An Insight into Design, Development & Testing of Insulation Piercing Connectors for LV Application
Introduction

- Designed for Indoor and outdoor applications
- Non-tension tap and splice applications
- Used in Insulated secondary distribution lines
Parts of the IPC

- Bottom Body - Glass reinforced thermoplastic
- Top Body - Glass reinforced thermoplastic
- Bolt & nut - Stainless steel
- Piercing teeth - tinned copper
- Cap - Glass reinforced thermoplastic
- Shearing head - Glass reinforced thermoplastic
- Pressure pad - Mild steel
Details regarding the material

- **Stainless steel**
  - Austenite stainless steel confirming UNI 6900
  - C (0.08), Mn (2.00), Si (1.00), P(0.045), Ni (8.00/12.00), Cr (18.00/20.00)

- **Mild Steel**
  - C (0.15-0.25), Mn (0.60-0.90), Si (0.15-0.35), P (0.03)

- **Tinned Copper**
  - Have Brinnel hardness >100
  - Copper alloy – Taken from the list of UNI2012

- **Glass Reinforced Plastic**
  - Withstand thermal and mechanical solicitation
  - water absorbing (UNI ISO62 or ASTMD 570) measured on samples dim 50x50x3,2mm was lower than 0.2% after 24 hours of water immersion at 23°C and lower than 1% under saturation condition.
  - Internal sliding module on samples dim 120x20x6mm, with 10N/sqmm bending moment, after 96 hours was =6500N/sqmm at 20°C and 4500N/sqmm at 80°C

- **Insulating Material**
  - during service operations within of temperature range of -30°C /+80°C
  - during short time current condition with max cable temperature of 250°C.
  - Resistant to UV rays
Tests Performed on the IPC

The IPC undergoes thorough testing before being certified suitable for use:

- Control of the building and execution characteristics
- Dimensional control
- Materials control
- Assembly and removal tests
- Verification of the electric and mechanic characteristics of clamping
- Verification of the residual break load of the main cable and of the sliding load of the derived cable
- Test for the characterization of the organic materials
- Long duration ageing tests for the organic materials
- Dielectric withstand test
- Percussion test
- Thermal cycles and high intensity currents tests in air
- Protection degree verification
- Verification of the dropping points of the sealing pastes and greases
Control of the building and execution characteristics

- Installation is possible with aerial cables already sagged as per specs.
- Components of connector should be so designed that the assembly will not require special training and connections should not be prone to mistake on account of errors or lack of skill of lineman.
- All parts are captive and assembling by single tool with dedicated screw accessory.
- It is possible to insert cables into connector easily and without fully unscrewing bolts or parts.
- Therefore it should be verified, by visual test, that the connectors are free from any construction defects or superficial irregularities.
- All external parts are designed to avoid damages on cable cores.
- Surface does not have sharp edge.
Dimensional control & Materials control

- All dimensions meet the drawing dimensions with tolerances
- The materials used for making IPC undergo proper materials tests for
  - Metallic material
    - Steel
    - Tinned copper
  - Insulating material
  - Thermoplastic used
Assembly and removal tests

- the assembly is easy
- the cores of the cable do not get damaged
- After the connector’s assembly it is verified that the cores of the cable are not damaged
- the disassembly of the connector is easy to perform
- Finally to check visually the contact marks left on the cable. This test should reveal a regular and uniform penetration.
Verification of the electric and mechanic characteristics of clamping

- **Connectors Assembly**
  - divide the assembled cables-connectors in two different groups and respectively be conditioned, for at least 2 hours, at the temperature of -10±1 °C and of 50 ± 1 °C.
  - Afterwards the assembled cables connectors should be taken out from the conditioning room and within max 2 minutes the connections should be performed, applying on the bolt the tightening torque. Shear head of the bolt should break below the max value 18Nm torque.

- Verification of the electric resistance of the connectors
- Verification of the mechanical resistance of the connectors
Verification of the residual break load of the main cable and of the sliding load of the derived cable

- Connectors Assembly
- Test with high intensity currents.
- Verification of the residual break load of the main cable
- Verification of the slipping load of the derived cable
Test for the characterization of the organic materials

- Thermo gravimetric analysis
  - treatment temperature field: 30-900°C
  - heating speed: 20°C/min
  - level and nature of the treatment atmosphere
    - N2: 100+10 ml/min up to 600°C
    - O2: 100+10 ml/min from 600°C to 900°C
  - It should be detected the mass losses according to the temperature and the temperatures at which the decomposition speeds are max (characteristic temperatures).

- Calorimetric analysis with differential scansion (DSC)
  - treatment temperature field: 30-300°C
  - heating speed: 10°C/min
  - level and nature of the treatment atmosphere: N2: 50+10 ml/min.
  - It should be detected the thermogram that indicates the status variation and the three required characteristic values, which are: the glassy transition temperature, the softening temperature, and % of the crystalline of the organic materials.
Long duration ageing tests for the organic materials

- Samples to be tested
- Endurance test against the climatic accelerated ageing.
- Heating test
- Verification of the materials’ conditions
- Verification of the reduced dielectric withstand
- Verification of the clamping couple
Dielectric withstand test

- The samples are dipped in water with a head not less than 10 cm, for 1 hour
- Application of the test current
- Tap water with a resistance less than 20Ω.
- The water container is made of metal and connected to the ground
- The clamping screws (or bolts) and the plate of the tested connector was electrically connected to the water’s container.
- For each sample the test tension at industrial frequency (50 Hz) is applied put between the conductors and the ground and the required value of 3/4/6 kV be reached in about 1 minute
Thermal cycles and high intensity currents tests

- This test was performed according to IEC1238-1.
- The test circuit comprising of 6 connectors underwent 200 heat cycle
- The short circuit test was performed on it.
- Further 800 cycles was conducted on the circuit.
- The tests conforms to the the standard
Percussion test

- The connectors, closed but not clamped, should be conditioned for at least 2 hours at the temperature of $-10 \pm 1 \degree C$
- For the test the striker have a mass of 0.5 kg while the fall’s height on the connectors was 1mt
- Each sample receives 5 strikes so that the striker’s tip hits the connector body on 5 different points
- The external peripheral parts was involved which were mainly exposed to strikes with concentrated loads in case of accidental fall
- At the end of the test, the connectors didn't have any holes or damages which was seen by visual inspection.
Protection degree verification

- The result of the test was positive with the following conditions:
  - With connector closed not clamped, the protection degree is IP 2x (12) (according to CEI 70-1).
  - After clamping the connector, the protection degree is IP 4x (12) (according to CEI 70-1).
Verification of the dropping points of the sealing pastes and greases

- stated by the standard ISO 2176 (which is ASTM D 566)
- dropping point of the eventual sealing paste or grease used in the connector is >160°C.
Advantages of IPC

- Lower Installation costs
- No special tool required
- While making connections to insulated conductors
  - No insulation stripping
  - No application of oxide inhibitor
- Consists of contact teeth
  - Designed to penetrate conductor insulation
  - Make electrical contacts
Installation of Insulation Piercing Connector

Insulation Piercing connector’s shear head is sheared at rated torque & Insulation of cable has been pierced

Insulation piercing connector’s shear head being tested by calibrated torque wrench
Enclosure for Conditioning Insulation Piercing Connector At – 10 Degree C

Insulation Piercing connectors being conditioned at – 10°C
### Applicable Standards

1. BS 3288  - Specification for Insulator & Conductor Fittings for Overhead Power Lines.

2. IEC 1238-1  - Compression & Mechanical Connectors for Power Cables with Cu & Al conductors (Test Methods & Requirements)

3. IEC 61284  - Overhead Lines-Requirements & Test for Fittings

4. ANSI C 119.4- American National Standard for Electric Connectors

5. AS/NZS 4396- Insulation piercing Connectors for 0.6/1 KV ABC