ARGOS PRODUCTS FOR HIGH PRECISION PAPI ALIGNEMENT AND AGLS FAST MEASUREMENT

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 checks. The international recommendations issued by ICAO and integrated by the Italian CAA - ENAC in the official book of recommendations for airports build and operate , state very precise rules 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 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 lies 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 figure 1)
Every transition on the glide path line is normally fixed using a reference instrument operated by a man on the ground. 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 is in any case affected by an error of +6'/-6'.

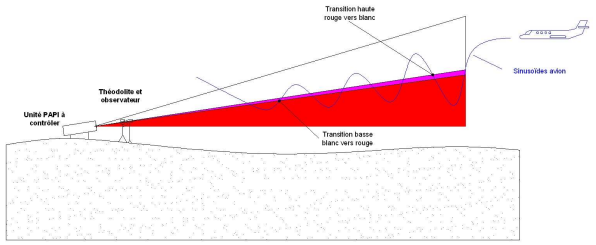

Figure 1

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 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.

Argos SMF/PAPI

The most advanced answer to the problem of precise PAPI alignment is given by the new product **SMF/PAPI**, 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 respect to the flight check.

The 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 .

Fig.2

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 in a flight check.

SMF/PAPI performs the measurements of elevation alignment in the range from 1° to 6° with the accuracy required by ICAO recommendations and is able to measure the overall inclination of the beam independently from the mechanical characteristics of the PAPI unit under test and the quality of the ground

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

SMF/PAPI can operate in automatic mode and in manual mode.

The typical measurement is done in automatic mode and is performed by the machine without requiring any kind of intervention or special skill by the operator.

The operator has only to perform the initial positioning of the instrument and the targeting of the PAPI box under test (see Fig.3) and then start the measurement.

Fig.3

The equipment is installed on a special camera tripod and typically works at a distance between 10 and 15 meters from the box under test and at a 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 respect to the PAPI unit. Once the operator has trimmed the tripod to put the measurement head in the position where the light beams of PAPI can be intercepted, he can carry out additional fine regulations by using the system software, whose interface is extremely simple.

The measurement procedure

The operator targets the PAPI moving the head of ***SMF/PAPI*** via the joystick given in the system software and the image provided by the built in wide-angle camera.
Once the PAPI beams appear approximately in the middle of the black window of the PC screen (see Fig.4), the operator has only to push a couple of software buttons and the system will start the measurement procedure in automatic mode.

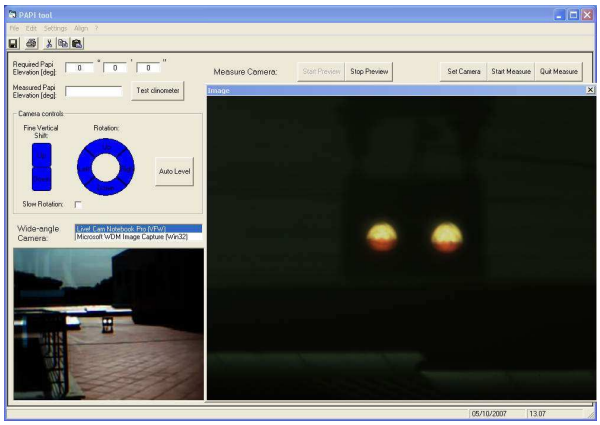

Fig.4

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)

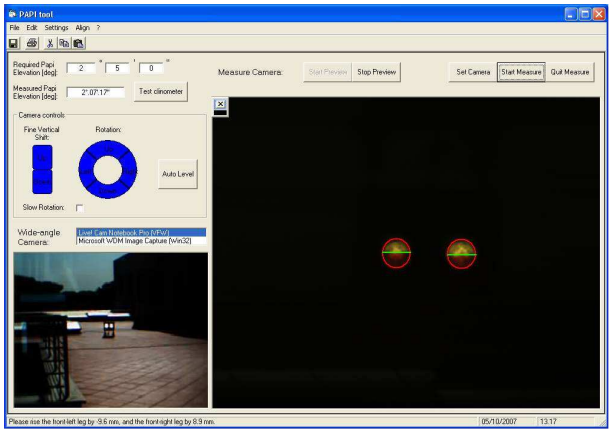

Fig.5

Once reached the transition ***SMF/PAPI*** automatically tilt up and down the measuring head to look for the axial alignment of the main observation camera with the light beam.

Once the axial alignment is reached and stabilized , ***SMF/PAPI*** automatically reads the inclination using a very high precision MIL 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 installation requirements.

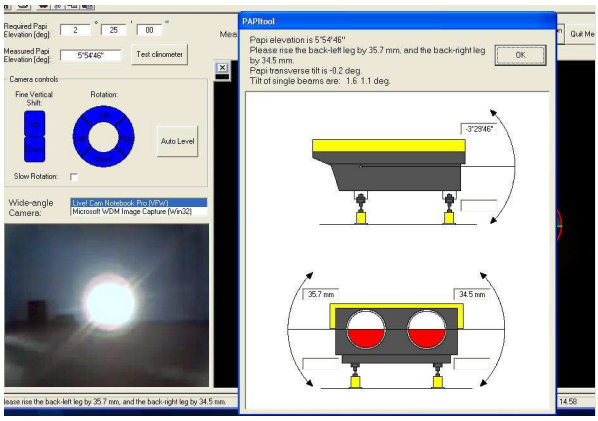

Fig. 6

The complete measurement procedure takes less than 10 minutes per unit and can be carried out in any weather or climatic conditions, being the system thermally stabilized.

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 that synchronisation of left and right bars can be obtained taking into account exclusively the average elevation angle and the average horizontality of each unit of the left and right wings. The most important contribution to a bad synchronisation is in fact depending by misalignment of elevation angles and horizontality of the corresponding units in the left and right wings. So that the possibility to detect and correct every misalignment with an high level of accuracy guarantees a good synchronisation 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 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 aperture of the unit
- Aperture angle of the PAPI bar
- Output intensity of the PAPI unit

SMF/PAPI is easy to use, hand portable and operated at low voltage (12 VDC) through a system of rechargeable batteries. The 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 where the instrument is placed
- 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
- Data acquired during the measurements are recorded in the system data-base for further analysis.
- Manual measurement procedures allowed in case of special needs (as bad weather conditions)
- According to results of measurement ***SMF/PAPI*** provides the operator with the corrections needed for a precise alignment of the PAPI unit.
- The instrument integrates in the system data-base all the information relevant to the units available from different manufacturers of PAPI lights .

Certification

On the basis of the experience of SMF/PAPI the Aerodrome Department of Italian CAA - **ENAC** issued a 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 an overall accuracy performance able 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 and 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 , restricting the

flight check for PAPI only in occasion of controls on navaids.
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 check .
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 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 opto-electronics 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 respect to a predefined angle imposed to the reference PAPI unit.

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.

INSTRUMENT CERTIFICATION REPORT
(PAPI UNIT VERTICAL COLOR TRANSITION ANGLE MEASUREMENT)

COLLECTIVE TEST DATA

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

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

	PASS	FAIL	REFERENCE TEST REPORTS	
Accuracy Test #1	X		Test #1 Measurement Report	Date: 23/10/2007
Precision Test #2	X		Test #2 Measurement Report	Date: 23/10/2007
Precision Test #3	X		Test #3 Measurement Report	Date: 23/10/2007

	DESCRIPTION	MEASUREMENT DATA	
Accuracy Test #1	Comparison with Reference Lab	Accuracy	
		17"	
Precision Test #2	Stable measuring point	Average Value	Standard deviation (σ)
		1° 32' 43"	16"
Precision Test #3	Variable measuring point	Average Value	Standard deviation (σ)
		1° 32' 28"	15"

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

Fig.7

The lab test demonstrated that the instrument designed and manufactured by Argos Ingegneria was conforming to ENAC requirements so that at the successful end of the field test sessions the instrument was certified as conforming the 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*** has measured the PAPI bars in the major Italian airports as Milano Linate – Milano Malpensa , Rome – Fiumicino and in several other Italian and European airports.

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 VWG 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
- Field rechargeable power station (12 VDC)
- Portable PC
- System software and data-base
- Power and data cables
- User and Maintenance Manual
- Certificate of Calibration
- Software licence

Fig.8

The product package includes also the operator(s) training at a customer site.

As additional services the customer may:

- Extend the standard warranty
- Ask for repair and calibration
- Start a standard maintenance contract
- Start an extended maintenance contract which includes also the periodical calibration of the instrument.

SMF/M – The Mobile system for Airfield Lights Measurement

The rapid and accurate measurement of the photometric performances of inset and elevated aerodrome lights (AGLS) is today a safety critical issue especially for airports certified for CAT II and CAT III operations. The achievement and maintain of quality of service for airfield light fittings is therefore demanding equipment able to perform measurements according to ICAO regulations requesting as low as possible time of non operability of airport runways. The need to save time in the measurement routine of AGL has pushed the manufactures of instruments for airport photometry to design and develop mobile systems capable to scan a complete airport AGLS in few hours with an high level of accuracy.

ICAO as regulatory authority, in the aim of a continuous improvement of the safety of airport operations has recommended in ADM-Part 4- Chap. 17 dedicated to the maintenance of AGL, the use of mobile measurement systems in order to increase the frequency and the effectiveness of periodical controls of airfield lights.

ARGOS SMF/M

SMF/M is the mobile photometric measurement system for AGL equipment designed , developed and manufactured by ARGOS INGEGNERIA to perform the measurement of the airfield lights while moving along runways and taxiways (no-stop mode).

SMF/M can be easily installed on the front of any commercial vehicle suitable to operate in the airfields. The Customer can decide for a fixed installation on a dedicated vehicle or for a temporary installation if the vehicle must be used for other tasks when not involved in measurement operations.

SMF/M is easy to use: the operator is assisted step by step by the system software running on the on-board PC.

Working principle

SMF/M is a based on the principle of a fixed and steady bar bringing a sensor array and moving on the same line where lamps to be measured lie.(see Fig.9)

Fig.9

The bar of ***SMF/F*** is installed to be orthogonal to the direction line and thus is able to cut the light beam emitted by the airfield fitting in its lower part when the bar is far and in its the upper part as soon as the bar comes closer to the fixture under measurement.
The vertical scan of the light beam as requested by the ICAO grid points is therefore accomplished by a reconstruction done by the system software on the basis of the samples acquired during the travel of the bar between the current lamp under measurement and the next one.
The bar (see Fig.10) hosts an array of 13 Lux sensors and 2 color sensors according to CIE 1931, distributed over the bar in order to get the best resolution/distance ratio

Fig.10

The bar also hosts a special head containing 2 optoelectronic sensors for precise fixture location and the alignment camera(see Fig.11). The sampling frequency is given by the unit of traveled distance and not by the time base. The ***SMF/M*** system is therefore not critical and user can stop the vehicle and restart it without affecting the measurement.
The operator can precisely and safely drive the vehicle using the alignment camera which reports the current position of the bar respect to the ideal line to be followed.

The ***SMF/M*** takes a sample of measures from sensors every 10 cm of the traveled distance. Distance is measured by an high resolution odometer (1 pulse every 0.7 mm) connected to a wheel mounted on the tail of the vehicle. ***SMF/M*** can consequently count on the appropriate amount of data to reach the figure of accuracy and precision requested by the application.
As soon as sampled data are transmitted via LAN to the system PC installed on the vehicle.
Once acquired, the ICAO grid points of all the measured fixtures are processed and posted in the system data base so that the operator can analyze all data relevant to the performance of a single fixture or the whole AGLS. The photometric data are provided through tables and diagrams, including the isocandela diagram requested by ICAO - Annex 14 recommendations.

In order to allow a precise measurement of all inset and elevated fittings of the airfield ***SMF/M*** implements a special multifunction optical sensor's head (see fig.11) able to continuously determine the angle under which each light appears to the measurement array and the transversal position of the lamp when the array is flying over the fixture.
When the bar of ***SMF/M*** is moving toward the lamp, the angle of the lamp under investigation increases as much as the lamp is closer to the bar. The value of the angle is therefore used to determine the precise height

of the light source in order to improve the accuracy of photometric measurement.

Fig.11

The optical head also includes a CCD camera which reports the image of the field on the display installed into the hosting vehicle (see Fig.12) to give the driver the visual reference for the correct alignment of the measurement array with the stream of lights to be measured.

Fig.12

Operations

The sensor bar can be easily adjusted in order to measure inset or elevated fixtures using the frame fitted to the car via a mechanical interface . The operator using the sliding arm of the frame can move the bar in the position suitable to the type of lamps to be measured. .(see fig. 13,14)

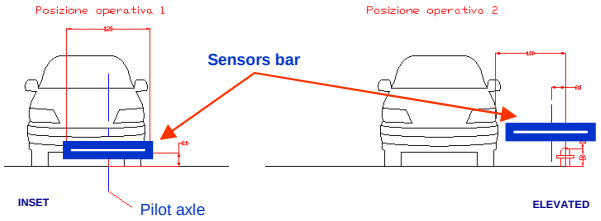

Fig.13

Fig.14

SMF/M System Software

The ***SMF/M*** system includes a portable PC , running a powerful software which provides the following tasks:

AGLS configuration: the whole airport airfield lighting system is described subdividing the AGLS into homogeneous groups of lamps (the so called subsystems, see fig.15a and 15b)

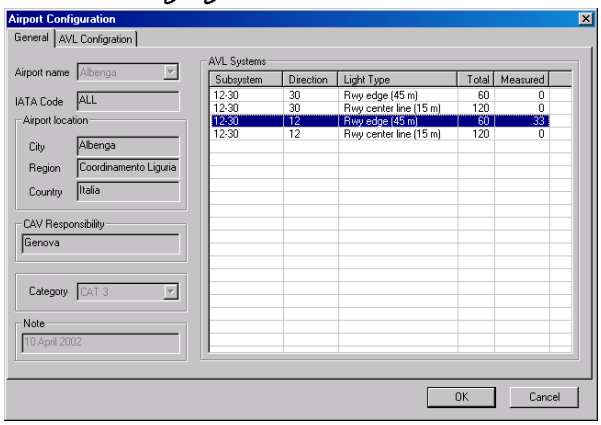

Fig.15a

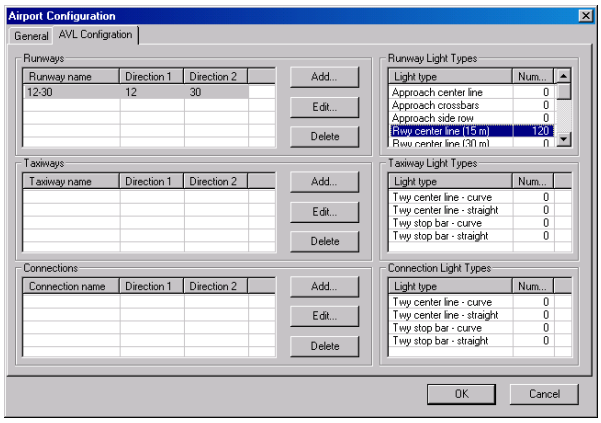

Fig.15b

AGLS measurement: operator selects the subsystem to be measured and start driving. The system acquires data samples , processes data , normalize data to ICAO grid points, store data into the system data base (see fig. 16a and 16b).

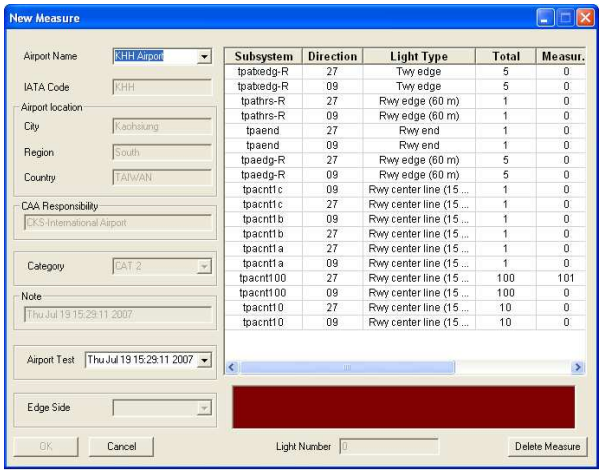

Fig.16a

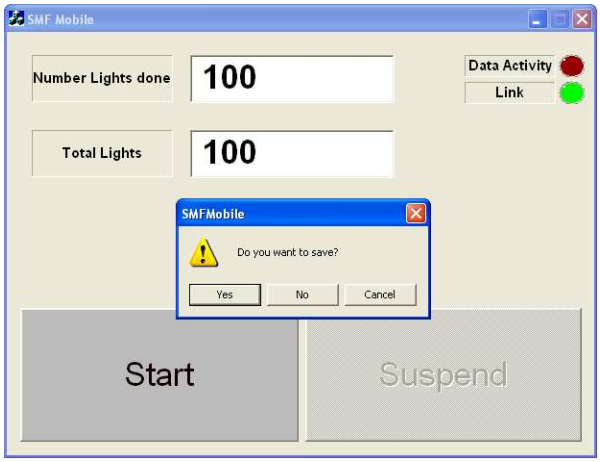

Fig.16b

AGLS Data reporting:
All the data stored in the system data base are made available on the system display (and on the system printer) to review and analyze the results of measurements. A synthesis of data measured is given in the following main system panel.

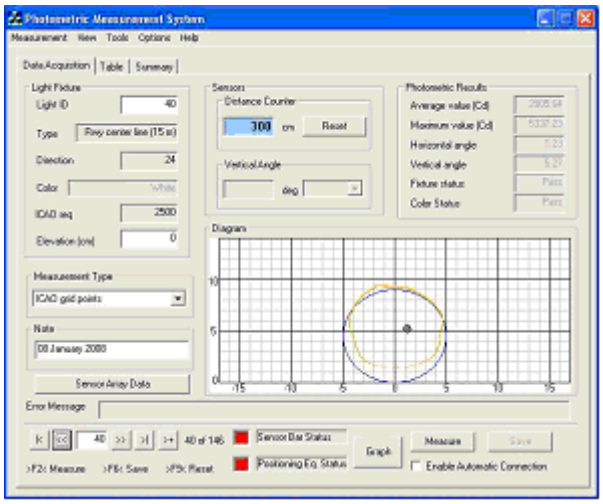

Fig.17

Data can be reported using bar histogram in order to show the results of measurements of a whole subsystem , showing the ICAO and user defined minimum thresholds of compliance (fig.18).For each fitting is available the isocandela diagrams , calculated using a vertical aperture of 13 ° against the 7° requested by ICAO specifications. This feature give the user a more precise definition especially for lamps exceeding the standard elevation of the beam (fig.19).

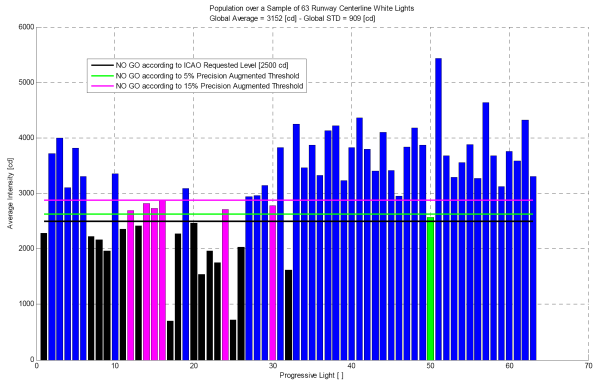

Fig.18

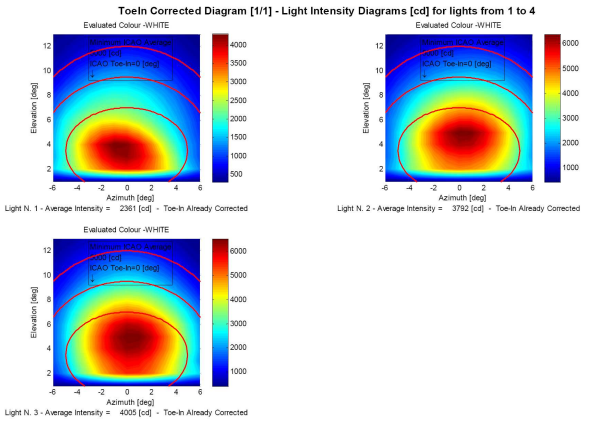

Fig.19

SMF/M accuracy and precision

The performances of ***SMF/M*** system have been assessed by the Airport Department of Italian Civil Aviation Authority ENAC for the certification of equipment in conformity to the technical standard APS-02.

The accuracy of ***SMF/M*** has been tested comparing data acquired by the system with the corresponding ones produced using a reference instrument and a manual procedure supported by a gouge representing the ICAO grid points. The results demonstrated that accuracy and precision of the instrument are better than **5%** .

The diagram in fig. 20 shows the figure of repeatability in terms of dispersion of data measured in different sessions within a given time interval and referred to the same source. In this case the diagram reports the centerline of an airport measured 3 times in the same sequence with *X* axis representing the distance and *Y* axis representing the value of candelas measured. The resulting 3 curves are close to be fully overlapped within 3% of averaged difference. In consideration of the overall assessed results the unit has been declared as conforming to APS-02.

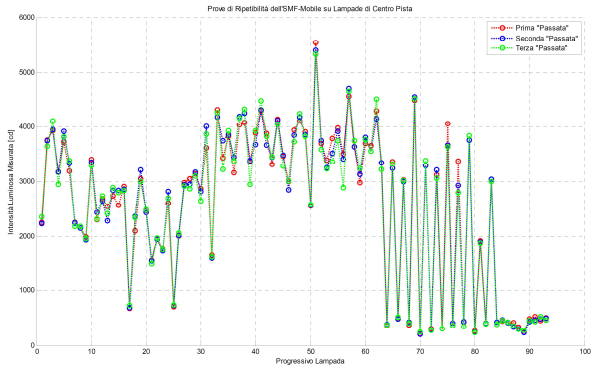

Fig.20

Technical specification of supply

- 13 Sensor bar – 0.25 LUX resolution
- 2 x CIE 1931 Color sensors
- High speed electronics for sensors oversampling via 16 bit low noise A/D converters
- 2 optoelectronic sensors for beam pointing
- Built-in camera for bar alignment
- Wheel odometer for distance measurement with a resolution of 0.7 mm
- Frame for bar supporting
- Power supply and cables
- Display for bar alignment
- Portable PC with System software
- User and Maintenance Manual
- Certificate of Calibration
- Software licence
- Max speed of measurement: 60 Km/h
- Max operating temperature 40°

Options

- GPS for easy lamp location in the airfield