AERODROMES PANEL (AP)

VISUAL AIDS WORKING GROUP (VAWG)

FIFTH MEETING

Montréal, Canada, 25 to 27 June 2008

Agenda Item 11: Any other business

NEW TECHNOLOGIES FOR HIGH PRECISION PAPI ALIGNEMENT

(Presented by P. Mazzaracchio - ENAC – Italian Civil Aviation Authority)

SUMMARY

PAPI (Precision Approach Path Indicator) is a crucial equipment of the AGLs for a safe approach to the runway, even in case of airports equipped with ILS. The need to keep the precise aiming of PAPI is limited by availability and high costs of flight checks. ENAC has investigated the state of the art of existing technologies and issued a set of official requirements for instruments to be used as an alternative to in flight and on the field PAPI checking methods. A real application of new requirements is also reported.

1. INTRODUCTION

Regulation issued by ICAO fixes some requirements about how to locate, install, align and maintain PAPI lights.
Such rules have been of course conceived on the basis of instruments and methods consolidated during last decades, so that the only way to achieve a good alignment of a PAPI unit had to be based first on an accurate adjustment of the aiming of the beam, followed by a flight check to control the effectiveness of the alignment.

ENAC (Italian CAA) observed the difficulties of maintenance operators to keep a precise PAPI alignment, when running periodic flight-checks for ILS (if present) or once per year for airports without ILS. Thus a PAPI misalignment can be detected and managed after several months. Moreover, a flight check is requested every time a corrective maintenance occurs on a PAPI unit, while delays in the availability of the flight check and the related hourly costs for aircraft, crew and instruments may become a problem for Airport Operators in order to preserve a steady alignment of PAPI bars. As a consequence often PAPI bars are not perfectly aligned, causing disappointments and claims of pilots and a virtual reduction of airport safety.

ENAC aerodrome department therefore issued a special set of requirements named APS-01, for the development of prototypes of a new generation of instruments devoted to measure and support the PAPI alignment, with an overall performance able to restrict the request for a flight check to periodic navaids and obstacles assessments.

2. DISCUSSION

The obvious implication is that every instrument conforming to APS-01 should be able to assess the PAPI beam elevation and orientation through an external observation in a near field condition respect to the flight check.
In fact using standard tools the alignment is performed through the adjustment of the box containing the projectors, which makes it necessary a flight check as it is impossible to have a perfect relationship between the configuration of the PAPI unit box and the final direction of single light beam, especially for units in use after a long period. In other words the use of precision clinometers can tell the maintenance operator which is the elevation (angle) of the part of the box where such clinometer lies, while nothing allows us to presume that the beam slope is exactly the same measured on the box. Besides the additional use of external aiming pads doesn't assure the required accuracy, needing a very precise evaluation of the distance between the beam and the aiming pad itself.

2.1 Definition of the problem

What really happens in a PAPI measurement can be easily expressed by the following formula:

$$\mathbf{Ir = Ic + C}$$

where:

Ir is the real angle of the output beam, **Ic** is the angle read on the clinometer scale and **C** is a random value (+/-) representing the contribute given by all the factors out of control of clinometer and affecting the real angle of the beam (including of course the accuracy of the clinometer itself).

The only way to check the real angle of the beam is therefore to look at it by the outside, using the eye of the pilot of the flight check to detect the transition white-to-red running up and down along the glide path. Every position of transition on the glide path line is fixed using a reference instrument, operated by a man on the ground. At the end of such procedure the angle of this so built glide path line is assumed as the nominal slope of the PAPI. Results of this in flight procedure are in any case affected by an error to be included within the allowed tolerance (usually +6'/-6').

2.2 The role of ENAC

The main goal of new ENAC regulation named APS-01 is to improve airport safety by setting up a reference standard for a new class of instruments and related procedures. These tools should be able to provide high accuracy and precision in PAPI alignment, allowing to increase number and quality of controls at a reduced cost with comparison to in flight procedure.

The feasibility for these advanced instruments has been confirmed by in depth evaluation of a new apparatus based on opto-electronics sensors in the emulation of the pilot's eye. This step has been done by ENAC in cooperation with the Italian industrial community.

2.3 Basic requirements

Depending by the manufacturer and equipment type, a PAPI unit can have one, two or three different beams which will form the single one detected by the eye of the pilot approaching the runway. The quality of each beam will therefore affect the whole performance of the unit. We have to consider parameters depending by the PAPI box assembly, such as:

- Vertical and horizontal orientation
- Height from the ground respect to runway threshold
- Status of mechanical structure (geometry)

and parameters depending by the single beam such as:

- Status and alignment of lenses
- Status and alignment (horizontality) of red filters
- Status and alignment of lamp reflectors
- Aperture angles
- Collimation in elevation and azimuth with the adjacent beam(s)

Consequently an instrument conforming to APS-01 specifications must measure the following parameters:

- Elevation angle of each beam in the PAPI unit
- Average elevation angle of the unit
- Average elevation angle (Glide Path) of the PAPI bar (A,B,C,D units)
- Horizontality of colour transition of each beam
- Average horizontality of colour transition of the PAPI unit
- Colour transition width of the unit
- Azimuth spread of the PAPI bar
- Photometric diagram of output intensity of the PAPI unit

with the following accuracy and precision:

- Accuracy : 1' of degree
- Precision : 1' of degree

Thanks to high level of accuracy granted by the instrument left and right bars synchronization is achieved just considering the average elevation angle and the average azimuth of each unit of the left and right wings. Indeed bad synchronization mainly depends on misalignment of elevation and azimuth angles of the corresponding units in the left and right wings: so the opportunity to detect and adjust every misalignment with an high level of accuracy guarantees a good synchronization of the two bars.

2.4 Operative requirements

Considering the skill of the personnel committed to AGL maintenance and the need to obtain reliable measurements, ENAC issued the following operative requirements for this new class of instruments:

- The instrument must be easy to use and operate at a low voltage through a system of rechargeable batteries
- The quality of measurement cannot be affected by the quality of the ground where the instrument is placed
- The instrument must be able to perform the measurement without any special care in setting the distance and the angular positioning (i.e it must work just looking at the beam when placed in front of the PAPI)
- The instrument must be able to perform the measurement of a whole PAPI wing within 1 hour (i.e 4 hours for a runway equipped with left and right wings in both directions)
- The instrument must be able to perform measurements also during daylight conditions
- All data collected during the measurements must be recorded into the system data-base for further analysis
- The instrument will allow also manual measurement procedures, should meteorological conditions not permit full automatic mode
- After the measurement the instrument must provide the operator with the corrections needed for a precise alignment of the PAPI unit. For this purpose the instrument must integrate in the system data-base all the information relevant to the units available from different manufacturers of PAPI lights.

2.5 Applicability of an instrument conforming the APS- 01

Until now PAPI flight checks have been compulsory for precision approach runways, in order to verify the harmonization of PAPI glide path with the ILS one. However an instrument conforming APS – 01 once the flight check has certified the installation of the PAPI lighting system can be used as exclusive method for periodical PAPI alignment tests, restricting the flight check for PAPI only when concurrent navigation radio aids cheks take place.
In all the other cases, i.e for non-precision instrumented runways, an instrument conforming the APS – 01 can be always used as exclusive method for PAPI alignment, given that the accuracy and precision (1') are better than the ones provided by the flight check .

2.6 A first application of APS – 01

A first application of APS – 01 is due to the Italian company Argos Ingegneria, which provided ENAC with an instrument fully compliant with the specified requirements.

The instrument called SMF/PAPI has been tested in an FAA approved laboratory, where a reference PAPI unit was aligned using lab methodologies. The results of tests are given in the tables of ANNEX A which show the high level of accuracy and precision obtained through the use of opto-electronics sensors assisted by highly sophisticated image analysis software.

3. CONCLUSIONS

3.1 This Working Group is requested to examine previous proposals and express proper evaluations on the possibility of adopting special regulation for such equipments inside Annex 14.

ANNEX A

Results of lab tests

Test# 1 represents the accuracy test and refers to a set of 10 measurements to be evaluated respect to the angle imposed to the reference PAPI unit.

Test#2 represents the precision test and refers to a set of 10 measurements carried out with the instrument in a stable position.

Test#3 represents a repetition of precision test with the instrument measuring the same reference PAPI unit from different positions.

TEST #1 MEASUREMENT REPORT
PAPI UNIT VERTICAL COLOR TRANSITION ANGLE

Accuracy Test (by Comparison with Reference Lab)

(This form is to be completed during or just after the test)

Test Laboratory: O.C.E.M. SPA San Giorgio di Piano (Bologna) Italy

Date: 23/10/2007 Operator: Sandro Lazzari / Mario Zitelli

PAPI fitting type: O.C.E.M. P/N 401CU-2-2 S/N V015415-07-0002

Reference color transition angle: 1° 33' 00"

Measuring instrument type: ARGOS INGEGNERIA SPA SMF/PAPI S/N AA0001

Measurement distance: 12 meters

	REFERENCE LABORATORY *	INSTRUMENT MEASURED DATA	TIME
Measurement #01		1°32'37"	12:59
Measurement #02		1°32'34"	13:01
Measurement #03		1°32'29"	13:04
Measurement #04		1°32'50"	13:06
Measurement #05		1°32'53"	13:08
Measurement #06		1°32'31"	13:11
Measurement #07		1°32'57"	13:13
Measurement #08		1°33'02"	13:15
Measurement #09		1°32'15"	13:17
Measurement #10		1°33'00"	13:19
Average value	1°33'00"	1°32'43"	
Standard deviation (σ)		16"	
Accuracy	30"	17"	
Note	The reference angle was given by an Optronik Model SMS 10c Goniophotometer. It was calibrated on July 25 2006 and was found compliant with ECE and SAE regulations.		

*Only the ***Average Value*** row is to be filled in the case of a single measurement or a PAPI unit set to a precise reference tilt (condition to be reported in the ***Note*** field).

REFERENCE LABORATORY	MEASURING INSTRUMENT OPERATOR	CERTIFICATION AUTHORITY
O.C.E.M. SpA RESPONSABILE COLLAUDO E SISTEMI DI TECNICA	Argos (signature)	(signature)
DATE	23/10/2007	
PLACE	BOLOGNA -- ITALY	

TEST #2 MEASUREMENT REPORT
PAPI UNIT VERTICAL COLOR TRANSITION ANGLE

Precision Test (from stable measuring point)

(This form is to be completed during or just after the test)

Test Laboratory: O.C.E.M. SPA San Giorgio di Piano (Bologna) Italy

Date: 23/10/2007 Operator: Sandro Lazzari / Mario Zitelli

PAPI fitting type: O.C.E.M. P/N 401CU-2-2 S/N V015415-07-0002

Reference color transition angle 1° 33' 00"

Measuring instrument type: ARGOS INGEGNERIA SPA SMF/PAPI S/N AA0001

Measurement distance: 12 meters

	MEASURED DATA	MEASUREMENT TIME
Measurement #01	1°32'37"	12:59
Measurement #02	1°32'34"	13:01
Measurement #03	1°32'29"	13:04
Measurement #04	1°32'50"	13:06
Measurement #05	1°32'53"	13:08
Measurement #06	1°32'31"	13:11
Measurement #07	1°32'57"	13:13
Measurement #08	1°33'02"	13:15
Measurement #09	1°32'15"	13:17
Measurement #10	1°33'00"	13:19
Average value	1°32'43"	
Standard deviation (σ)	16"	
Note	The reference angle was given by an Optronik Model SMS 10c Goniophotometer. It was calibrated on July 25 2006 and was found compliant with ECE and SAE regulations.	

REFERENCE LABORATORY	MEASURING INSTRUMENT VENDOR	CERTIFICATION AUTHORITY
O.C.E.M. SpA RESPONSABILE COLLAUDO E ASSISTENZA TECNICA (signature)	Argos S.p.A. (signature)	(signature)
DATE	23/10/2007	
PLACE	BOLOGNA -- ITALY	

TEST #3 MEASUREMENT REPORT
PAPI UNIT VERTICAL COLOR TRANSITION ANGLE

Precision Test (from variable measuring point)

(This form is to be completed during or just after the test)

Test Laboratory: O.C.E.M. SPA San Giorgio di Piano (Bologna) Italy

Date: 23/10/2007 Operator: Sandro Lazzari / Mario Zitelli

PAPI fitting type: O.C.E.M. P/N 401CU-2-2 S/N V015415-07-0002

Reference color transition angle 1° 33' 00"

Measuring instrument type: ARGOS INGEGNERIA SPA SMF/PAPI S/N AA0001

Initial measurement distance: 12,5 meters

	MEASURED DATA	MEASUREMENT TIME	APPLIED MOVEMENT
Measurement #01	1°32'27"	15:14	
Measurement #02	1°32'17"	15:19	Forward 50 cm
Measurement #03	1°32'32"	15:22	Right 30 cm
Measurement #04	1°32'27"	15:25	Left 50 cm
Measurement #05	1°32'57"	15:29	Forward 50 cm
Measurement #06	1°32'37"	15:34	Tripod left leg +5 cm
Measurement #07	1°32'04"	15.38	Right 30 cm
Measurement #08	1°32'16"	15:43	Tripod right leg +5 cm
Measurement #09	1°32'44"	15:47	Backward 50 cm
Measurement #10	1°32'22"	15:55	Backward 50 cm
Average value	1°32'28"		
Standard deviation (σ)	15"		
Note	The reference angle was given by an Optronik Model SMS 10c Goniophotometer. It was calibrated on July 25 2006 and was found compliant with ECE and SAE regulations.		

REFERENCE LABORATORY	MEASURING INSTRUMENT VENDOR	CERTIFICATION AUTHORITY
O.C.E.M. SpA RESPONSABILE COLLAUDO E ASSISTENZA TECNICA (signature)	Argos S.p.A. Ingegneria (signature)	(signature)
DATE	23/10/2007	
PLACE	BOLOGNA -- ITALY	