Doc 9157
AN/901

Aerodrome Design Manual

Part 4
Visual Aids

Approved by the Secretary General and published under his authority

Fourth Edition — 2004

International Civil Aviation Organization

Published in separate English, French, Russian and Spanish editions by the International Civil Aviation Organization. All correspondence, except orders and subscriptions, should be addressed to the Secretary General.

Orders should be sent to one of the following addresses, together with the appropriate remittance in U.S. dollars or in the currency of the country in which the order is placed. Customers are encouraged to use credit cards (MasterCard, Visa or American Express) to avoid delivery delays. Information on payment by credit card and by other methods is available in the Ordering Information Section of the *Catalogue of ICAO Publications*.

International Civil Aviation Organization. Attention: Customer Services Unit, 999 University Street, Montréal, Quebec, Canada H3C 5H7
Telephone: +1 514-954-8022; Facsimile: +1 514-954-6769; Sitatex: YULCAYA; E-mail: sales@icao.int;
World Wide Web: http://www.icao.int

Botswana. Kags and Tsar Investments (PTY) Ltd., Private Bag 254/525, Gaborone
Telephone: +267 390 4384/8; Facsimile: +267 395 0004; E-mail: ops@kagsandtsar.co.bw

Cameroon. KnowHow, 1, Rue de la Chambre de Commerce-Bonanjo, B.P. 4676, Douala / Telephone: +237 343 98 42; Facsimile: +237 343 89 25;
E-mail: knowhow_doc@yahoo.fr

China. Glory Master International Limited, Room 434B, Hongshen Trade Centre, 428 Dong Fang Road, Pudong, Shanghai 200120
Telephone: +86 137 0177 4638; Facsimile: +86 21 5888 1629; E-mail: glorymaster@online.sh.cn

Egypt. ICAO Regional Director, Middle East Office, Egyptian Civil Aviation Complex, Cairo Airport Road, Heliopolis, Cairo 11776
Telephone: +20 2 267 4840; Facsimile: +20 2 267 4843; Sitatex: CAICAYA; E-mail: icaomid@cairo.icao.int

Germany. UNO-Verlag GmbH, August-Bebel-Allee 6, 53175 Bonn / Telephone: +49 0 228-94 90 2-0; Facsimile: +49 0 228-94 90 2-22;
E-mail: info@uno-verlag.de; World Wide Web: http://www.uno-verlag.de

India. Oxford Book and Stationery Co., 57, Medha Apartments, Mayur Vihar, Phase-1, New Delhi – 110 091
Telephone: +91 11 65659897; Facsimile: +91 11 22743532

India. Sterling Book House – SBH, 181, Dr. D. N. Road, Fort, Mumbai 400 001
Telephone: +91 22 2261 2521, 2265 9599; Facsimile: +91 22 2262 3551; E-mail: sbh@vsnl.com

India. The English Book Store, 17-L Connaught Circus, New Delhi 110001
Telephone: +91 11 2341-7936, 2341-7126; Facsimile: +91 11 2341-7731; E-mail: ebs@vsnl.com

Japan. Japan Civil Aviation Promotion Foundation, 15-12, 1-chome, Toranomon, Minato-Ku, Tokyo
Telephone: +81 3 3503-2686; Facsimile: +81 3 3503-2689

Kenya. ICAO Regional Director, Eastern and Southern African Office, United Nations Accommodation, P.O. Box 46294, Nairobi
Telephone: +254 20 7622 395; Facsimile: +254 20 7623 028; Sitatex: NBOCAYA; E-mail: icao@icao.unon.org

Mexico. Director Regional de la OACI, Oficina Norteamérica, Centroamérica y Caribe, Av. Presidente Masaryk No. 29, 3er Piso,
Col. Chapultepec Morales, C.P. 11570, México D.F. / Teléfono: +52 55 52 50 32 11; Facsímile: +52 55 52 03 27 57;
Correo-e: icao_nacc@mexico.icao.int

Nigeria. Landover Company, P.O. Box 3165, Ikeja, Lagos
Telephone: +234 1 4979780; Facsimile: +234 1 4979788; Sitatex: LOSLORK; E-mail: aviation@landovercompany.com

Peru. Director Regional de la OACI, Oficina Sudamérica, Av. Víctor Andrés Belaúnde No. 147, San Isidro, Lima (Centro Empresarial Real, Vía Principal No. 102, Edificio Real 4, Floor 4)
Teléfono: +51 1 611 8686; Facsímile: +51 1 611 8689; Correo-e: mail@lima.icao.int

Russian Federation. Aviaizdat, 48, Ivan Franko Street, Moscow 121351 / Telephone: +7 095 417-0405; Facsimile: +7 095 417-0254

Senegal. Directeur régional de l'OACI, Bureau Afrique occidentale et centrale, Boîte postale 2356, Dakar
Téléphone: +221 839 9393; Fax: +221 823 6926; Sitatex: DKRCAYA; Courriel: icaodkr@icao.sn

Slovakia. Letové prevádzkové služby Slovenskej Republiky, Štátny podnik, 823 07 Bratislava 21
Telephone: +421 2 4857 1111; Facsimile: +421 2 4857 2105; E-mail: sa.icao@lps.sk

South Africa. Avex Air Training (Pty) Ltd., Private Bag X102, Halfway House, 1685, Johannesburg
Telephone: +27 11 315-0003/4; Facsimile: +27 11 805-3649; E-mail: avex@iafrica.com

Spain. A.E.N.A. — Aeropuertos Españoles y Navegación Aérea, Calle Juan Ignacio Luca de Tena, 14, Planta Tercera, Despacho 3. 11,
28027 Madrid / Teléfono: +34 91 321-3148; Facsímile: +34 91 321-3157; Correo-e: sscc.ventasoaci@aena.es

Switzerland. Adeco-Editions van Diermen, Attn: Mr. Martin Richard Van Diermen, Chemin du Lacuez 41, CH-1807 Blonay
Telephone: +41 021 943 2673; Facsimile: +41 021 943 3605; E-mail: mvandiermen@adeco.org

Thailand. ICAO Regional Director, Asia and Pacific Office, P.O. Box 11, Samyaek Ladprao, Bangkok 10901
Telephone: +66 2 537 8189; Facsimile: +66 2 537 8199; Sitatex: BKKCAYA; E-mail: icao_apac@bangkok.icao.int

United Kingdom. Airplan Flight Equipment Ltd. (AFE), 1a Ringway Trading Estate, Shadowmoss Road, Manchester M22 5LH
Telephone: +44 161 499 0023; Facsimile: +44 161 499 0298; E-mail: enquiries@afeonline.com; World Wide Web: http://www.afeonline.com

3/08

Catalogue of ICAO Publications

Issued annually, the Catalogue lists all publications currently available. Supplements to the Catalogue announce new publications, amendments, supplements, etc. The Catalogue is accessible on the ICAO website at www.icao.int.

Doc 9157
AN/901

Aerodrome Design Manual

Part 4
Visual Aids

Approved by the Secretary General
and published under his authority

Fourth Edition — 2004

International Civil Aviation Organization

AMENDMENTS

The issue of amendments is announced regularly in the *ICAO Journal* and in the monthly *Supplement to the Catalogue of ICAO Publications and Audio-visual Training Aids*, which holders of this publication should consult. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

AMENDMENTS		
No.	Date	Entered by

CORRIGENDA		
No.	Date	Entered by
1	1/3/04	ICAO

FOREWORD

Proper design and installation of visual aids are prerequisites for the safety and regularity of civil aviation. Accordingly, this manual includes guidance on the characteristics of visual aids used at airports.

The material included herein is closely associated with the specifications contained in Annex 14 — *Aerodromes*, Volume I — *Aerodrome Design and Operations*. The main purpose of the manual is to assist States in the implementation of these specifications and thereby help to ensure their uniform application.

This fourth edition incorporates changes and additions resulting from an overall review made by the Secretariat. The more important of these changes/additions are as follows:

a) the deletion of VASIS and 3-BAR VASIS as standard visual approach slope indicator systems (Chapter 8);

b) updated material on surface movement guidance and control systems (Chapter 10);

c) updated guidance material on signs (Chapter 11);

d) updated material on visual docking guidance systems (Chapter 12);

e) guidance on marking and lighting of obstacles (Chapter 14);

f) updated material on frangibility of visual aids (Chapter 15);

g) guidance on the application of approach and runway lighting systems (Chapter 16);

h) guidance on maintenance of lighting performance (Chapter 17); and

i) material on measurement of intensity for steady burning and flashing lights (Chapter 18).

It is intended that the manual be kept up to date. Future editions will be improved based on the work of the Visual Aids Panel of ICAO as well as on experience gained and comments and suggestions received from users of this manual. Readers are therefore invited to give their views, comments and suggestions on this edition. These should be directed to the Secretary General of ICAO.

Table of Contents

Chapter 1

Functional Requirements of Visual Ground Aids

1.1 INTRODUCTION

The purpose of this chapter is to provide engineering personnel with a general appreciation of the task of the pilot-in-command in relation to the use of and reliance upon visual aids and visual cues in approaching, landing and operating on the airport surface. The information provided herein is for illustrative purposes only and is not necessarily meant to imply ICAO approval or endorsement of the operational practices and procedures described. For currently approved detailed operational procedures and practices, reference should be made to pertinent operational and training documents.

1.2 OPERATIONAL FACTORS

The pilot's problem

1.2.1 Human beings are two-dimensional animals. From the moment we first start to crawl, we interpret visual cues and use our sense of balance to travel over the surface of the earth. This long and gradual learning process continues as we later take charge of various types of mechanical transport on land or water, by which time we have years of accumulated experience on which to draw. As soon as we take to the air we have a third dimension to cope with, and this means that all our years of experience in solving two-dimensional problems are no longer sufficient.

1.2.2 There are two ways of controlling an aircraft in flight — either manually or by means of the automatic pilot. The pilot can effect manual control either by reference to the instrument panel or by reference to visual cues in the outside world. The latter method presupposes adequate visibility and a clearly defined horizon, which may be the actual horizon or an apparent horizon perceived from gradients in the texture or the detail on the earth's surface.

1.2.3 Some of the most difficult tasks when flying an aircraft visually are judging the approach to a runway and the subsequent landing manoeuvre. During the approach, not only must the speed be carefully controlled, but continuous simultaneous corrections in all three dimensions are necessary in order to follow the correct flight path. For a straight-in approach, this may be defined as the intersection of two planes at right angles, the vertical plane containing the extended centre line of the runway and the other plane containing the approach slope.

1.2.4 Maintaining an accurate approach slope solely by reference to a view of the outside world is often difficult. The task difficulty varies for each aircraft. Propeller-driven aircraft have an almost instantaneous reaction to an increase in power; the faster airflow over the wings from the speeded-up propellers provide an immediate increase in lift. The jet engine is not only slower to respond to an advance in throttle setting, but also has no direct effect on the airflow over the wing. Not until the whole mass of the aircraft has been accelerated following an increase in thrust will an increase in lift result. The conditions where a visual approach slope indicator system shall be provided are listed in Annex 14, Volume I, 5.3.5.1.

1.2.5 It is essential that aircraft cross the runway threshold with a safe margin of both height and speed. In order to effect a smooth touchdown, both the speed and the rate of descent must be simultaneously reduced in the manoeuvre known as the landing flare, so that the wheels touch the runway just prior to or as the wing stalls.

1.2.6 After touchdown, the pilot has a continuing requirement for directional guidance to keep the aircraft along or near the middle of the runway (at touchdown speeds generally within a range of 100 kt to 160 kt or 185 km/h to 296 km/h). The pilot also needs information from which an assessment can be made of the length of runway remaining and, once the aircraft has slowed sufficiently, advance warning of a suitable runway exit, its width clearly delineated where taxiway centre line lighting is not provided.

1.2.7 Once clear of the runway, the pilot has to taxi the decidedly unwieldy vehicle along an often complicated layout of taxiways to the correct parking/docking position on an apron which may well be congested. The pilot must be given a clear indication of the route to follow and be prevented from crossing any runway in use, as well as being protected from conflicting taxiing aircraft and vehicles.

1.2.8 If we examine the case of long-bodied jets, the taxiing pilot has to control one of the largest, heaviest and most inefficiently powered tricycles ever made. The pilot is seated at least 6 m above the ground, and the nearest point ahead which can be seen is more than 12 m. The steerable nose wheel is several metres behind the pilot's seat on the flight deck (this brings its own special problems when negotiating a curve), while the main wheel bogies are at least 27 m behind. There is, of course, no "direct drive" to these wheels, and thrust from the jet engines, notoriously inefficient at low forward speeds, must be used. As with many modern swept-wing jets (irrespective of size), it is often impossible for the pilot to see the wing tips from the flight deck.

1.2.9 The manner in which all the varied operational requirements outlined in the preceding paragraphs are satisfied by visual aids is described in detail in Section 1.4.

The four Cs

1.2.10 There are four main elements that comprise the character of the complete airport lighting system as it has evolved from research and development programmes and practical field experience over a long period of time. These elements may be conveniently referred to as the "four Cs" — configuration, colour, candelas and coverage. Both configuration and colour provide information essential to dynamic three-dimensional orientation. Configuration provides guidance information, and colour informs the pilot of the aircraft's location within the system. Candelas and coverage refer to light characteristics essential to the proper functioning of configuration and colour. A competent pilot will be intimately familiar with system configuration and colour and will also be aware of candela changes which increase or decrease light output. These four elements apply to all airport lighting systems, in greatly varying degrees, depending on such factors as the size of the airport and the visibility conditions in which operations are envisaged, and are reviewed in the paragraphs which follow.

Configuration

1.2.11 This concerns the location of components and spacing of lights and markings within the system. Lights are arranged in both longitudinal and transverse rows with respect to the runway axis, whereas painted runway markings are aligned only longitudinally with the runway axis. (The foreshortening effect of viewing transverse markings at approach angles makes painted transverse markings impractical.)

1.2.12 Light spacing varies primarily with regard to whether a longitudinal or transverse array is involved. It is apparent that a pilot's perspective of visual aid systems causes widely spaced lights in a longitudinal row to assume a "linear effect". On the other hand, close spacings are required to achieve a "linear effect" with lights in a transverse row. Another factor influencing light spacing is the visibility under which the system is to be used. When operations are conducted in lower visibilities, closer spacings are required, especially in longitudinal rows, to provide adequate visual cues within the reduced visual range.

1.2.13 Locating and installing lights for the runway edge, threshold and runway end was never a problem since the very words themselves denote location. Installing threshold lights is somewhat complicated, however, when the threshold is displaced. Development of semi-flush light fittings makes it possible to locate runway lighting in a standard configuration within runway pavement. Spacing of lights associated with runway edges has changed very little since runways were first lighted. Primary visual guidance in low visibilities comes from the centre line and touchdown zone lighting systems.

1.2.14 While development of runway lighting is fairly uncomplicated, approach light research and development has resulted in major differences in both location and spacing for systems in various States. In contemplating operations for precision approach Category II runways, it was agreed that a standard configuration was needed for at least the 300 m of the system before the threshold. A cooperative programme by ICAO States achieved this objective in the 1960s.

Colour

1.2.15 The function of coloured light signals is to help identify the different lighting systems of the aerodrome, to convey instructions or information and to increase conspicuity. Thus, for example, runway edge lights are white, and taxiway edge lights are blue; red obstacle lights are more readily seen against a background of white lights than are lights of other colours, their red colour also indicating a hazard.

1.2.16 Although many colours can be recognized when the coloured surfaces are large enough to be seen as an area,