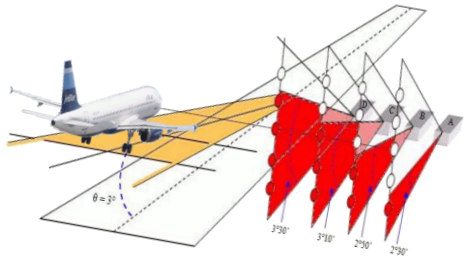
# SMF/PAPI : THE DEFINITIVE SOLUTION FOR HIGH PRECISION PAPI ALIGNEMENT

## 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 gauge will not give the required accuracy due to need of a very precise measurement of the height of the gauge and the distance between the beam and the gauge.

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.

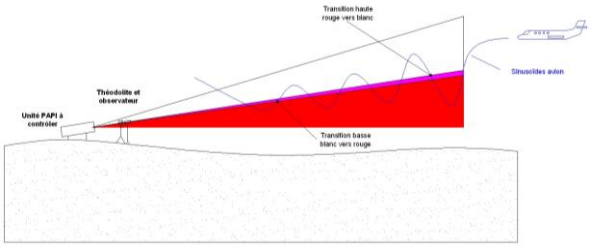



**Figure 1**

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 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.

**Fig.2**

The optoelectronic sensor is driven by an advanced image analysis software, 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 color transition emulating in near field conditions what the pilot sees from the aircraft. The key point of procedure is the horizontal auto-leveling 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.

**Fig.3**

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 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 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 instrument is remote controlled from a tablet pc allowing maintenance operators to adjust PAPI tilt and elevation watching in real time effects of

their adjustments on PAPI beams. The system is powered by a very light LiPo battery for easy use and transportation.

## 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.

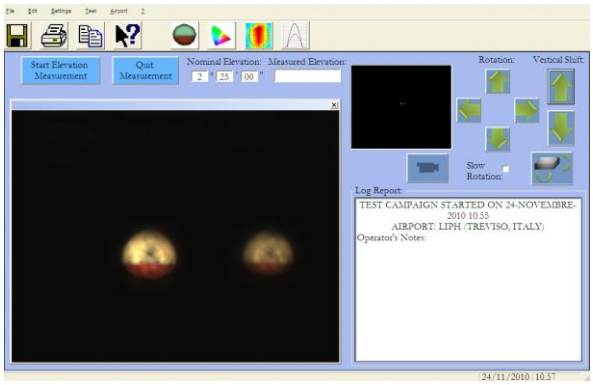



**Fig.4**

***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)

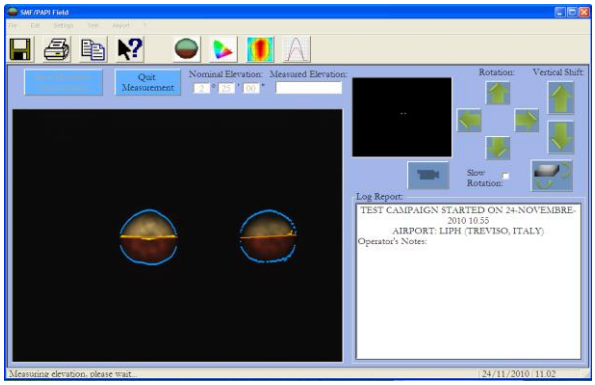



**Fig.5**

Once reached the transition 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.

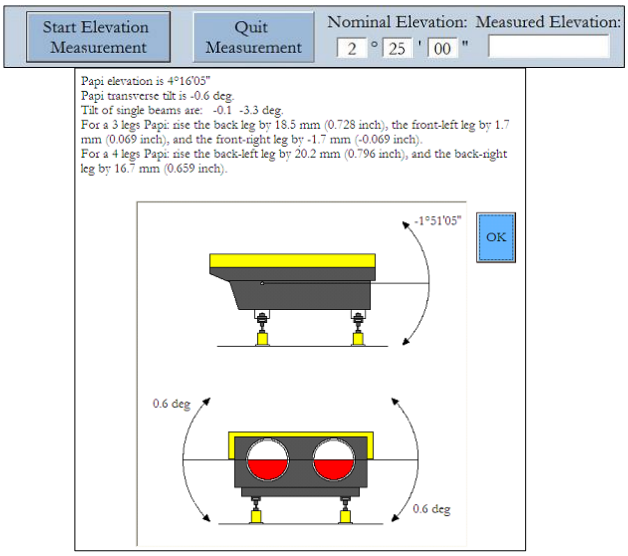



**Fig. 6**

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 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 color transition of each beam
- Average horizontality of color transition of the PAPI unit
- Color 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)

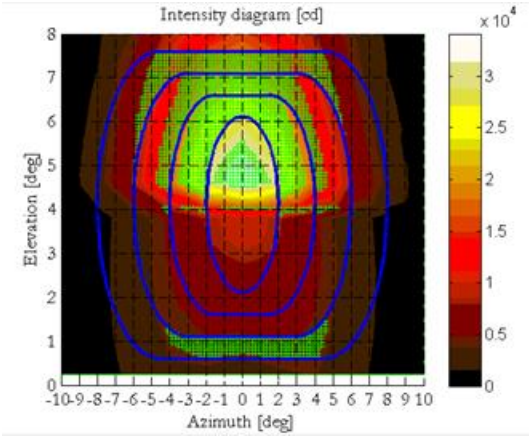



**Fig. 6-1 Isocandela Diagram**

***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 color 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

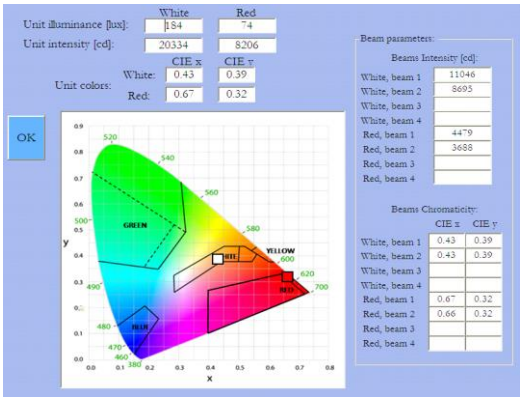



**Fig. 6-2 Chromaticity Diagram**

## 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.

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 reduced costs with comparison to in flight procedures.

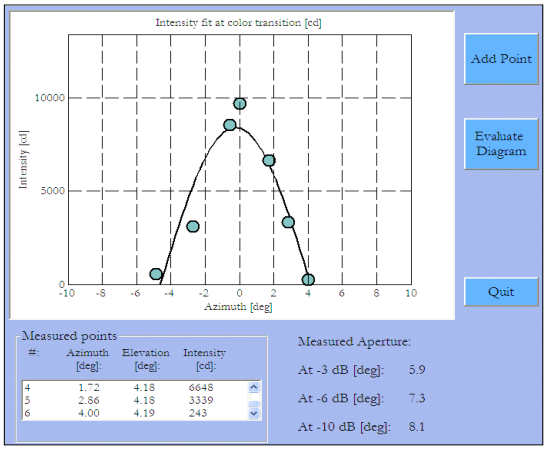



**Fig. 6-3 Beam Aperture Diagram**

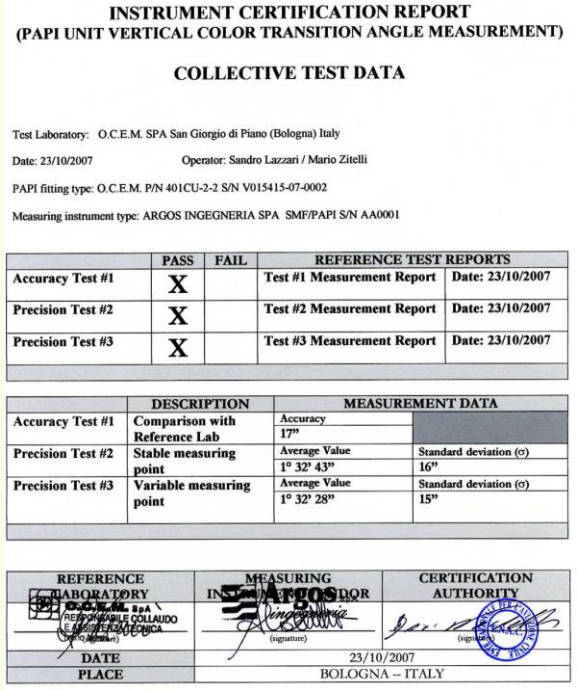
Before to start the field tests, ENAC required a severe lab test session to assess the absolute accuracy and precision of ***SMF/PAPI.***

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.

**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 1° 32' 43" | Standard deviation (σ) 16" |
| Precision Test #3 | Variable measuring point | Average Value 1° 32' 28" | Standard deviation (σ) 15" |

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

Fig.7

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 to 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 MEETING, October 2009, Osaka – Japan) 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 LiPo battery
- Ruggedized PC
- Gps antenna
- 2 Ruggedized bags
- System software and data-base
- Power and data cables
- User and Maintenance Manual
- Certificate of Calibration
- Software license

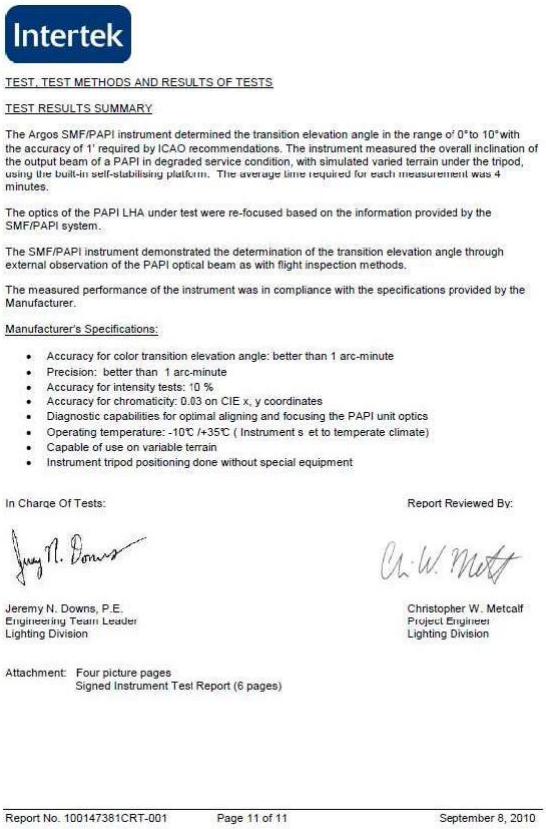
Fig.8

**Available services to customer:**

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

**SMF/PAPI – References**

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



Intertek

TEST, TEST METHODS AND RESULTS OF TESTS

TEST RESULTS SUMMARY

The Argos SMF/PAPI instrument determined the transition elevation angle in the range of 0° to 10° with the accuracy of 1' required by ICAO recommendations. The instrument measured the overall inclination of the output beam of a PAPI in degraded service condition, with simulated varied terrain under the tripod, using the built-in self-stabilising platform. The average time required for each measurement was 4 minutes.

The optics of the PAPI LHA under test were re-focused based on the information provided by the SMF/PAPI system.

The SMF/PAPI instrument demonstrated the determination of the transition elevation angle through external observation of the PAPI optical beam as with flight inspection methods.

The measured performance of the instrument was in compliance with the specifications provided by the Manufacturer.

Manufacturer's Specifications:

- Accuracy for color transition elevation angle: better than 1 arc-minute
- Precision: better than 1 arc-minute
- Accuracy for intensity tests: 10 %
- Accuracy for chromaticity: 0.03 on CIE x, y coordinates
- Diagnostic capabilities for optimal aligning and focusing the PAPI unit optics
- Operating temperature: -10℃ /+35℃ ( Instrument s et to temperate climate)
- Capable of use on variable terrain
- Instrument tripod positioning done without special equipment

In Charge Of Tests: Report Reviewed By:

Jeremy N. Downs, P.E.
Engineering Team Leader
Lighting Division

Christopher W. Metcalf
Project Engineer
Lighting Division

Attachment: Four picture pages
Signed Instrument Test Report (6 pages)

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**Fig. 9 FAA Approved Laboratory Certificate**

**SMF/PAPI – Specifications**

| Parameter | Accuracy |
|---|---|
| • Elevation angle of each beam in the PAPI unit | Better than 1' |
| • Average elevation angle of the unit | Better than 1' |
| • Average elevation angle (Glide Path) of the PAPI bar (A,B,C,D units) | Better than 1' |
| • Horizontality of color transition of each beam | 0.2° |
| • Horizontality of color transition of the PAPI unit | 0.2° |
| • Color transition aperture of the unit | 1' |
| • Aperture angle of the PAPI unit | 1° |
| • Output intensity/illuminance of the PAPI unit | 10 % |
| • CIE (x,y) chromaticity of the PAPI unit | 0.03 on x and y |

**SMF/PAPI – Weight and Dimensions**

| Item | Dimensions | | Weight |
|---|---|---|---|
| Measurement Head including cover | H | 345 mm | 6,2 Kg |
| | L | 188 mm | |
| | W | 240 mm | |
| Head case | H | 230 mm | 3,8 Kg |
| | L | 380 mm | |
| | W | 490 mm | |
| Tripod including bag | H | 950 mm | 5,7 Kg |
| | W | 250 mm | |
| | | | |
| 12 VDC LiPo Battery | H | 360 mm | 1,8 Kg |
| | L | 330 mm | |
| | W | 140 mm | |
| Ruggedized PC | H | 69 mm | 1,34 Kg |
| | L | 203 mm | |
| | W | 127 mm | |

**Accessories:**

**SMF CLC – CALIBRATOR**

SMF Collimated Laser Calibrator (SMF/CLC) is the tool for calibrating the SMF/PAPI instrument during the Elevation and the Chromaticity/Intensity Tests. This instrument is a new generation laser level that guarantees the positioning of a laser beam with a stable and affordable inclination regarding the horizon. The accuracy of such elevation is below 15 arc-seconds at any environmental temperature to guarantee that the reference beam maintain the alignment with respect to the level of bench axis. The SMF/CLC optical beam elevation is measured by a high precision electronic inclinometer placed in the same frame of reference as the generated laser beam. SMF/CLC innovative optics permits the self-detection and diagnostic of any misalignment between the laser and the inclinometer of the calibration tool. Three external precision adjustment screws are used to position the SMF/CLC in horizontal position first and then to the requested elevation, while the current elevation and horizontality angles are provided in real time on the instrument display. A USB connection communicates with the same notebook provided with the SMF/PAPI instrument. The system software simultaneously detects the SMF/CLC elevation angle and horizontality as well as the SMF/PAPI instrument measurement results. On the basis of data received a new calibration record is created and updated into the SMF/PAPI instrument memory.

**Fig. 10 SMF CLC**

In order to re-calibrate the SMF/PAPI, a 2 step automatic elevation test is required, measuring the laser beam at 3° and 6° approximately (proper values are displayed by the system software). The provided calibration software executes the tests automatically and calculates new calibration parameters for the SMF/PAPI instrument.

**Fig. 10 SMF CLC setup**

## SMF/CLC – Specifications

| | |
|---|---|
| **Beam elevation range (continuous regulation)** | **0° to 10°** |
| **Accuracy on beam elevation** | ±15 arc-seconds = 0.0052 deg |
| **Operating temperature** | +0 °C to +35 °C |
| **Storage temperature** | -10 °C to +70 °C |
| **Power supply** | 110/220 V AC |
| **Power consumption** | less than 16 W |
| **Laser output** | Class II, visible red dot, 630 nm |
| **Pointing accuracy** | ± 0.1 mm/m |
| **Dimensions** | 295 x 230 x 165 mm |
| **Weight** | 3 kg |