The problem of PAPI alignment

The Precision Approach Path Indicator – the PAPI - is a crucial equipment of the AGLS for a safe approach to the runway even in case of airports equipped with ILS. The will to maintain the precise aiming of PAPI has been until now limited by availability and high costs of flight inspections. The international recommendations issued by ICAO in Annex 14 state very precise rules about how to locate, install, align and maintain PAPI lights. Nevertheless such rules have been of course conceived on the basis of instruments and methods consolidated in decades of years so that the only way to achieve a good alignment of a PAPI unit had to be based on an accurate adjustment of the aiming of the beam, first, followed by a flight check to control the effectiveness of the alignment.

In fact the alignment performed through the adjustment of PAPI unit registers using a precision clinometer can tell the maintenance operator what is the inclination (angle) of the part of the box where the clinometer is applied while nothing allows to presume that the beam is exactly assuming the same angle of the box itself. Moreover the usage of external optical gouge will not give the required accuracy due to need of a very precise measurement of the height of the gouge and the distance between the beam and the gouge.

The only way to check the angle of the beam is therefore to look at the beam by 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 (see fig.1). Every transition on the glide path line is therefore detected by the pilot and fixed using a reference instrument operated by a man on the ground or the on-board AFIS system. At the end of procedure the angle of the so built glide path line is the angle of the PAPI. The result of this in flight procedure may be in any case affected by an error up to ± 6’, due to the typical accuracy of procedure and the human factor at the moment of transition detection signaling.

Difficulties of maintenance operators have been also observed to keep a precise PAPI alignment, when running periodic flight-checks for 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 may become a problem for Airport Operators to guarantee the 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.

The solution

The most advanced answer to the problem of precise PAPI alignment is today given by the SMF/PAPI system, a revolutionary machine designed and manufactured by Argos Ingegneria and able to assess the parameters of PAPI beams through an external observation in a near field.
condition with an higher accuracy with respect to the flight check.

**Argos SMF/PAPI**

*SMF/PAPI* is an easy system built around a special photometric sensor head (see Fig.2) able to determine via a fully automatic procedure all the alignment parameters of the PAPI unit under test.

The optoelectronic sensor is driven by an advanced image analysis, running on a portable PC, while the elevation angle is measured by means of pure gravitational methods. In particular, the system measures the elevation angle of the PAPI colour transition emulating in near field conditions what the pilot sees from the aircraft. The key point of procedure is the horizontal auto-levelling of the measurement head, just like during a flight inspection.

*SMF/PAPI* performs the measurements of elevation alignment in the range from 1° to 10° with the accuracy required by ICAO recommendations and is able to measure the overall inclination of the beam independently of mechanical characteristics of the PAPI unit under test and the quality of the ground.

The measurement procedure performed by *SMF/PAPI* is quick and easy and can be repeated by the user periodically or when some special maintenance occurs, like repair or replacement of a PAPI unit.

Measurement is carried out automatically, being the intervention of the operator limited to perform the initial positioning of the instrument, the targeting of the PAPI box under test (see Fig.3) and the launch of the measurement.

The *SMF/PAPI* sensor head is installed on a special camera tripod, typically placed 10 to 15 meters far from the box under test, at an height between 1.0 and 1.5 m. Once positioned the equipment automatically stabilizes itself in the horizontal position.

The measurement head can rotate horizontally so that the measurement system can tolerate to be placed not exactly orthogonal with respect to the front side of PAPI unit. Once the operator has trimmed the tripod to put the measurement head in the position where the beams of PAPI appear, additional fine regulations can be operated using the friendly interface of system software.
The measurement procedure

The operator targets the PAPI moving the head of **SMF/PAPI** via the joystick given in the system software and the feedback provided by the image of the built in wide-angle camera.

Once the color transition of PAPI beams appear approximately in the middle of the black window of the PC screen (see Fig.4), the operator has only to click on a software button and the system will start the measurement procedure in automatic mode.

**SMF/PAPI** begins the observation of PAPI light beam emulating the eye of the pilot in the search of red/white transition. (see Fig.5)

Once reached the transition area, **SMF/PAPI** automatically tilt up and down the measuring sensor to search for the axial alignment of the main observation camera with the light beam transition plane.

Once the axial alignment is reached and stabilized, **SMF/PAPI** automatically reads the inclination using a high accuracy thermally stabilized electronic clinometer, giving a precise feedback (see Fig.6) to the operator about the corrections to be done on PAPI legs to get an alignment in full accordance with the nominal installation requirements.

The complete measurement procedure takes less than 10 minutes per unit and can be also carried out behind the glass of a vehicle to face any weather or climatic condition.

The **SMF/PAPI** system can save in the internal data base all the PAPIs settings (i.e. the elevation angles of each unit) set at the time of the certification flight, with or without ILS, and get them as the reference values for further measurements. The user is therefore guaranteed that should the units need to be realigned after a maintenance intervention, they always will assume the same parameters set at the time of certification flight.

The high level of accuracy and precision of **SMF/PAPI** allows the use of PAPI lights as reference for checking the ILS alignment. A periodic measurement of PAPI units allows...
the operator to check and maintain a perfect alignment of PAPI lights so that should occur a misalignment with ILS, it must be investigated first as depending by ILS equipment.

The high level of accuracy of the instrument allows to synchronize left and right bars, when requested. The most important contribution to a bad synchronization is in fact depending by misalignment of elevation angles and horizontality of the corresponding units in the left and right wings. Accurate detection and correction of every misalignment therefore guarantees a perfect synchronization of the two bars.

**SMF/PAPI Operating Performances**

SMF/PAPI is able to measure with an accuracy and precision better than 1’ the following PAPI parameters:

- Elevation angle of color transition of each beam in the PAPI unit
- Average elevation angle of the unit (fig.6)
- 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 aperture of the unit
- Beam aperture of the PAPI unit (fig. 6-3)
- Output intensity of the PAPI unit (fig.6-1)
- Chromaticity of white and red areas of PAPI unit beams (fig. 6-2)

**SMF/PAPI** is easy to use, hand portable and operated at low voltage (12 VDC) through a power-pack of rechargeable batteries. Major performances of the instrument are:

- Accuracy: better than 1’
- Precision: better than 1’
- Night and Day operation (direct sun illumination not allowed)
- Operating temperature: -10°C /+50°C
- Operating Rh: 95% NC
- Quality of measurement not affected by the ground shape
- No special care in setting the distance and the angular positioning of the instrument
- Measurement of a whole PAPI wing bar in less than 1 hour
- Measurement of colour and beam intensity
- Measurement Data stored in the system data-base for further analysis.
- Immediate feedback to drive the operator for a precise alignment of the PAPI unit.
- Typical data of Models and manufacturers of PAPI lights integrated in the system data-base

- Powerful and configurable automatic PDF report generation
The main goal of the new ENAC regulation APS-01 is therefore to improve airport safety by setting up a reference standard for a new class of instruments and related procedures. These tools are able to provide high accuracy and precision in PAPI alignment increasing the frequency and quality of controls at a reduced costs with comparison to in flight procedures.

Before to start the field tests, ENAC required a severe lab test session to assess the absolute accuracy and precision of SMF/PAPI. The instrument has been tested in an FAA approved laboratory (Fig.9), where a reference PAPI unit was aligned using lab methodologies. The results of tests given in the following tables demonstrate the high level of accuracy and precision obtained through the use of optoelectronics sensors assisted by highly sophisticated image analysis software. The results of tests are given in Fig.7, where:

**Test n° 1** reports the results of the accuracy test and refers to 10 measurements with respect to a predefined angle imposed to the reference PAPI unit.

**Certification**

On the basis of the experience of SMF/PAPI the Aerodrome Department of Italian CAA - ENAC issued the technical standard of requirements identified as APS-01, for the certification of a new class of instruments devoted to measure and support the PAPI alignment and capable of the proper accuracy to restrict the need for the flight check to periodic NAVAIDS and obstacles assessments.

**Applicability of an instrument conforming the APS-01**

Until now the flight check has been requested for instrumented precision runways in order to verify the harmonization of PAPI glide path with the ILS one. However an instrument conforming to the APS – 01 once the flight check has certified the installation of the PAPI lighting system, can be used as exclusive method for PAPI alignment, limiting the flight check for PAPI in occasion of NAVAIDS assessment.

In all the other cases, i.e. for non-precision instrumented runways, every 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 inspections.
Test n° 2 reports the results of the precision test and refers to 10 measurements carried out with the instrument in a stable position.

Test n° 3 reports the results of the precision test with the instrument measuring the same reference PAPI unit from different positions.

Lab tests demonstrated that the instrument designed and manufactured by Argos Ingegneria was conforming to ENAC requirements. Following the successful completion of field tests sessions, the instrument was certified as conforming with APS -01 and allowed to be used in Italian airports.

The official use of the instrument started in January 2008, after the release of the certification and until now the SMF/PAPI measured hundreds of PAPI bars worldwide, while Spain, Greece, Turkey, Mexico and Canada have already certified SMF/PAPI as alternative of Flight Check for testing PAPI lights.

ICAO Recommendations

The AERODROMES PANEL (AP) VISUAL AIDS WORKING GROUP (VAWG, FIFTH MEETING, 25 to 27 June 2008, Montréal – Canada) has been requested to examine proposals and express proper evaluations on the possibility of adopting special regulation for new class equipment like SMF/PAPI inside Annex 14. After such invitation the Group agreed to add to ADM - Part 4 a new paragraph, describing minimal requirements and accepting the proposal of the VAWG and of the Secretariat, a new paragraph has been drafted to be added to Aerodrome Design Manual – Part 4.

SMF/PAPI - Supply and services

The SMF/PAPI product is delivered to customer as a complete set (see Fig.8) which includes:

- Main measurement head
- Tripod
- Rechargeable 12 VDC power pack
- Portable PC
- System software and data-base
- Power and data cables
- User and Maintenance Manual
- Certificate of Calibration
- Software licence
Available services to customer:

- Warranty extension
- Repair and calibration
- Maintenance contract
- Full maintenance contract (which includes the periodical calibration of the instrument).

SMF/PAPI – References

Italy, USA, Canada, Spain, Mexico, Greece, Turkey, Sudan, Angola, Nigeria, Russian Federation, Colombia, Indonesia, Bangladesh

SMF/PAPI – Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation angle of each beam in the PAPI unit</td>
<td>Better than 1'</td>
</tr>
<tr>
<td>Average elevation angle of the unit</td>
<td>Better than 1'</td>
</tr>
<tr>
<td>Average elevation angle (Glide Path) of the PAPI bar (A,B,C,D units)</td>
<td>Better than 1'</td>
</tr>
<tr>
<td>Horizontality of colour transition of each beam</td>
<td>0.2°</td>
</tr>
<tr>
<td>Horizontality of colour transition of the PAPI unit</td>
<td>0.2°</td>
</tr>
<tr>
<td>Colour transition aperture of the unit</td>
<td>1'</td>
</tr>
<tr>
<td>Aperture angle of the PAPI unit</td>
<td>1°</td>
</tr>
<tr>
<td>Output intensity/illuminance of the PAPI unit</td>
<td>10 %</td>
</tr>
<tr>
<td>CIE (x,y) chromaticity of the PAPI unit</td>
<td>0.03 on x and y</td>
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</tbody>
</table>

SMF/PAPI – Weight and Dimensions

<table>
<thead>
<tr>
<th>Item</th>
<th>Dimensions</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement Head including cover</td>
<td>H 345 mm</td>
<td>6,2 Kg</td>
</tr>
<tr>
<td></td>
<td>L 188 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>W 240 mm</td>
<td></td>
</tr>
<tr>
<td>Head case</td>
<td>H 230 mm</td>
<td>3,8 Kg</td>
</tr>
<tr>
<td></td>
<td>L 380 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>W 490 mm</td>
<td></td>
</tr>
<tr>
<td>Tripod including bag</td>
<td>H 950 mm</td>
<td>5,7 Kg</td>
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<tr>
<td></td>
<td>W 250 mm</td>
<td></td>
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<tr>
<td>12 VDC Power Pack</td>
<td>H 360 mm</td>
<td>2,0 Kg</td>
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<tr>
<td></td>
<td>L 330 mm</td>
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</tr>
<tr>
<td></td>
<td>W 140 mm</td>
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<tr>
<td>PC including bag and cables</td>
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<td>5,5 Kg</td>
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<td></td>
<td>L 450 mm</td>
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</tr>
<tr>
<td></td>
<td>W 340 mm</td>
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