is meant by surface movement guidance and control?

1.1.1 In its broadest sense surface movement guidance and control is the provision of guidance to, and the control of, all aircraft and ground vehicles on the movement area of an aerodrome. "Guidance" relates to facilities, information and advice necessary to enable the pilots of aircraft or the drivers of ground vehicles to find their way on the aerodrome and to keep the aircraft or vehicles on the surfaces or within the areas intended for their use. "Control" means the measures necessary to prevent collisions and to ensure that the traffic flows smoothly and efficiently.

1.1.2 A surface movement guidance and control system provides guidance to, and control of, an aircraft from the landing runway to the parking position on the apron and back again to the runway used for take-off, as well as from the maintenance area to the apron, or vice versa. The system also provides guidance to, and control of, all ground vehicles whose functions require them to operate on the movement area, e.g., aerodrome management vehicles, aircraft servicing vehicles, rescue and fire-fighting vehicles, and vehicles engaged in construction work. Additionally, a surface movement guidance and control system assists in safeguarding against unauthorized or inadvertent entry on to operational runways.

1.2 What does a surface movement guidance and control system comprise?

1.2.1 In this Circular the term "Surface Movement Guidance and Control (SMGC) System" is applied to the system of aids, facilities and procedures designed to meet the requirements for guidance and control of surface traffic consistent with the particular operational conditions at a particular aerodrome.

1.2.2 An SMGC system comprises an appropriate combination of visual aids, non-visual aids, radiotelephony communications, procedures, control and information facilities. Systems range from the very simple at small aerodromes with light traffic operating only in good visibility to the complex at large and busy aerodromes with operations in very low visibility conditions. SMGC system components are discussed in detail in Chapter 4.

1.3 Who does a surface movement guidance and control system involve?

1.3.1 Because of the multi-disciplinary interests in surface movement guidance and control, there is a need to co-ordinate fully all current and planned use of surface movement guidance and control systems to ensure compatibility with aerodrome engineering, operations, communications, aerodrome control service and pilot requirements. Additionally, there is a need to maintain compatibility of practices between ICAO Member States. At aerodromes which are jointly used for civil and military operations, co-ordination with the military is necessary.

1.3.2 Aerodrome authorities should ensure that there is appropriate consultation and co-ordination during planning of the SMGC system. During all stages of planning, consultation involving the aerodrome authority, the appropriate branches of the administration of the State concerned (including aerodrome engineering, air traffic control, communications and operations specialists), operators, pilots and the military (if appropriate), would be necessary as a means of ascertaining and confirming the various requirements associated with the SMGC system.

CHAPTER 2 - THE NEED FOR SMGC

2.1 Operational Conditions

2.1.1 The SMGC system to be provided at a particular aerodrome is dependent upon three main operational conditions. They are:

a) the visibility conditions under which the aerodrome authority plans to maintain operations;

b) the traffic density; and

c) the complexity of the aerodrome layout.

Each of these three factors has been studied and, for the purpose of discussing SMGC systems, sub-divided and defined according to the terms indicated in Table 2-1. Whenever these terms are used throughout this Circular they have the meanings given to them in Table 2-1. Typical examples of aerodrome layout categories are given at Figure 2-1.

2.1.2 Table 2-1 makes reference to "visibility 5" which would require blind taxiing of aircraft. As the cost of the electronic equipment necessary to make this possible does not generally justify installation of such equipment at the present time, visibility condition 5 will not be considered in further discussions.

2.2 Operational Requirements

2.2.1 The operational requirements to be met by SMGC systems have been discussed for many years. The current requirements are shown in Table 2-2. It should be noted that these requirements confine the extent of the SMGC system to the movement area. It is recognized that a requirement exists for guidance and control of emergency vehicles outside the movement area but this is considered to be beyond the area of applicability of the SMGC system.

2.3 Reasons for Providing an SMGC System

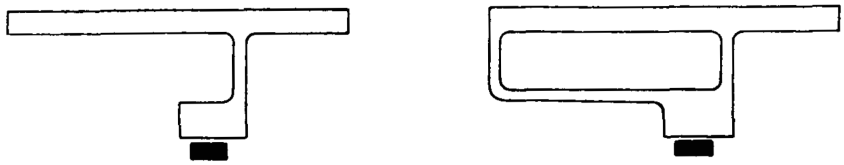
2.3.1 The main reason for providing an SMGC system is to enable an aerodrome to cope safely with the ground movement demands placed on it under specified operational conditions. The system should be designed to prevent collisions between aircraft, between aircraft and ground vehicles, between aircraft and obstructions, between vehicles and obstructions, and between vehicles. In the simplest case, i.e., in good visibility conditions and with light traffic, this objective may be achieved by a system of visual signs and a set of aerodrome traffic rules requiring pilots and vehicle drivers to watch out and to give way in accordance with specified procedures. In more complex situations, particularly under poor visibility conditions and/or heavy traffic, a more elaborate system will be required.

2.3.1.1 An essential safety function of an SMGC system is to safeguard against unauthorized or inadvertent entry on to operational runways. Under poor visibility conditions this may require a means of electronic surveillance to assist air traffic control personnel.

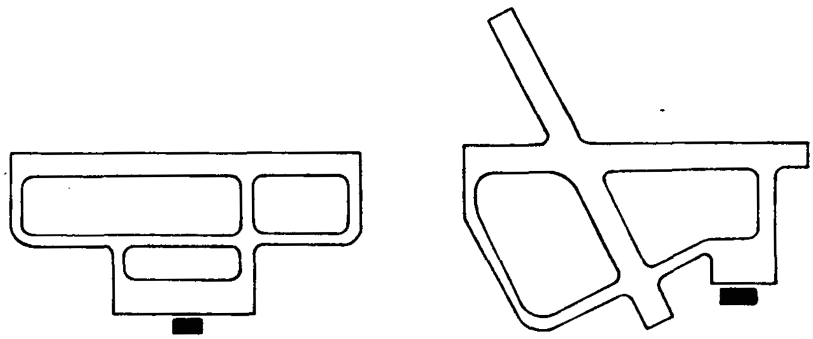
2.3.1.2 Another important safety function of an SMGC system is to provide assistance to rescue and fire-fighting vehicles in locating, and proceeding to the site of an accident on a movement area.

TABLE 2-1. OPERATIONAL CONDITIONS ASSOCIATED WITH SMGC SYSTEMS - EXPLANATION OF TERMS

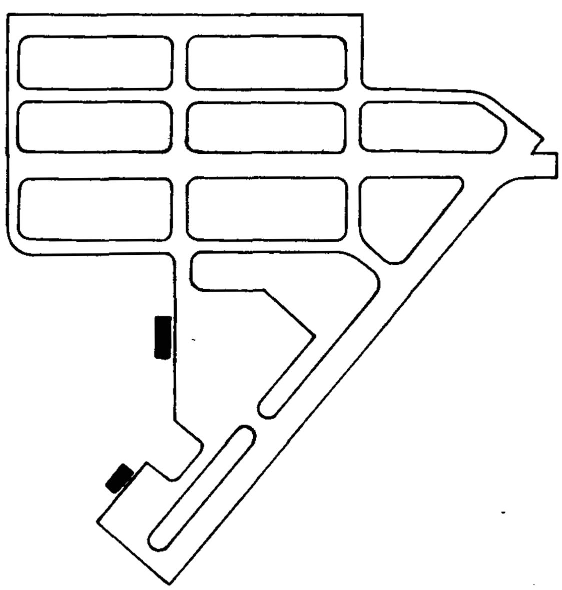
	VISIBILITY CONDITIONS
Condition 1	visibility sufficient for the pilot to taxi and to avoid collision with other traffic on taxiways and at intersections by visual reference, and for personnel of control units to exercise control over all traffic on the basis of visual surveillance;
Condition 2	visibility sufficient for the pilot to taxi and to avoid collision with other traffic on taxiways and at intersections by visual reference, but insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance;
Condition 3	visibility sufficient for the pilot to taxi and to avoid collision with other traffic on the same taxiway but not at intersections by visual reference, and insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance;
Condition 4	visibility sufficient for the pilot to maintain the centre line of the taxiway by visual reference, but insufficient to avoid collision with other traffic on the same taxiway or at intersections by visual reference or for personnel of control units to exercise control over all traffic on the basis of visual surveillance; and
Condition 5	visibility insufficient for the pilot to taxi by visual reference or for personnel of control units to exercise control over any traffic on the basis of visual surveillance.
	TRAFFIC DENSITY *(in the mean busy hour as determined by the individual State)*
Light (L)	not greater than 15 movements per runway, or typically less than 20 total aerodrome movements;
Medium (M)	of the order of 16 to 25 movements per runway, or typically between 20 to 35 total aerodrome movements;
Heavy (H)	of the order of 26 or more movements per runway, or typically more than 35 total aerodrome movements;
	AERODROME LAYOUT The three principal layouts considered are:
Layout a	taxiways without intersections, serving a single runway;
Layout b	taxiways with intersections, serving one or two runways in a simple layout; and
Layout c	taxiways with many intersections, serving multiple runways in a complex layout.
	Note: Not all aerodromes will fit precisely into these categories, but appropriate authorities are encouraged to classify each aerodrome into one of the above layouts taking into account local considerations.



Layout a – Taxiways without intersections serving a single runway.



Layout b – Taxiways with intersections serving one or two runways in a simple layout.



Layout c – Taxiways with many intersections serving multiple runways in a complex layout.

Figure 2-1. Typical Examples of Aerodrome Layout Categories

TABLE 2-2.- OPERATIONAL REQUIREMENTS OF SURFACE MOVEMENT GUIDANCE AND CONTROL SYSTEMS

The SMGC system employed should be appropriate to the visibility, traffic density and aerodrome layout and should provide:

1. Requirements of a general nature

   a) communication capability between the appropriate control unit(s), and between the appropriate control unit(s) and aircraft, and between the appropriate control unit(s) and ground vehicles;

   b) acceptable workloads on the users of the SMGC system;

   c) optimum use of aids and procedures already specified in ICAO regulatory documents;

   d) compatibility between individual elements of the guidance and control systems.

2. Requirements of pilots

   a) guidance and control beginning at the end of roll-out on arrival and extending up to alignment for take-off on departure;

   b) information on the route to be followed;

   c) information on position along the route being followed;

   d) guidance along the route being followed;

   e) warning of:

      1) changes in direction,
      2) stops and other speed adjustments;

   f) identification of areas to be avoided;

   g) information to prevent collision with other aircraft, ground vehicles or obstacles;

   h) information of system failures affecting safety.

3. Requirements of appropriate control units

   a) information on the identity, position and progress of aircraft including aircraft under tow;

   b) information on the identity position and progress of ground vehicles whose movements might conflict with aircraft movements;

   c) information on the presence of temporary obstacles or other hazards;

   d) information on the operational status of elements of the system.

TABLE 2-2.- OPERATIONAL REQUIREMENTS OF SURFACE MOVEMENT GUIDANCE AND CONTROL SYSTEMS (Cont'd)

4. Requirements of ground vehicles on the movement area

a) Emergency vehicles

1) information on the route to be followed;
2) guidance along the route being followed;
3) crash location capability;
4) information to prevent collision with aircraft and ground vehicles; and

b) Other ground vehicles

1) information on the route to be followed;
2) guidance along the route being followed;
3) information to prevent collision with aircraft and ground vehicles.

2.3.2 It should be emphasized that an SMGC system should be designed to maintain regularity of movement on the ground under different operational conditions. Regularity of traffic operations suffer when visibility conditions are reduced and under heavy traffic conditions. The objective is to have an SMGC system which is compatible with the landing and take-off capacity of the runways and the demands placed on the aerodrome.

2.3.3 It has been stated that all aerodromes require an SMGC system. However, each SMGC system must be related to the operational conditions existing at the aerodrome. Complex systems are not required and are uneconomic at aerodromes where visibility, traffic density and aerodrome layout do not present a problem for the ground movement of aircraft or vehicles. SMGC systems should be developed with a modular concept in mind so that components can be added when traffic requirements justify. It should further be borne in mind that technical research will continue in this field and new components will be developed which may either complement or replace existing SMGC components.

CHAPTER 3 - FUNCTIONS AND RESPONSIBILITIES

3.1 Division of Responsibilities and their Transfer

3.1.1 Air Traffic Services

At aerodromes equipped with an aerodrome control unit the operational responsibility for co-ordinating the movement of aircraft on an aerodrome will belong to the appropriate air traffic control service. At aerodromes which are not equipped with a control unit, an advisory service may be provided by an aerodrome flight information service. For the sake of simplicity the generic term "air traffic service" (ATS) is sometimes used in this circular to refer to the service which is responsible for co-ordinating ground movements on an aerodrome.

3.1.1.1 Use of Radiotelephony Procedures and Phraseology

Radiotelephony will be the primary method of communication between the controller and aircraft, surface vehicles, and rescue and fire-fighting vehicles. It is important that radiotelephony (RTF) communications be conducted in a standard manner both with regard to phraseology, procedures and language. At busy aerodromes the workload on the controller can be extremely high and SMGC systems should be designed with a view to minimizing the need for RTF communication.

3.1.1.2 Issue of Taxi Clearance to Facilitate SMGC

The appropriate air traffic service will be responsible for the release of aircraft in a sequence which will expedite the traffic flow, and for the expeditious routing of arriving aircraft.

In good visibility sequencing can be done by visual observation and radiotelephony. In reduced visibility or where traffic density warrants, more advanced means need to be provided since ATS becomes progressively more involved in guidance and control.

3.1.1.3 Determination of Taxi Routes to be Followed

At the planning stage the ATS and the Aerodrome Authority jointly should determine the basic routings to be taken by aircraft and vehicles on the aerodrome. The aim should be to achieve the most expeditious and orderly traffic flow possible. ATS will advise the pilot, or vehicle driver, as to the particular route to be followed and will, where necessary, resolve conflicts at intersections.

3.1.1.4 Monitoring of SMGC Aids

As the bodies responsible for operating the SMGC system, the appropriate ATS unit and the Aerodrome Authority should be aware of the need to monitor the system and to have any failures rectified as soon as is practicable. This monitoring may take the form of visual surveillance of lights, including reports from pilots, and of electrical monitoring of electrical and electronic components of the system.

3.1.1.5 Control of other than Aircraft Traffic on the Manoeuvring Area

While the principal task of an air traffic controller is the control of aircraft, he is also responsible for regulating vehicles. With the exception of rescue and fire-fighting vehicles when responding to an emergency, the controller should ensure that aircraft receive priority and are not hindered by the movement of vehicles. It is important that power be vested in the Aerodrome Authority and the appropriate air traffic service to carry out this task effectively.

3.1.1.6 Operation of Visual Guidance and Control Aids

The appropriate air traffic service (generally the air traffic control (ATC) unit) will be responsible for operating the visual components of the control system, including stop bars, taxiway centre line lights and routing designators. That unit will also need to ensure that the lights are illuminated at the appropriate time. With regard to lights installed on the apron, and to parking and docking guidance systems, it will be necessary at each airport to determine which body will be responsible for their operation.

3.1.1.7 Transfer of Responsibilities Between Controller and Pilot

When the visibility is adequate, the responsibility for avoiding collision is a joint pilot/ATS responsibility with the controller always responsible for the resolution of intersection conflicts where an air traffic control service is provided. As visibility reduces below SMGC condition 3 this responsibility will be transfered to the ATC unit.

3.1.1.8 Transfer of Responsibility Between Controller and Ground Vehicles

The operators of ground vehicles will be responsible for avoiding collisions between their vehicles and aircraft, and between their vehicles and other vehicles. When visibility reduces, it shall be at the discretion of the air traffic controller to restrict movements of vehicles as necessary. The amount of control over the movement of ground vehicles exercised by the aerodrome control service will increase as visibility reduces (see 6.3.3).

3.1.1.9 Initiation and Termination of Low Visibility Procedures

It will be the responsibility of the air traffic control unit to initiate procedures appropriate to poor visibility operations. To assist in this, advice will be needed from the meteorological office so that advance preparations can be made for low minima procedures. Aerodrome security procedures may take some time to implement, and should therefore be started, if possible, in time to complete them before reducing visibility requires other actions such as the application of greater aircraft separation. When the visibility improves, the cancellation of these procedures will take place at the discretion of the air traffic control unit. (Refer to 5.5 concerning initiation and termination of low visibility procedures.)

3.1.2 Apron Control

At certain aerodromes, control of traffic on the apron is not the responsibility of the air traffic control unit. At these aerodromes there should be a designated body responsible for ensuring the safe movement of aircraft on the apron. This body will assume the responsibilities of ATS but only in the apron area. All rules and regulations applicable to aircraft movements should be consistent with normal air traffic control rules and regulations and close liaison between the two bodies will be necessary.

3.1.3 Pilots

The pilot will respond to the instructions given by apron control and the air traffic control unit. He will follow the designated taxiway routes and he should be provided with the means to enable him to do this without difficulty. In good visibility this may be achieved by clearly marked and well maintained signs. In low visibility other means will need to be provided. The pilot's responsibilities with respect to collision avoidance are discussed in 4.6.

3.1.4 Aerodrome Authority

3.1.4.1 Movement Area Inspections

The Aerodrome Authority will be responsible for conducting frequent inspections of the movement area to ensure that the areas reserved for aircraft movements are kept unobstructed and in good repair. It is particularly important that an inspection be completed before the initiation of low visibility procedures as these procedures will, in themselves, prevent such an inspection. (Refer to 6.1 for discussion on routine inspections of SMGC aids.)

3.1.4.2 Ground Staff

The Aerodrome Authority and ATS will be responsible for the regulation and control, respectively of ground staff on the movement area. The Aerodrome Authority will be responsible for ensuring that ground staff using RTF are properly trained and monitored in its use. During low visibility operations, it will be particularly important to restrict the movement of ground staff on the movement area to a minimum. (Refer to 5.5 for details of procedures for low visibility conditions.)

3.1.4.3 Monitoring of SMGC Aids

The Aerodrome Authority will normally be responsible for ensuring that all visual components of the SMGC system are kept serviceable. This will require frequent physical inspections of these visual components.

3.1.4.4 Designation of Taxiways

In conjunction with the ATC service the Aerodrome Authority will be responsible for defining the taxiways and for designing taxiway routings applicable to the types of operations expected to take place at the aerodrome.

3.1.4.5 Low Visibility Movement Area Protection Measures

During periods of reduced visibility it will be the responsibility of the Aerodrome Authority (or other competent authority) to ensure that the number of persons and vehicles authorized to enter the movement area is kept to a minimum. In addition, the Aerodrome Authority will be responsible for ensuring that means are provided that will enable the ATS to detect the presence of aircraft, obstacles, and vehicles on runways.

3.2 Avoidance of Over-Control

3.2.1 The surface movement guidance and control system should provide a degree of control which is adequate to meet the needs of pilots and controllers.

3.2.2 It is important to ensure that the efficiency of the over-all system is not impaired by the imposition of unnecessary controls and restrictions on pilots and controllers. Pilots and controllers should be allowed to exercise their specific responsibilities when circumstances so permit. When circumstances do not allow this, additional restraints are progressively required to ensure safety of ground movement. It is particularly important that these restraints be removed promptly as conditions improve.

3.2.3 Future advances in automated systems may permit a high degree of control without the associated reduction in traffic capacity which is a feature of most contemporary manual systems.

CHAPTER 4 - COMPONENTS OF SMGC SYSTEMS (AIDS AND PROCEDURES)

4.1 Provision of Routes for Aircraft

4.1.1 On an aerodrome the movement of taxiing aircraft generally falls into a distinctive pattern in which the major traffic flows are between:

a) runway(s) and apron(s)

b) apron(s) and maintenance area(s)

c) maintenance area(s) and runway(s)

Where possible standardized routes should be arranged between these locations which are direct, simple, and capable of being used in both good and bad visibility and which offer minimum conflict with the routes of other aircraft or vehicles. One-way systems should be introduced where this can be done without greatly extending taxiing distances.

4.1.2 Care should be taken to ensure that the routes are adequate for the largest aircraft likely to use them, and that aircraft using them do not offer problems of:

a) interference with navigation aids,

b) penetration of obstacle limitation surfaces,

c) obstruction of radar transmissions,

d) physical obstruction (e.g., inadequate clearance from aircraft holding for take-off from an intermediate point on the runway),

e) jet blast.

4.1.3 Routes on an aerodrome will vary according to the runways in use for landing and take-off. A route plan must allow for an orderly transition from one operational mode to another, e.g., following a runway change, and also for the aircraft which, after taxiing for take-off, needs to return to the apron.

4.1.4 For aerodromes where standard taxiing routes are provided, details of such routes should be published in the appropriate aeronautical information publication and shown on aerodrome charts. Routes should normally be identified by designators. The designators of taxi routes should be distinctively different from those of the runways, instrument departure routes and airways.

4.1.5 A settled and recognized standard route system offers advantages over a random system, namely higher degree of safety, greater expedition of movement, more confident operation in reduced visibility and less RTF workload.

4.2 Provision of Routes and Restrictions of Ground Movement

4.2.1 The servicing and maintenance of aircraft and of aerodrome installations inevitably demands the presence of vehicles on the movement area. Annex 11 requires that the movement of persons or vehicles on the manoeuvring area shall be controlled as necessary to avoid hazard to them, or to aircraft; amplification of this requirement is contained in PANS-RAC, Part V. Chapter 4 of the *Aerodrome Design Manual*, Part 2, stresses the importance of planning aerodrome facilities for the maximum segregation of aircraft and vehicular traffic, with land side road systems so designed that vehicles have access to all public areas of the aerodrome without travelling on the movement area (*Aerodrome Design Manual* (Doc 9157-AN/901), Part 2, *Taxiways, Aprons and Holding Bays)*.

4.2.2 The *Aerodrome Design Manual*, Part 2, points out the value of air side roads to eliminate, or lessen, the use of runways and taxiways by ground vehicles which need access to the movement area. For example, aerodrome perimeter service roads may provide access to navigation aids, or from one service area to another. An air side road may connect one terminal with another for airline vehicles, baggage trains, etc. Every effort should be made to avoid air side roads crossing runways and taxiways, or affecting the function of navigation aids. If it is necessary for an access road to cross the extended centre line of a runway the road should be so located that vehicles travelling on it do not become obstacles to aircraft operations.

4.2.3 On an apron, interaction between aircraft and vehicles is unavoidable, and guidance for drivers is necessary if safe and efficient use is to be made of the available space. Apron safety lines (see *Aerodrome Design Manual*, Part 2) should be provided on a paved apron to define the limits of areas established for use by ground vehicles and other aircraft servicing equipment. These lines should be of a conspicuous colour and should contrast with apron markings for aircraft. Vehicle crossings from terminal area or air side road to a stand, and from stand to stand, should be designated by conspicuous painted lines.

4.2.4 Air side route systems for vehicle movement fall into five broad categories:

a) roads which are completely segregated from aircraft movements,

b) roads which cross taxiways in maintenance areas but which are segregated from operational aircraft movement,

c) routes which cross operational runways or taxiways,

d) apron routes,

e) vehicle movement along operational taxiways and runways.

The manoeuvring area should be protected from inadvertent entry by persons and vehicles from air side roads, e.g. by signs or traffic lights on access roads. The movement of persons on foot should only be allowed on runways, taxiways or apron service roads, when absolutely necessary.

4.2.5 Where building or other activity calls for localized free moving traffic, the boundaries of a temporarily closed area should be marked as described in Annex 14, and any movement outside the area should comply with normal aerodrome regulations. (Annex 14, 2.8 stipulates the requirements for promulgating information on the condition of the movement area.)

4.3 Communications Requirements

4.3.1 The task of an aerodrome control service falls into three main divisions:

a) control of air traffic in the circuit and in the approach, landing and departure phases of flight,

b) control of taxiing aircraft and vehicles on the manoeuvring area,

c) acquisition and passing of airways clearances, weather information and other flight data.

At an aerodrome with light traffic it is normal for one controller to be responsible for all of these duties, using one RTF channel for all purposes and making use also of a signalling lamp. At a large aerodrome with heavy traffic, the aerodrome control function may be shared between a number of controllers and assistants and may carry a total RTF loading which demands the simultaneous use of several channels. The signalling lamp is too limited as a means of conveying messages and ambiguous in interpretation to have any part to play except in light traffic on small aerodromes.

4.3.2 In a growing aerodrome or traffic situation the point at which additional control positions need to be introduced may hinge solely upon RTF channel loading, or the decision may be prompted by other factors such as controller workload generated by the particular mix of traffic, complexity of aerodrome layout, or the need to provide a control position which offers a better view of the manoeuvring area. Whether or not the duplication of positions is due to RTF loading, each position should have its own discrete frequency.

4.3.3 A typical usage of two RTF channels is to have the service described in 4.3.1 a) on one frequency and 4.3.1 b) and c) on the other; b) and c) subsequently become divided when workload develops to the point at which another channel is required. In some instances it may become necessary to open an additional frequency, or frequencies, during the busy hours of the day, and then revert to a more limited communication channel usage in the less busy periods.

4.3.4 It is customary for non-aeronautical radio frequencies to be used for communication between ground vehicles and various aerodrome agencies such as contractors, customs, police, airline companies, etc., but it must be ensured that when operating on the movement area use of the non-aeronautical frequency does not preclude maintenance of a listening watch on the ground movement control frequency.

4.3.5 A spare frequency for use if a normal channel is jammed/overloaded is a highly desirable facility which can, on occasion, save a great deal of trouble and delay.

4.3.6 At many aerodromes provision is made for a discrete RTF contact between emergency services vehicles and an aircraft which has landed after declaring an emergency, or in any emergency when the aircraft is on the ground and capable of being manoeuvred. This is of particular significance with large aircraft where it is important for the crews of the emergency vehicles to be aware of the pilot's intentions so that risk to aircraft occupants and to personnel on the emergency vehicles may be minimized. For such a discrete frequency to be of value it is obviously necessary that all users of radiotelephony equipment be competent in speaking a common language.

4.4 Provision of Route Guidance for Aircraft

4.4.1 The degree of route guidance required depends upon visibility conditions, complexity of airport layout and traffic density. Facilities for ground movement guidance in visibility conditions 1 to 4 inclusive are:

1.	Runway centre line marking	Annex 14, Chapter 5
2.	Taxiway centre line marking	Annex 14, Chapter 5
3.	Taxi-holding position marking	Annex 14, Chapter 5
4.	Visual aids for denoting restricted use areas	Annex 14, Chapter 7
5.	Runway edge lights (night)	Annex 14, Chapter 5
6.	Taxiway edge lights (night)	Annex 14, Chapter 5
7.	Signs	Annex 14, Chapter 5
8.	Apron marking	Currently no ICAO specifications See Note A below
9.	Taxiway intersection marking	Currently no ICAO specifications See Note B below
10.	Aerodrome chart	Annex 4, Chapter 13
11.	Radiotelephony equipment	Annex 11, Chapter 6
12.	Runway protection lights	Currently no ICAO specifications See Note C below
13.	Clearance bars	Annex 14, Chapter 5
14.	Monitoring apparatus	Annex 14, Chapter 8; *Aerodrome Design Manual*, Part 4
15.	Taxiway centre line lights	Annex 14, Chapter 5
16.	Taxiway centre line light control	Currently no ICAO specifications See *Aerodrome Design Manual*, Part 4
17.	Stop bars	Annex 14, Chapter 5
18.	Taxiway lighting - high intensity	Annex 14, Chapter 5
19.	Docking guidance	Currently no ICAO specifications See Note D below
20.	Non-visual surveillance system	Currently no ICAO specifications See 4.6.2

Notes:

A. *Apron marking specifications developed by the Visual Aids Panel have been reviewed by States and are currently under study by ICAO.*

B. *Taxiway intersection markings are required to indicate holding positions at taxiway/taxiway intersections. Action to develop appropriate specifications for such markings has been initiated by the Visual Aids Panel.*

C. *Runway protection lights are flashing lights located at runway holding positions either on, or adjacent to, holding position signs to improve their conspicuity. The Visual Aids Panel is currently working on development of specifications for such lights.*

D. *Apron parking/docking guidance system specifications developed by the Visual Aids Panel have been reviewed by States and are currently under study by ICAO.*

4.4.2 Table 4-1 indicates the scale of provision which the experience of States shows to be appropriate to the various operational conditions.

TABLE 4-1. GUIDANCE ON SMGC SYSTEM COMPONENTS FOR CRITICAL OPERATIONAL CONDITONS

1. Grouping of SMGC System Components

Component Group	*System Components*	
	Aid	*Responsibility/Procedure*
A	Apron markings (See 4.4.1, Note A) Runway centre line marking (Annex 14, Chapter 5) Taxiway centre line marking (Annex 14, Chapter 5) Taxi-holding position marking (Annex 14, Chapter 5) Visual aids for denoting restricted use areas (Annex 14, Chapter 7) Runway edge lights (Annex 14, Chapter 5) Taxiway edge lights (Annex 14, Chapter 5) Obstacle lighting (Annex 14, Chapter 6) Signs (Annex 14, Chapter 5) Parking guidance (Annex 14, Chapter 5) Taxiway intersection marking – where applicable (See 4.4.1, Note B)	***Aerodrome Authority:*** Periodic electrical monitoring of SMGC aids (Annex 14, Chapter 8. See 4.7 following) Designation of taxiways Movement area inspections (Annex 14, Chapter 2) Regulation of ground staff conduct on the movement area (See Chapter 5) ***Pilot:*** Adherence to a ground movement traffic rules and regulations (Annex 2, PANS-RAC)
	Note: The provision of an aerodrome control service for airports with traffic density L or with layout a or b, is an administrative decision.	
B	Aerodrome chart (Annex 4, Chapter 13)	***Aerodrome Authority:*** Initiate amendment of aerodrome chart as necessary
C	Aerodrome control service *Note: The provision of an aerodrome control service for airports with traffic density L or with layout a or b, is an administrative decision.* Signalling lamp (Annex 14, Chapter 5) Radiotelephony equipment Runway protection lights (See 4.4.1, Note C)	***Aerodrome Authority:*** Regulation of ground staff in radiotelephony procedures (Annex 10, PANS-RAC. See 5.2 following) ***Control Unit:*** Visual monitoring of SMGC aids (Annex 11, Chapter 7) Use of radiotelephony procedures and phraseology (PANS-RAC, Part 9) Use of signalling lamp (Annex 2, Appendix A) Control of other than aircraft traffic on the movement area (PANS-RAC, Part 5) ***Pilot:*** Use of radiotelephony procedures and phraseology (Annex 10, PANS-RAC. See 4.3 and 5.2)

D		*Aerodrome Authority:* Designation of taxiway routes (See 4.1) *Control Unit:* Determination of the taxiway route to be followed (PANS-RAC, Part 5)
E		*Control Unit:* Application of sequencing procedures (See 5.3)
F	Clearance bars (Annex 14, Chapter 5) Monitoring system (Annex 14, Chapter 8, *Aerodrome Design Manual,* Part 4)	*Aerodrome Authority:* Low visibility movement area protection measures (See 5.5.1) *Control Unit:* Application of separation instructions at intersections (PANS-RAC, Part 5) Application of gate holding procedures (See 5.4) Initiation and termination of low visibility procedures (PANS-RAC, Part 5. See 5.5 following) Transfer of responsibility between controller and pilot at intersections (See 3.1.1.7) *Pilot:* Transfer of responsibility between controller and pilot at intersections (See 3.1.1.7)
G	Taxiway centre line lights (Annex 14, Chapter 5) Note: *A system for the control (by selective switching) of taxiway centre line lights is required for visibility condition 4 and perhaps for heavy traffic density (H) specified in Table 2-1.*	
H	Stop bars (Annex 14, Chapter 5) Taxiway lighting – high intensity (Annex 14, Chapter 5) Docking guidance (if docks provided) (See 4.4.1, Note D) Crash locators for emergency vehicles (Currently no ICAO specifications)	*Aerodrome Authority:* Continual electrical monitoring of SMGC aid (Annex 14, Chapter 8) *Control Unit:* Application of separation criteria (PANS-RAC, Part 5. See 5.6 following) Transfer of responsibility between controller and pilot along taxiways and at intersections (See 5.6) Continual electrical monitoring of SMGC aids (Annex 11, Chapter 7. See 4.7 following) Operation of visual guidance and control aids (PANS-RAC, Part 5) *Pilot:* Transfer of responsibility between controller and pilot along taxiways and at intersections (See 5.6)
I	Airport surface surveillance radar (Currently no ICAO specifications, see 4.6.2)	*Control Unit:* Monitoring of surface movement

Table 4-1 *(cont.)*

2. Component Groups Appropriate to Critical Operational Conditions for Aerodrome Layout

*AERODROME LAYOUT**	*TRAFFIC DENSITY**	*VISIBILITY CONDITIONS**				
		1	*2*	*3*	*4*	*5*
a	Light	A	AB	ABC	ABC FGH	Components of visibility 5 not yet determined
	Medium	ACE	ABCE	ABC EFG	ABCE FGH	
	Heavy	ACE Elements of component groups G and H may be appropriate.	ABC EG Elements of component group H may be appropriate.	ABCE FGH	ABCE FGH	
b	Light	AB	AB	ABC F Component group G may be appropriate.	ABC FGH	Components of visibility 5 not yet determined
	Medium	ABCE	ABCE	ABC EFG	ABCE FGH	
	Heavy	ABC EGH	ABCE GHI	ABCE FGHI	ABCE FGHI	
c	Light	ABCDG	ABCDG	ABCD FG	ABCD FGH	Components of visibility 5 not yet determined
	Medium	ABCD EG	ABCD EG	ABCD EFG	ABCD EFGH	
	Heavy	ABCD EGH	ABCD EGHI	ABCDE FGHI	ABCDE FGHI	

* See Table 2-1 for explanation of operational conditions.

4.5 Provision of Means of Control

4.5.1 Effective control of traffic on the movement area requires that:

a) the area is closed to all traffic except that which is cleared to enter,

b) the traffic conforms to recognized rules and procedures,

c) the control facilities provided are adequate for the aerodrome layout category, traffic density and visibility.

4.5.2 The movement area should be fenced or otherwise protected against unauthorized entry, and should be provided with controlled entry points. Authorized drivers should carry a pass, and vehicles cleared for entry to the movement area should clearly be identifiable as authorized to be there either by:

a) their specialist design,

b) their colour and markings,

c) having an approved identification token prominently displayed, in accordance with Annex 14, Chapter 6.

4.5.3 Procedures are considered in Chapter 5 of this Circular. Facilities for control within the movement area are:

1.	Signs	Annex 14, Chapter 5
2.	Vehicular traffic control lights	Currently no ICAO specifications
3.	Controlled barriers	Currently no ICAO specifications
4.	Surface markings	Annex 14, Chapter 5
5.	Signalling lamps	Annex 14, Chapter 5; Annex 2 Appendix A
6.	Radiotelephony facilities	Annex 11, Chapter 6
7.	Runway protection lights	Currently no ICAO specifications See 4.4.1 Note C
8.	Clearance bars	Annex 14, Chapter 5
9.	Stop bars	Annex 14, Chapter 5
10.	Non-visual surveillance systems	Currently no ICAO specifications See 4.6.2
11.	Monitoring apparatus	Annex 14, Chapter 8; *Aerodrome Design Manual*, Part 4

4.5.4 The disposition and usage of control facilities will be determined by aerodrome size and layout, traffic demand and weather conditions. Facilities applicable to critical operational conditions are shown at Table 4-1. The prime objectives will be to:

a) Leave runways free for the landing and take-off of aircraft by protecting them from unauthorized encroachment of vehicles or aircraft. Facilities used to achieve this objective include:

    Signs

    Surface marking

    Signalling lamps

    RTF facilities

    Runway protection lights

    Clearance bars

    Stop bars

    Non-visual surveillance systems.

b) Provide for the safe and expeditious movement of taxiing aircraft. Facilities used to achieve this objective include:

    Signs

    Surface marking

    Signalling lamps

    RTF facilities

    Clearance bars

    Stop bars

    Non-visual surveillance systems.

c) Allow for safe interaction between aircraft and vehicles on the apron. Facilities used to achieve this objective include:

    Signs

    Surface markings

    RTF facilities.

d) Permit maximum freedom of movement on the movement area consistent with safety on perimeter and access roads. Facilities used to achieve this objective include:

    Signs

    Road traffic control lights

    RTF facilities

    Controlled barriers for road traffic.

4.6 Surveillance - Visual and Non-visual

4.6.1 Visual Surveillance

4.6.1.1 In good visibility conditions the operational efficiency of the SMGC system at an aerodrome depends upon the controller's visual awareness of the traffic situation and on the contribution the pilot can make from his appreciation of the location of other aircraft, and of the general environment in which he is moving. The pilot normally is responsible for maintaining safe separation from other aircraft while taxiing; this he does by the "see and be seen" principle which, in general, works safely and well, (allowing for assistance and control by ATC as required). As visibility declines and the controller progressively loses sight of the aerodrome it is necessary for ATC to adjust its methods of control in order to maintain optimum safe capacity for the prevailing operational conditions. The amount of adjustment required will depend upon:

a) degree and trend of visibility deterioration,

b) size and complexity of the aerodrome,

c) traffic demand, and

d) control and guidance facilities available.

4.6.1.2 In accordance with the operational conditions described in Table 2-1, visibility condition 2 provides visibility sufficient for the pilot to taxi and avoid collision with other traffic on taxiways and at intersections by visual reference, but insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance. In a given location, the larger the aerodrome the more likely this condition will occur at the aerodrome. Under such visibility conditions normal air traffic demand could be expected but there may need to be restrictions on vehicular traffic on the manoeuvring area. Some constraint on capacity and increase in pilot and controller workload could be expected due to the inability of the controller to see all of the manoeuvring area, and the need to acquire information by RTF which, in good visibility conditions, would have been available from observation. Depending upon aerodrome size, the range of visibility encompassed by condition 2 is very wide, i.e., from 500 m to about 3 km, and control methods will need to be related to the level of visibility, the trend and other factors listed in 4.6.1.1.

4.6.1.3 At condition 3 level of visibility visual surveillance from the control tower can contribute in only a minor way to safe movement on the manoeuvring area, the chief visual contribution to collision avoidance being the pilot's ability to separate himself from a preceding aircraft on the same taxiway. Since the pilot's visual capability in this condition does not extend to crossing traffic, then each active crossing needs to be protected. The ATC workload generated and the capacity of the SMGC system will depend upon the number of active crossings which require to be negotiated.

4.6.1.4 In visibility condition 4 neither the ATC unit nor the pilot can prevent collision by action based solely on visual observation of traffic. It follows therefore, that for movement in these conditions the ATC unit must undertake the responsibility for providing separation. The form of separation and SMGC system capacity will depend upon the provision of SMGC components (see 5.6.3), and especially upon the number of segments, identifiable to both pilot and controller, into which a given route can be divided. For example, if a direct route from apron to runway represents 20 minutes taxiing time, and there is no means of division, the effective departure capacity is three movements an hour. If the route can be divided into four segments and the pilot's occupancy of each segment in sequence can be confirmed, then the capacity of the route is nine movements an hour.

4.6.2 Non-visual Surveillance

4.6.2.1 The problems of continuing aerodrome operations at an acceptable level of safety and capacity with visibility insufficient for the exercise of visual surface movement control led to the development of many techniques of non-visual surveillance. These techniques offer three basic forms of surveillance:

a) those characterized by a sensor which surveys the manoeuvring area and produces a facsimile display of the runways and taxiways together with the traffic upon them;

b) those which use a linear sensor to monitor the entry and exit points of traffic on defined divisions or "blocks" on the manoeuvring area surface, this being then indicated as block occupancy on a display;

c) those which use a form of small area sensor to indicate the occupancy of sectors of the aerodrome surface.

4.6.2.2 The most widely used method of non-visual surveillance is a) which, in the form of aerodrome surface surveillance radar, has been in operational use since the early 1960s. Ideally, this presents the controller with a radar derived plan of the aerodrome surface with the movement area clearly distinguished and traffic, whether moving or stationary, shown as radar blips. So equipped, the controller is to a considerable extent compensated for the loss of visual contact with traffic and can, by observation of the display, determine runway occupancy, taxiway movement, progress of vehicular traffic, etc.

4.6.2.2.1 Later developments of surface surveillance, or airport surface detection equipment (ASDE), radars have overcome some of the weather and attenuation problems which limited the effectiveness of earlier models, but the characteristics required of the radar entail the use of frequency bands which are sensitive to certain types of rain and fog. The result is a compromise between the need for high resolution and the need for good performance in precipitation. For various reasons it is not practicable to use ASDE to provide precise directional guidance or to achieve safe separation down to the limits achievable visually by pilots. The experience of States indicates the role of ASDE as that of a monitoring device rather than a means of positive control (see Chapter 8).

4.6.2.3 In the system at 4.6.2.1 b) taxiways are divided into defined lengths; methods of definition may include inductive loops and electro-magnetic beams. The system's logic keeps track of which blocks are occupied, and maintains identity if this is injected at the start of the movement. If the track lengths or blocks are designated also by stop bars a positive control and separation system is possible, the spacing between aircraft being determined by the size of the blocks. The main problems with this system are:

a) Except for a simple taxiway layout and light traffic, a computer would be necessary to monitor the sequence of block occupancy.

b) Block occupancy other than that established through the sensor (e.g., by a vehicle entering the block from the side) would not be indicated. If such a vehicle subsequently moved along the taxiway, route sequence and identity logic of other movement could be disturbed.

c) There is likely to be a heavy maintenance programme.

d) The system is complex and costly.

4.6.2.4 Small area sensors (4.6.2.1 c)) can be used to survey a particular area such as a runway, or to build up a mosaic picture of the airport. Specialized radars and other techniques are available (see Chapter 8). The main advantages of airport surveillance in this form are that the weather and coverage deficiencies of a centrally located single ASDE can be avoided. The chief disadvantages are those of complexity and cost.

4.7 Monitoring

4.7.1 Lighting

4.7.1.1 Surface movement guidance and control relies heavily upon lights for safe operations in reduced visibility and at night, and it is of vital importance that ATC should be aware of any discrepancies between the lighting selected on the lighting control panel in the control tower and the lights which actually show on the aerodrome surface. Normally in good visibility conditions at night it is not difficult to see whether the switches thrown bring on the appropriate surface lights, the problems arise in reduced visibility when the lights are not visible to the controller.

4.7.1.2 In conditions when direct visual appraisal or aerodrome surface lights is not possible, monitoring is usually carried out by:

a) observation of "mimic" or "tell-tale" lights on the lighting control panel;

b) checking of power supply and circuit state indicators.

It is important that lighting display panels are so engineered that they constitute effective monitors of surface lighting. Many lighting control panels provide a tell-tale indication only of the lighting selected and do not indicate whether the lights are actually lit. A feed-back mimic may indicate whether a particular group of lights is on or not, but may not reflect individual light failures which could be significant for movement in low visibility. Power supply and circuit state indications can provide information on percentage light outage without showing the specific nature of the failures. Problems can arise from failure of lamps to go out, as well as from failure to light, on selection. Safe and efficient ground movement in low visibility demands a monitoring system so designed that the controller is speedily aware, and continuously reminded, of any lighting failure which could affect safety or cause taxiing difficulties in the area for which he has responsibility.

4.7.1.3 Information is available in the *Aerodrome Design Manual*, Part 4 concerning the type of electical monitor indicating system which should be installed to verify instantly that all lighting equipment is in good working order. Sample monitor signals to indicate the operational status of an installation are:

a) installation out of order: tell-tale light off,

b) installation in order: tell-tale light on and steady,

c) installation faulty when switched on: tell-tale light blinking.

Different blinking frequencies can indicate different degrees of fault and a failure warning is accompanied by a sound alarm.

4.7.1.4 The extent and detail of monitoring that can be done in the control tower will depend upon the size and complexity of the lighting system. For an elementary layout full systems monitoring might be acceptable in the tower. At a large aerodrome, well equipped for low visibility operations, lighting control and monitor operations might need to be concentrated in a technical control room. The panel in the control tower would indicate a fault, the more sophisticated engineer's panel would indicate the precise nature of the fault and this information would be immediately relayed to the appropriate ATS unit.

4.7.1.5 To ensure the integrity of monitoring systems it is desirable that their power supply should be obtained from an autonomous source. (See Annex 14, 8.1 for specifications regarding the application and characteristics of a secondary power supply.) Maintenance is likely to be a light task, but one which must be carried out with regularity.

4.7.2 Non-visual Aids

4.7.2.1 With the introduction of non-visual techniques to SMGC the dependence of ATC upon the correct functioning of the non-visual aids will be such that, as with aerodrome lighting, a monitor system must be provided to indicate any malfunction.

CHAPTER 5 - PROCEDURES

5.1 Application of Ground Movement Traffic Rules and Regulations

5.1.1 Rules for the regulation of aircraft movements on the ground are contained in ICAO Annex 2 and PANS-RAC (Doc 4444-RAC/501), but equivalent rules for use by ground vehicles need to be provided and enforced. At aerodromes without an air traffic control service the rules and the need for strict adherence to rules becomes even more important.

5.1.2 Except in very poor visibility conditions, and then only at the expense of capacity, it is not practicable to exercise total control over all traffic on the movement area. Within the field of reasonable constraint which varies according to conditions and is described in other parts of this Circular, safety and expedition depends upon aircraft and vehicles conforming to standard ground movement rules and regulations. Appropriate authorities should establish suitable rules related to the operation of aircraft and ground vehicles on the movement area.

5.1.3 The rules and regulations for ground movement of vehicles on the movement area should encompass at least the following points.

A General

Only vehicles and/or equipment which have a specific and necessary function to perform in connexion with aircraft or aerodrome facilities should be granted admission to the movement area.

B Requirements of vehicles and/or equipment operators

1. A vehicle operator *shall:*

   a) be conversant with these rules and regulations or be in the company of a person who is conversant with them;

   b) be capable of reacting to visual signals, e.g., be able to distinguish between the colours of the signals;

   c) give way to aircraft at all times;

   d) obtain ATS clearance prior to entering the manoeuvring area and comply with the terms and limitations of the clearance;

   e) follow specified routes and guide lines and not encroach safety lines;

   f) approach aircraft with utmost care, especially when the aircraft engines are running and its anti-collision lights are operating;

   g) obey movement area speed restrictions;

   h) where appropriate, be experienced in the operation of RTF equipment and capable of correctly reacting to RTF messages;

i) where appropriate, maintain a continuous listening watch on the ground movement control (GMC) channel, requesting ATS clearances as required by aerodrome regulations and complying with ATS instructions; and

j) be familiar with the aerodrome layout and the signs and signals used on the aerodrome.

2. A vehicle operator *shall not:*

a) position a vehicle so that it interferes with the movement of aircraft;

b) pass close behind an aircraft with its engines running and its anti-collision lights operating, or position a vehicle in a jet blast or propeller slipstream;

c) operate a vehicle so that it crosses aircraft control signals, stop bars or control lines without ATS authorization;

d) operate a vehicle in reverse gear, expect as required for aircraft manoeuvring or servicing;

e) leave a vehicle unattended; and

f) operate a vehicle during the hours of darkness or periods of restricted visibility unless it is equipped with suitable lighting (see C, 1 c) below).

C <u>Requirements of vehicles and/or equipement</u>

1. Vehicles and equipment *shall be:*

a) fitted with a suitable vehicle obstruction light visible through 360 degrees,

b) equipped as per Annex 14, and

c) fitted with at least two front lights (white) and two rear lights (red) if operated during the hours of darkness or during periods of restricted visibility.

2. Trailer trains must not exceed the length specified by the aerodrome authority and they must have serviceable overrun and parking brake systems. They must carry red reflectors at the rear and along the sides as appropriate if used in low visibility or at night.

5.2 RTF Procedures and Phraseology

5.2.1 General

5.2.1.1 The importance of correct use of language and phraseology and of adherence to associated procedures cannot be overemphasized. The safety and efficiency of ground movement depends not only upon the clarity of understanding between the controller and each of the pilots or vehicle operators in contact with him, but also upon the intelligent co-operation from them. Such co-operation requires an understanding of the over-all situation which, in whole or in part, is gained by monitoring RTF transmissions.

5.2.1.2 Annex 10 and PANS-RAC contain the recognized RTF procedures and phraseology. It was accepted from the beginning that these could not be exhaustive, and that with the passage of time new procedures and phraseologies would need to be recognized The development of SMGC systems has produced the need for additional phraseology.

5.2.2 Phraseology

5.2.2.1 RTF phraseology associated with surface movement guidance and control systems is contained in the PANS-RAC, Part 9. However, it may be necessary to develop additional phraseology to meet specific requirements not presently covered in the PANS-RAC.

5.3 Traffic Sequencing Procedures (aircraft in motion)

5.3.1 Sequencing is the arrangement of taxiing aircraft into the most operationally effective order. For departures this means the order which offers the best departure rate and least over-all delay. For arrivals it entails arranging a sequence which is convenient for apron entry and subsequent parking, and causes minimum disruption to departures.

5.3.2 At many aerodromes the broad strategy of departure order is controlled by gate holding procedures (see 5.4). Sequencing of departing aircraft in motion is a means of adjusting to late changes in the order. Sequencing methods will vary according to aerodrome layout, type and quantity of traffic and weather conditions, particularly visibility. Sequencing methods include:

a) allocating taxi routes of different length,

b) allocating priority at intersections (holding en route),

c) by-passing at the holding point,

d) entering the runway for take-off from an intermediate point,

e) entering the runway to backtrack to take-off point,

f) delaying exit from apron.

5.3.3 At most aerodromes the necessary interval between landings provides adequate spacing between arrivals at the apron. When there is a requirement to control the timing or the order of traffic taxiing to the apron the methods employed will be as in 5.3.2 a) and b). The application of a) may be by ATC direction after leaving the runway, or by suggesting that an aircraft take a particular turn-off point.

5.3.4 Apron control may be carried out by:

a) an autonomous unit (aerodrome authority or operating company),

b) the ATS,

c) the ATS and the autonomous unit, e.g., vehicles and apron management are carried out by the aerodrome authority whereas RTF contact and aircraft-to-aircraft separation are carried out by the ATS.

In the first case the desired order of entrance to the apron and stand allocation may need to be indicated to the ATS. In the second, the ATS itself would retain control and maintain awareness of the apron situation. The third case would call for co-ordination between the ATS and the apron authority.

5.4 Gate Holding Procedures

5.4.1 When it is known that a planned departure will be subject to significant delay due to factors such as:

a) en-route or terminal clearance limitations, or

b) weather conditions below pilot's operating limits,

there are advantages in delaying engine start-up and absorbing the delay on the apron. This technique saves fuel and engine running time, and reduces the probability of the restricted aircraft blocking the route of other aircraft which are not subject to delay.

5.4.2 A method of dealing with 5.4.1 a) is for the ATC service to operate a "request engine start" procedure with intending departures, and to maintain a close liaison with the air traffic control centre on the length of delay applicable on the routes served by the aerodrome. On receipt of the "request engine start" transmission the controller will consider the required departure time in relation to likely taxiing time and delay at the holding point, and issue an engine start-up time calculated to absorb most of the residual time with engines off. For example,

Request engine start 10.10

Designated take-off time 10.42

Average taxiing time to holding point .... 8 minutes

Estimated taxiing contingency .... 6 minutes

Time from "engine start" to "ready to taxi" .... 4 minutes

Instruction given "Start engines at 10.24".

5.4.3 With 5.4.1 b), since a pilot's operating limits are normally not known to the ATC service, the onus is placed on the pilot to defer his call for engine start until conditions are within his departure limits or, possibly, one increment below such limits. In this way, aircraft arrive at the holding point in the order of their ability to depart.

5.5 Low-Visibility Procedures

5.5.1 Under low-visibility conditions special procedures such as the following are needed to ensure safety of movement.

a) No vehicles to be permitted on the manoeuvring area unless in radiotelephone contact with the ATC service.

b) Runway access and exits to be limited to those essential for aircraft movement.

c) All unguarded gates and/or entrances to the movement area to be kept locked and to be inspected at frequent intervals.

d) Procedures to ensure that airlines and other organizations with movement area access to be warned of the reduced visibility procedures. This is of particular importance in those cases where companies exercise control of their own movement area gates.

e) Non-essential working parties and/or vehicles to be withdrawn from the movement area. This requirement presupposes that the ATC service maintains a strict register and control of vehicle movement and location at all times so that there can be certainity of complete withdrawal when weather deteriorates.

Notes:

1. *Particular attention should be given to areas, such as maintenance areas, where there may be intensive vehicle movement that could inadvertently encroach upon the manoeuvring area.*
2. *Contingency procedures should include restricted visibility operations.*

5.5.2 In declining visibility the ATC procedures and the aerodrome protection measures associated with low visibilities, such as visibility condition 4, may need to be put into operation at higher limits than the listed threshold of the visibility condition, in order to avoid the following:

a) the lower visibility being experienced while aircraft and vehicles on the manoeuvring area are still being operated to the procedural requirements for a higher visibility; and

b) the manoeuvring area being inadequately protected for the length of time it takes to implement the protection measures.

In order to facilitate this, a measurable "trigger point" for initiation of low visibility procedures needs to be established, together with a similar predetermined point for termination of the procedures.

5.5.3 In most cases the trigger point will need to be related to the reaching of a specified visibility in deteriorating weather. The selection of an initiating visibility will be governed by the expected rate of weather deterioration and the time it takes to complete manoeuvring area protection measures, thus the lead time can be determined only by local knowledge. Experience has shown that it is better to go into full protection at an early stage in worsening weather, and have for a time an over-protected system, than it is to be late in application and be left for a period of time with an operationally ineffective aerodrome.

5.5.4 Termination of low visibility procedures will similarly be governed by the reaching of a given visibility, but now in an improving weather situation. As an example, one major aerodrome initiates low visibility procedures at 600 m Runway Visual Range (RVR) in reducing visibility and terminates them when 800 m RVR is reached on a firm trend of improvement.

5.6 Application of Intersectional and Longitudinal Separation Measures

5.6.1 General

5.6.1.1 As there is no technique of ATC applied separation between taxiing aircraft which approaches the efficiency of that which can be applied by pilots in good visibility it follows that, allowing for ATC action on priorities and such other assistance and control that circumstances may dictate, the interests of both ATC and pilots are best served by leaving responsibility for collision avoidance with the pilot while conditions are such that he can safely fulfil the function. At most major aerodromes this will be for more than 95 per cent of the time.

5.6.1.2 As is recognized in the visibility categorizations in this Circular, see-and-be-seen separation can continue after the controller has lost sight of the manoeuvring area, and can continue for in-line following traffic at lower visibilities than for traffic on joining or crossing routes. No one mode of surface movement control is applicable to all weather conditions, and the factor which dictates the choice should be taxiway visibility, but taxiways are not instrumented for visibility measurement, and RVRs are normally used as a guide to what is likely to be experienced en route to and from the runway. Over the surface of an aerodrome there can be considerable variation in visibility conditions. Thus reports from pilots and local knowledge of weather peculiarities can be of value in supplementing the RVR readings.

5.6.1.3 The modes of control include the following:

a) see-and-be-seen with "give-way" intersection control; action from ATC as and when necessary;

b) see-and-be-seen with visual ATC directed priority at intersections;

c) stop bar intersectional control, see-and-be-seen elsewhere;

d) stop bar intersectional control and ATC assistance in longitudinal separation.

In deteriorating visibility (see 5.5) positive separation measures may need to be taken in advance of the specified visibility criteria in order to ensure that aircraft are not left at visual spacing standards in visibility conditions below that at which see-and-be-seen can safely be maintained.

5.6.2 Separation at Intersections

5.6.2.1 "Give-way" intersection control and "visual ATC directed priority" are commonly used methods which do not necessarily demand markings or lights at the intersections. Control of traffic at intersections in the conditions postulated by visibility condition 3 or lower demands that:

a) surface traffic is able to recognize the intersection and stop, when signalled to do so, allowing adequate clearance for crossing movement,

b) ATC is able to maintain a sequential record of traffic movement, and clear or hold aircraft and vehicles to maintain the maximum expedition consistent with safety.

5.6.2.2 It follows that markings and/or lights must protect each approach to an intersection used in these conditions, and that:

a) pilots and drivers must obtain crossing clearance at every intersection, or

b) the system, under the control of ATC, must indicate without ambiguity which movement is to hold and which to cross.

The restriction and ATC workload per movement implied by a) confines the method to aerodromes with light traffic and/or few intersections. If medium or heavy demand is to be catered for at aerodrome of layouts b or c. More complex control such as controlled centre line lighting linked to stop bars will be needed. When a route is set-up on such a system, crossing routes are automatically barred; this is of great value where there are complex junctions.

5.6.3 Longitudinal Separation (Evaluation by the United Kingdom)

5.6.3.1 The minimum safe separation limit between following aircraft is a function of their differential speeds, with the worst case being that of a following aircraft closing on a stationary one. Research carried out by the United Kingdom* into low visibility movement on aerodromes indicates that for an aircraft moving at 10 to 15 knots a visibility equating to 150 metres RVR is the lowest at which it is reasonable to expect a pilot to be able to see a stationary aircraft ahead of him, and to brake to a stop with reasonable separation from that aircraft. This allows for the present brightness of aircraft tail lights, the fact that the position of the light may not be known to the following pilot, and that his eyes are likely to be focused near the taxiway centre line (see Figure 5-1).

5.6.3.2 In the absence of non-visual taxi guidance, the lower limit of surface operation must be the visibility below which the pilot is unable to taxi on visual reference. Clearly, this will depend upon a number of factors including surface markings, type and spacing of taxiway lights and lamp technology generally. Some aircraft flight decks offer a better angle of vision for taxiing than others and a pilot who is familiar with an aerodrome layout is likely to be capable of taxiing there at lower visibilities than one who is not a regular user. In the United Kingdom the centre line and stop bar system has been used by air transport aircraft down to 75 metres RVR equivalent, but considering that at least three lamps need to be seen to define a path, and that stop bars need to be recognized in time to bring the aircraft to a halt before crossing them, the practicalities would imply that this is near the lower limit of visual guidance.

5.6.3.3 Allowing for the introduction of longitudinal separation measures in advance of the actual need (see 5.5.1), and some degree of spread about the limits of operation, then application of longitudinal separation may need to take place in visibility of, for instance, less than 300 metres. Aerodrome authorities will need to consider the occurrence and persistence of visibilities in this lower range, the likely traffic demand in these conditions, and the cost of provision for such movement as against the benefits obtained.

5.6.3.4 The value and limitations of ASDE for the purpose of longitudinal separation is discussed in 4.6.2 and Chapter 8. Cost and complexity virtually rule out linear or small area surveillance systems for a complete aerodrome (although these may find application to limited areas having special problems, e.g., a taxiway shaded from the control tower by a building), thus if the demand to be catered for is in excess of the limited control capacity of ASDE, then visual control provision is required. A practicable system of visual guidance and control offered by current technology is the switched taxiway centre line light system with integrated stop bars.

5.6.3.5 As discussed in 4.6.1.4 the capacity of a stop bar defined block control system is related to the number of blocks into which a given route can be divided, but the experience of the United Kingdom suggests that the ATC workload involved in switching lights, RTF communication and problems of maintaining identify also can act as a constraint on the amount of traffic which can safely be controlled. The ability of a pilot to identify his position by reference to illuminated location boards is a help, and ASDE is essential to the achievement of maximum feasible capacity, but unless maintained identification and automated block control is also provided, the capacity of a block control system cannot be expected to approach that of normal good visibility operations (see Chapter 8). Studies into the provision of position and identity information have been carried out in several States, but financial considerations and complexity have so far discouraged developments.

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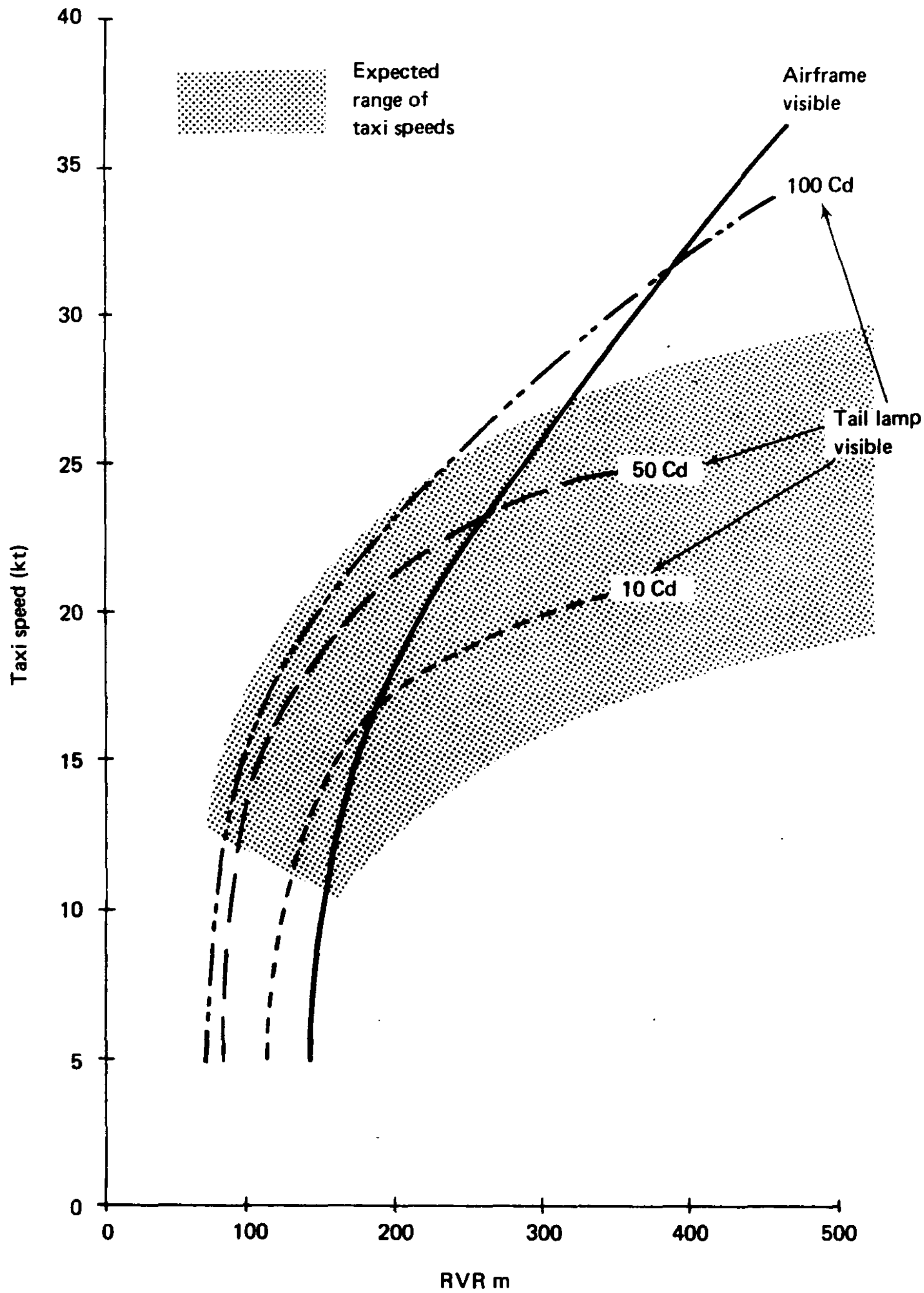
* Report in *Royal Aircraft Establishment Technical Reports 72225* and *73028*.



Research by the United Kingdom into problems associated with the surface movement of aircraft in low visibility resulted, inter alia, in this graph which represents the lowest visibility (as RVR) versus speed in which a pilot can be expected to see the tail, or tail light, of a preceding stationary aircraft, and be able to stop at 0.1g, to avoid collision, with up to one second recognition/reaction time.

Figure 5-1. Relationship Between Safe Taxiing Speed and Visibility (RVR)

(From *Royal Aircraft Establishment Technical Report 73028*)

5.6.3.6 The longitudinal separation provided by ATC will need to be related to the control facilities provided and, therefore, will be specific to each aerodrome. The separation provided by ATC must be such as to ensure that:

a) a following aircraft does not conflict with its leading aircraft,

b) a following aircraft does not affect the manoeuvring requirements of its leading aircraft,

c) a following aircraft is not affected by the manoeuvring or power applications of its leading aircraft.

5.6.3.7 Where an aerodrome is equipped with controllable taxiway centre line lights and integrated stop bars, as recommended in Annex 14, separation can be achieved by providing taxiing aircraft with a continuous centre line of lights to its clearance limit which should be defined by a red stop bar. The clearance limit, in every instance, will be based upon the known position of the previously cleared aircraft and will comply with the requirements of 5.6.3.6 a), b) and c). A "known position" may be a positive location identification by a pilot, a radar derived position check or, preferably, an aircraft position report confirmed by radar. Onward clearance must be sequential, and consist of RTF clearance to the next (defined) point, confirmed by the suppression of the stop bar and illumination of centre line lights to the next stop bar. The system demands a separation minimum of one block between aircraft or vehicles under control.

5.7 Emergency Procedures

5.7.1 Aerodromes will have established aerodrome emergency plans in which ATC will be involved. An aerodrome emergency plan is intended to ensure proper and immediate co-ordination of aerodrome services with other appropriate agencies that could be of assistance in responding to emergencies occurring on or in the vicinity of an aerodrome. Emergency situations envisaged include:

a) aircraft emergencies,

b) acts of unlawful interference with civil aviation,

c) occurrences involving dangerous goods,

d) structural building fires.

ATC would of necessity need to be involved in their capacity as controllers of surface movement, in any such plan, together with many other departments, services and agencies.

5.7.2 In the event of an emergency situation on the movement area occurring in good visibility conditions it may be assumed that the ATC ground movement controller will either observe the incident, or be among the first to know of it, and that he will initiate emergency action. If an aircraft is involved the ATC service will supply the rescue and fire-fighting services with the location and type, take action to safeguard other traffic on the movement area, restrict further entry into the area and maintain contact with the emergency command post.

5.7.3 If an emergency occurs on the movement area in poor visibility and at visibilities below the limit of ATC visual surveillance, the pattern of events is likely to be:

a) realization that an incident has occurred,

b) "freezing" of traffic on the movement area,

c) initiation of emergency action,

d) discovery of the location of the incident or accident,

e) safeguarding of traffic on the movement area,

f) restriction of entry of other traffic,

g) assistance to rescue and fire-fighting vehicles,

h) liaison with emergency command post.

5.7.4 The recognition by the ATC service of an emergency situation may result from:

a) RTF message from aircraft involved,

b) RTF message from other aircraft,

c) information from vehicles, security guards or other persons,

d) visual indications (e.g., a glow through the fog),

e) aural indications,

f) failure of aircraft to respond to RTF transmissions,

g) aerodrome surface surveillance radar indications.

With the exception of f), determination of location may be determined by any one, or a combination of, the means listed in a) to g).

5.7.5 ATC action following recognition of an incident or accident and determination of the location will depend upon the nature and severity of the occurrence. Responsibilities may include:

a) switching of taxiway lights to provide guidance for emergency vehicles,

b) use of surface surveillance radar to assist emergency vehicles,

c) the re-routing of other traffic clear of the occurrence area,

d) re-arrangement of route system to permit continuation of aerodrome operations,

e) assessment, and indication to those concerned, of the surface movement capacity in the new conditions,

f) facilitation of traffic movement concerned with the removal of damaged aircraft or vehicles,

g) arrangement for the inspection of the occurrence area and assessment of damage to aerodrome surface, lights and other facilities.

CHAPTER 6 - MAINTENANCE OF SMGC SYSTEMS

6.1 Routine Inspection

6.1.1 The various components of the SMGC system comprising route guidance are listed in 4.4.1. All these components will require routine inspection, cleaning, servicing and maintenance in common with other elements of the aviation ground lighting. Guidance on the preventive maintenance of illuminated visual aids is contained in Annex 14, Chapter 9, and in the *Aerodrome Design Manual,* (Doc 9157-AN/901), Part 4 - *Visual Aids,* Chapter 1.

6.1.2 The integrity and reliability of the SMGC system should match the other visual and non-visual navigational aids. Routine re-painting programmes will suffice to ensure that those components of the system comprising runway and taxiway markings, taxi holding position markings and signs are adequate for the conditions of visibility for which they are intended. The integrity of the SMGC lighting components will depend upon the design of both the internal aerodrome circuits and the external power supply.

The reliability of the system will depend upon the degree of inspection carried out and the programme of preventive maintenance employed. The acceptability of unserviceable elements within the visual guidance control system will depend upon the spacing of the taxiway centre line and stop bar lights, and the visibility limits within which the system is designed to provide guidance.

6.1.3 Special Checks

Where visual aids are provided for operations below visibility condition 2, special inspections should be carried out whenever possible before the low visibility operations are initiated. These inspections should ensure that serviceability is sufficient to provide continuous guidance and that no two consecutive taxiway centre line lights or more than one stop bar lamp on each side of the taxiway centre line have failed.

6.1.4 Daily Checks

Inspections within the movement area should be carried out as frequently as possible and with a minimum frequency as follows:

Runways - daily at first light and at dusk if night flying is to take place

Taxiways - daily for those in normal regular use

Aprons - daily at first light.

Checks should include inspection of the following aids:

a) Signs (route)

b) Runway centre line marking

c) Taxiway centre line marking

d) Holding position marking

e) Runway edge lights

f) Runway centre line lights

g) Taxiway edge lights

h) Taxiway centre line lights

i) Runway protection lights

j) Clearance bars

k) Stop bars

l) CAT II/III holding signs

m) Information signs (Annex 14, Chapter 5)

n) Obstruction lights within the manoeuvring area.

Attention should particularly be directed to serviceability of mandatory and information signs, conspicuity of taxiway markings, stand identification numbers and parking guidance markings.

6.1.5 Weekly Checks

Weekly checks should be carried out on the following:

a) SMGC route control equipment

b) Docking guidance systems

c) Vehicle anti-collision lights

d) SMGC monitor system.

6.1.6 General

6.1.6.1 Longer term periodical checks should be carried out in accordance with the guidance provided in the *Aerodrome Design Manual*, (Doc 9157-AN/901), Part 4 - *Visual Aids*.

6.1.6.2 Where high intensity taxiway centre line and stop bar lighting is provided for operations below visibility condition 2, particular attention should be paid to cleanliness of taxiway centre line and stop bar lights, and in the conspicuity of taxiway centre line and apron guidance markings.

6.1.7 Inspections After Unserviceability

Special inspections should be carried out after major maintenance or snow clearance operations and before the section of affected taxiway is returned to operational use.

6.2 Routine Maintenance

6.2.1 The extent to which routine maintenance can be combined with routine inspection will depend upon local arrangements. Where personnel carrying out routine inspection and light cleaning are skilled electricians, maintenance as necessary should be included in the daily checks. If the inspections are carried out by operational staff who are not qualified in maintenance, close liaison will be necessary with the appropriate aerodrome maintenance personnel to ensure that follow-up action is taken as necessary.

6.2.2 Daily maintenance at busy aerodromes with high sustained movement rates is difficult to arrange and work within the movement area may have to be carried out at night. Work schedules should be prepared for replacement of burnt out lamps or rectification of circuit faults, as revealed by the daily checks. At aerodromes with a large and complex taxiway system, it may be necessary to have more than one maintenance team operating on fault rectification within the movement area during periods when the traffic pattern is low.

6.3 Special Fault Rectification

6.3.1 In addition to the routine maintenance, it will be necessary at busy and complex aerodromes to have personnel available for special fault rectification when failures occur which affect the ability of the system to meet the operational requirement. This will be essential where a centralized control system has been provided and operations are being carried out in restricted visibilities.

6.3.2 Special fault rectification will be necessary where consecutive lamp failures have occurred within the taxiway centre line lights or stop bars, where runway protection lights have failed or where lamp failure has occurred affecting mandatory signs.

6.3.3 When operations are occurring in restricted visibility conditions and faults occur, it will be necessary to consider whether the system can continue to give safe guidance and control without immediate fault rectification, or whether operations have to be restricted while the fault is rectified. Aerodrome operators will take account of the need to ensure that when low visibility operations are being conducted, only in the most exceptional circumstances should ground vehicles be permitted to enter the manoeuvring area for this purpose, and when they do so, safe separation between vehicles and aircraft must be ensured.

6.3.4 Where SMGC systems utilizing block separation have been provided, the equipment maintenance will depend upon the control computer system in use. A typical existing system employs a dual control computer providing a fully updated standby which is available to take over from the main equipment in the event of failure and is able to communicate with one of several associated control line signalling units. The taxiways and runways are divided into traffic blocks, each provided with green centre line lighting and terminating in a traffic bar. All taxiway lights are remotely controlled by a system providing override safeguards to ensure that conflicting routes are recognized as invalid. For example, an override is provided so that a taxiway route could not be set up across a runway without being accepted by the ATC aerodrome controller. In order to provide adequate control and to ensure safety is maintained in a high traffic density environment, adequate on-call maintenance has to be provided to ensure that rectification of faults is carried out by a first line servicing team on a 24-hour basis.

6.3.5 Computer system faults require attention by specialist staff. Since the system is duplicated, normally full tests can be deferred to periods of light traffic movement, caution being necessary to avoid selection of routes without agreement of the lighting control operator. Faults can be traced through the route selection relays and cable terminations to field circuits. First line servicing of control equipment by printed circuit board exchange can be diagnosed and repaired as necessary. Maintenance personnel should be available to clear system faults and intermittent problems of a random nature as they occur.

6.3.6 A typical staff requirement for SMGC equipment maintenance has been found to be an inspector, an engineer, a technician and a special tradesman (craftsman). Computer systems maintenance is carried out by contract with a specialist computer maintenance organization.

CHAPTER 7 - REVIEW OF SYSTEM AND IMPROVEMENT

7.1 Regular reviews of the SMGC system should be carried out to ensure that the system is fulfilling its intended task, and to assist the aerodrome authority in planning ahead for the orderly introduction of a more advanced system and the necessary supporting facilities, as and when warranted. Ideally, a master plan will have been prepared for the aerodrome in the early stages of its development, in which case a review of the system at regular intervals will serve to monitor the development of the aerodrome in relation to the time frame employed in the master plan.

7.2 In all cases, the SMGC system will need to be reviewed under one or more of the following circumstances:

a) the volume of traffic increases significantly,

b) the category of operations served by one or more runways is improved,

c) the aerodrome layout is changed, i.e., new runways, taxiways, or aprons are brought into operation.

It is also conceivable that ATS restructuring of the airspace surrounding the aerodrome, or other external circumstances, may affect the flow of traffic to and from the aerodrome, and consequently the pattern of movements on the runways, thereby influencing the SMGC system requirements.

7.3 Apart from traffic movement counts, the extent to which increased traffic volume is causing deterioration of the effectiveness of the SMGC system may be determined by the appearance of the following symptoms:

a) a marked need for increased vigilance in the visual surveillance of surface traffic movements, generated by the number of movements occurring simultaneously throughout the aerodrome complex,

b) a marked increase in the loading on the communications channels used for SMGC,

c) an increase in the number of problems occurring at crossing points and runway/taxiway intersections, requiring intervention by the controller and thereby contributing to the increase in radio communications,

d) the occurrence of bottlenecks, congestion, and delays in surface traffic movements.

7.4 Recognizing that over-control of surface movement traffic tends to retard the traffic flow, the aim should be to ensure as far as possible that aircraft released from the apron to the runway for take-off, or directed from the active runway to the apron after landing, are provided with adequate route guidance, and that the route itself is protected up to the clearance limit given to the aircraft concerned. SMGC systems based on this concept will have the following advantages:

a) The loading on communications channels will be significantly reduced, and will be limited almost entirely to the transmission of brief taxi clearances.

b) Visual surveillance requirements of the movement area will be eased, and confined mainly to the monitoring of traffic at significant crossing points which would also be clearance limits.

c) Pilot confidence in such a system would further facilitate the control task by encouraging the absorption of ATC delays on the apron, or in holding bays, until shortly before departure clearance is received, thus serving to reduce the over-all volume of traffic involved.

7.5 Thus, an update of the SMGC system to accommodate an increased volume of surface traffic movements in low visibility will entail a gradual conversion from a system based on "see and avoid" to a system employing more formal control methods, comparable to the different methods employed by the air traffic services in handling VFR and IFR traffic in the airspace. For example, as the system develops:

a) taxiway centre line lighting will be needed to augment centre line marking for route guidance,

b) controllable centre line lighting may be needed to augment route indicator signs,

c) traffic signals and/or stop bars or other suitable signals may be required to define clearance limits, intersections, etc.,

d) a uniform and complete system of taxiway designators will be needed in order to permit clear and concise definition of the route to be followed,

e) additional ground control communication frequencies may be needed in order to segregate traffic flows (e.g., departures, arrivals, ground service vehicles, etc.),

f) aerodrome surface surveillance radar may be needed.

7.6 When SMGC system improvements are associated with an upgrading in the low visibility usage of runways, the emphasis will be on the additional measures necessary to accommodate surface traffic movements in reduced visibility.

7.7 Primary consideration will need to be given to ensuring protection of the runways themselves from unauthorized or inadvertent entry, either by aircraft or vehicular traffic. This can be achieved effectively through the use of stop bars or other equivalent traffic control signals at each and every access route to the runway. Such a system also provides additional safety for flight operations under any conditions, particularly at night and at busy airports with multiple runway operations and an associated high volume of surface traffic.

7.8 Depending upon the visibility category of operations to be served by the runway, it will be necessary to augment the route guidance system, probably by means of centre line lighting and/or high intensity lighting. A means of control by selective switching of the lighting will be a desirable asset as a means of facilitating the ground traffic control function. Provision must also be made for the control of traffic (both aircraft and ground vehicles) at intersections. Location identifiers that are effective in the reduced visibilities to be catered for will also be required.

7.9 Again, depending upon the visibility conditions, it may be necessary to extend the lighted route guidance system on to the apron (with suitable identification of the taxiway/apron intersection), so that continual guidance is provided up to the point where the apron parking or docking guidance system is visible to the pilot.

7.10 In conclusion, for operations in reduced visibilities, it will be necessary to provide the ground movement controllers with an effective radar surveillance system capable of scanning the entire movement area. Such a system should be intended primarily for surveillance and the tactical resolution of traffic conflicts, with the primary guidance and control of traffic being accomplished by the procedural methods previously described.

CHAPTER 8 - POSSIBLE FUTURE DEVELOPMENTS

8.1 Limitations of Present Systems

8.1.1 General

8.1.1.1 The basic requirement of a SMGC system is that it should provide for the safe surface movement of aircraft and necessary vehicles down to the minima at which aircraft are permitted to land or take-off at an aerodrome, and possess a capacity for guidance and control which is equal to the likely traffic demand in any operational condition. In general, and allowing that there is room for improvement at all levels, the main shortfall in SMGC safety margins and capacity occurs in low visibility, and it is in this area that the main effort of research and development is likely to be concentrated.

8.1.1.2 Rarely is the provision of SMGC facilities at an aerodrome geared to a specific traffic demand and visibility condition. The normal condition is an inheritance of piecemeal development and local initiative which, coupled with the various operators' methods and aircraft type constraints, produces for the pilot a variety of SMGC aids and procedures, and for the controller a wide range of aircraft movement capabilities. Prominent in any list of limitations of present systems must be the uncertainty caused by lack of standardization.

8.1.1.3 Chapter 4 lists the facilities and services assessed as capable of meeting the different levels of traffic demand and aerodrome complexity in a range of visibility conditions reaching down to the lowest at which visual guidance is feasible. The development of the systems in Table 4-1 is designed so that each new element overcomes a deficiency in the previous provision, but no facility or procedure will be adequate for all conditions likely to be encountered. The degree of disadvantage, and thus the stimulus for improvement, will vary from aerodrome to aerodrome. For example:

Painted surface marks:	may be obscured by snow or sand.
Signalling lamp:	has little or no value in concentrated traffic, medium/large airports or low visibility.
VHF radiotelephony communications:	liable to misinterpretation, and in low visibility, to saturation at lower traffic levels than normal due to its greater use.
Taxiway centre line lights:	may be obscured by snow or sand.
Taxiway edge lights:	limited guidance value in low visibility.
Centre line light control (manual):	workload involved in switching and selecting can act as constraint on capacity.
Stop bars, clearance bars:	may be obscured by snow or sand.
Aerodrome surface surveillance radar:	sensitive to certain weather conditions and offers problems of maintenance of identity.

Low visibility movement area protection measures: often difficult to organize reliably, particularly if there are long intervals between periods of application.

The frequency of occurrence and persistence of adverse conditions, and their effect upon aerodrome operations will be a factor contributing to selection of facilities, specialized modification and procedural methods, but except at aerodromes liable to extreme climatic conditions, SMGC development is likely to be mainly concerned with ensuring that this service does not become the constraining element in low visibility conditions.

8.1.1.4 Given that an aerodrome is adequately equipped with visual aids, the provision of an aerodrome surface surveillance radar can make a most valuable contribution to the safety and efficiency of ground movement control in reduced visibility and at night; optimum capacity for the conditions is unlikely to be achieved without it. Aerodrome surface surveillance radar permits a continuous check on runway occupancy and taxiway usage, it allows rapid appreciation of lighting control requirements and facilitates clearances for aircraft and vehicles. In emergencies it can play a part in the expeditious movement of emergency vehicles and the safe disposition of other traffic; but it too has its limitations.

8.1.1.5 The accuracy of manoeuvre required on taxiways, and which can satisfactorily be defined by lights and lines, is far more precise than could be provided by aerodrome surface surveillance radar direction. Similarly, although surface surveillance radar can provide precise positional information to the controller, it is a very difficult task for the controller to position an aircraft precisely using such radar. It is necessary for the pilot to be able to comply with the surface movement control instructions given by the controller without the radar being used to provide directional guidance, or to afford any ultimate prescribed separation.

8.1.1.6 At a major aerodrome a large part of the manoeuvring area can be obscured from the control tower while visibility is still within the limits at which traffic can be expected to operate at the normal level of demand, i.e., in visibility condition 2. In these conditions, while the usefulness of aerodrome surface surveillance radar could scarcely be exaggerated, the feasibility of monitoring in detail all traffic likely to be present on the manoeuvring area is nil. There are two main problems.

a) The workload and concentration involved in detailed monitoring is very high and restricts control capacity.

b) There is a limit to the amount of traffic which a controller can, on an surface surveillance radar display, identify and mentally maintain the identification for an extended period.

In summary, aerodrome surface surveillance radar has a valuable contribution to make to the safety and efficiency of surface movement control in reduced visibility and at night, but it is an adjunct and not an alternative to adequate provision of visual guidance and control facilities and manoeuvring area protection measures.

8.1.2 Capacity

8.1.2.1 There is currently no facility, or combination of facilities, which compensates fully for a controller's loss of visual contact with the aerodrome surface and the traffic on it. Information derived by other methods such as RTF communication of aerodrome surface surveillance radar is rarely as comprehensive or informative, and is far less economic in terms of the workload expended in its acquisition. In a manual system the ATC workload per movement increases as visibility decreases and the traffic handling capacity of the aerodrome control service declines. On other than simple route systems the capacity curve can fall sharply in visibility condition 3 when separation at intersections becomes the responsibility of the controller.

8.1.3 Guidance and Control

8.1.3.1 High intensity centre line lights, spaced at appropriate intervals as specified in Annex 14, are capable of providing guidance down to and including visibility condition 4, the lowest visibility condition at which visual taxiing movement is practicable. Used in conjunction with stop bars, both guidance and control to the lowest visual limits is feasible. In essence, guidance and control is accomplished by providing a ribbon of lights to the clearance limit which is denoted by a stop bar; a section of lights beyond the stop bar will extinguish when the bar is lit. With onward clearance the stop bar is switched off and the centre line of lights illuminated to the next clearance limit. In low visibility a non-visual surveillance system can provide the information necessary for determination of route, priority and clearance limit.

8.1.3.2 Such a system can reduce the usage of RTF and offer benefits in other than low visibility conditions, but as a manually operated facility it suffers from two major drawbacks.

a) At a large and busy aerodrome the workload involved in the manual switching of surface lights limits the capacity of the system and this may not meet the demand.

b) The identity of each aircraft needs to be maintained throughout its pattern of movement: the centre line and stop bar system, in itself, does not meet this requirement.

8.1.3.3 Present SMGC systems rely heavily upon RTF. RTF is an extremely flexible tool of control, but suffers from the disadvantages of:

a) being easily jammed by one faulty transmitter,

b) messages being liable to misinterpretation,

c) having a finite verbal capacity, which entails a reduction in controlled movement capacity as RTF per aircraft increases (as it does in deteriorating weather or abnormal operational conditions).

8.2 Automated Non-Visual Concepts

8.2.1 Guidance and Control

8.2.1.1 A prerequisite for automation of a SMGC system is a reliable method of identifying and tracking all movements on the manoeuvring area. This will involve interface with terminal area automation systems. As operational weather minima are reduced the need for non-visual surveillance techniques becomes more important, and with increasing movement rates in these lower visibilities the requirements of these techniques becomes more demanding. At a large and complex aerodrome automation may offer advantages even in clear weather conditions.

8.2.1.2 Non-visual surveillance can be carried out using a variety of basic principles. The principle employed depends fundamentally on whether the aircraft will co-operate or whether it must be regarded as passive. When maintenance of identity is a requirement a degree of co-operation is necessary if identity is to be positively presented, and not merely predicted by sequential movement patterns following and initial input. The techniques of surveillance can be further subdivided into:

a) centralized systems

b) peripheral systems

c) multiple small area systems

d) block signalling systems.

8.2.2 Centralized Systems

8.2.2.1 This group of systems is characterized by having a single sensor mounted in the middle of the aerodrome and surveying the movement area from that point. Prime examples are primary or secondary radar. The major disadvantage of such a system is that there will inevitably be shadow areas in which movement information will be inadequate. The major advantage is that the single installation close to the control tower minimizes complexity and cost.

8.2.3 Peripheral Systems

8.2.3.1 These form an extension of the centralized technique by the provision of a series of sensors mounted round the periphery of an aerodrome thus eliminating a much higher proportion of the shadow areas. The disadvantages of the system lie in the multiple installations required, the extra communication links and the need for correlation of the data from the various sensors.

8.2.4 Multiple Small Area Systems

8.2.4.1 As the name implies, small area systems make use of techniques to survey small areas, either to supplement other systems, or to build up a mosaic picture of the aerodrome. Methods available include specialized radars, magnetometers, ultrasonics, electrostatics, infra-red receivers and seismic sensors. Although small area surveillance has particular value in specific application, such as Corail (a surveillance system based on Doppler radar designed to monitor the runway and part of the approach), there are problems in area boundary definition when the coverage has to be applied over the whole manoeuvring area. Disadvantages include complexity and cost.

8.2.5 Block Signalling Systems

8.2.5.1 This technique is used on most railway signalling systems and entails counting vehicles into and out of each section of the track. Operation permits only one vehicle per section, hence control logic is simple provided the sensors are reliable. An aerodrome can be operated in the same manner by dividing the paved surface into sectors or blocks and placing line sensors across the pavement at each block boundary to detect any vehicle crossing that boundary. Computer logic could then track a vehicle, maintaining its identity if identification was introduced at the start of its route. This concept is attractive in that sensors can be relatively simple, and that each block can be monitored by only two sensor installations. However a practical SMGC sensor device has not yet been demonstrated and a considerable effort may be required for its development. The block signalling concept also permits adjustment of positional accuracy in different parts of the taxiway system to meet control requirements, by varying block sizes. The concept lends itself to automation and to association with the centre line and stop bar guidance and control methods.

8.2.5.2 The major disadvantages of the block signalling system are:

a) the large number of sensors likely to be required,

b) the dependence of the system on the integrity of each detector - failure to detect or a spurious detection could disturb the logic of the system,

c) the degree to which the system is confined to the paved area. If vehicles were to join or leave the system via the unpaved area without authority and appropriate adjustment of the system, the logic could be completely defeated,

d) the high cost of installation and maintenance.

8.2.6 Primary and Secondary Surveillance Radar

8.2.6.1 Track-while-scan primary radar techniques allow an aircraft, once identified and labelled, to be automatically tracked by the radar with identity displayed. These techniques were, however, developed for air surveillance where most radar returns are from aircraft; this is not the case with a surface surveillance radar where most of the returns are from the ground or buildings. A simple transfer of the airborne target tracking technique to a ground application is not possible. Techniques for the primary tracking and labelling of surface surveillance radar have been proposed, but considerable research and development would be necessary before feasibility could be determined.

8.2.6.2 Secondary surveillance radar, relying on a response from the aircraft with a unique code format, provides the identity information required by the ground movement controller, but its volumetric resolution was designed for airborne separation standards of miles and, with standard interrogation methods, is unsuited to the separation in terms of metres to be expected on the aerodrome surface. Research has provided two possible answers:

a) a selectively addressed secondary surveillance radar system/discrete address beacon system (ADSEL/DABS) components of secondary surveillance radar (SSR),

b) advanced techniques of interrogation and processing of transponder replies via multiple receivers, to overcome the limitations of conventional aircraft transponder fit.

The chief advantage of b) is that it uses a signal source already accepted as a standard fitment on aircraft, while a) carries all the advantages of a selective address system and, additionally, offers a data transfer capability which could help with the communication problem, but it calls for an additional aircraft fit which, by all precedent, would affect the time it takes to become agreed and established.

8.3 The Comprehensive Automated SMGC System

8.3.1 The SMGC system must be flexible enough to meet requirements through the range of conditions from good visibility by day to the lowest visibility in which aircraft operations will occur. The degree of control applied must be adequate to the prevailing conditions, but over-control, which by implication means unnecessary restriction, should be avoided. A comprehensive system should, therefore, be so designed that components and procedures can progressively be applied to counter guidance and separation problems caused by declining visibility or heavy traffic, the objective being to offer optimum safe capacity for the conditions obtaining. Capacity at any time should, as a minimum, be equal to the service rate likely to be achieved on the runways at that time. Preferably there should be spare capacity to meet any increased movement rates which may be possible due to improved techniques, and to cope with aircraft and vehicles moving on routes other than to and from the runways, e.g., aircraft on tow to and from the maintenance areas.

8.3.2 The system must be capable of providing safe visual reference for the pilot between the runway exit/access taxiway and the stand, and other necessary routes, both as regards route guidance and separation from other aircraft or surface vehicles, and it should provide the controller with positive identification of all aircraft on the manoeuvring area. It should require minimum use of voice communication between aircraft and controller, and place minimum reliance on human memory for routeing commands and cancellation of routes. The workload on the controller/system operator must not be the limiting factor in the operation of the system. In the event of a fault developing in the system it should fail safe, and the system should be compatible with the requirements of the aerodrome emergency plan.

8.3.3 Of the automated concepts considered, the block signalling concept interfaced with the terminal area automation system for runway crossing control, offers the most promising approach to the automation of guidance and control lighting, the sensors feeding in the precise positional information necessary for the computerized switching function. This usage of sensors to provide positional information appears potentially more significant than that of their use for surveillance, since there is little doubt that both surveillance and maintenance of identity can more efficiently and reliably be performed by radar.

8.3.4 SSR, if developed to suit ground movement control requirements as indicated in 8.2.6.2, will permit the identity labelling of transponder-equipped aircraft and vehicles, but it will not provide returns from traffic not equipped with transponders, intruders, or from aircraft or vehicles whose transponder fails to function. If there exists the feasibility of intruding traffic on the manoeuvring area, or there is need to monitor traffic whether or not it caries a serviceable transponder, then primary aerodrome surface surveillance radar will be required in addition to SSR.

8.3.5 A comprehensive automated SMGC system, consequently, may need to include a sensor triggered, computer switched, taxiway centre line and stop bar lighting system, and a combined primary and secondary surface surveillance radar installation. More than one scanner location may be necessary in order to provide adequate coverage.

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