WORLDWIDE CABLE EXPERTS

Your guide to Medium Voltage cable testing and certification
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Medium voltage (MV) cables are a vital component for generation and distribution networks. Cable products used in systems with voltage ranges up to 36kV are classified as MV.

In medium voltage cable systems efficiency can be measured by how we minimise the losses. As the voltage is increased in a system the losses of electricity, as it is transmitted down the line, are in turn minimised.

As traditional power generation sources start to be replaced or require to operate simultaneously with renewable or clean energy sources, the impact and demand for reliable generation with high output ratios becomes even more important.

Typically, the operators of power distribution networks undertake their own in-house components and systems testing.

Testing standards for their unique application have long been established and imbedded in maintenance procedures.

Over time, it is inevitable that a cable system will undergo some design changes. Modifications could include changes to a cable’s construction, the need to withstand higher stress, the introduction or substitution of materials, changes in manufacturing processes and any other changes which directly impact the original design.

Introduction to medium voltage testing

The experts in cable testing for all cable types, to recognised standards and across all major sectors

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Introduction

Technological improvements

Why do manufacturers continue to make changes? In a world where what is understood to be a reliable system is ever evolving, this need drives the enhancement of current solutions.

Technological advancements in materials, configurations, manufacturing processes and even the systems within which the cable is used occur all the time. As the primary live component in the electrical circuit, cable products are pivotal to the safe and successful transportation of energy. All of the factors outlined above contribute to the need for on-going evaluation of how they perform in operation and subsequent enhancements to improve the product’s overall quality.

Advances, particularly in the field of materials technology provide opportunities to make incremental improvements to the performance of all cables, however they must be validated by comprehensive testing.

A cable manufacturer’s goal is often to launch innovative product solutions to the market, in a quick and economically viable way.

Maintaining product reliability and integrity should be the primary focus and independent verification of product quality, to internationally recognised standards, is the best way to evidence consistency.

In placing the end user needs for reliability at the fore, the consequences of unplanned change could result in product failures, incurring short-term financial gains which could be at the expense of a manufacturers reputation and credibility to produce strong, consistent and quality cable products.
**MV vs LV cable constructions**

Cable designs can come in a range of sizes, types and have the need to comply to a range of standards. The very construction and processing of an MV cable is far more complex than that of a low voltage (LV) cable.

**A typical MV construction**

Insulation
- **MV insulation** must be applied in a catenary continuous vulcanisation (CCV) line, within a curved (catenary) tube - a typical tube is 140m long, this is where curing occurs.

The MV construction is also made up of three layers including the inner semi-con, insulation and outer semi-con, the raw materials are significantly different to those used in LV cables.

The XLPE used is different to that used in LV and must be pure, without adding any additives for colouring to ensure the dielectric strength is the highest it can be.

**LV insulation** is applied via a horizontally aligned extruder process.

**Metallic screen**
- **MV cable** requires a metallic screen
- **LV cable** has no metallic screen
Standards

In-depth cable testing

With increased competition, the use of alternative materials is an easy way for a cable manufacturer to differentiate their product ranges. In developing mixes of materials which are different to those offered by competitors, a cable product’s characteristics and properties can be enhanced or altered to suit the end application’s requirements.

As a result of this activity, the necessity to perform independent type tests prior to the product entering the end user market, or to repeat these type tests as part of an on-going assessment is required, in order to prove performance characteristics becomes an essential activity for manufacturers.

There is an increasing global need for MV cables, as the experts in cable testing BASEC believes these cables should be type tested to ensure product quality is consistent with industry standards.

Leading standards include:

**IEC 60502-2**

Applicable to power cables with extruded solid insulation, part 2 is specific to cable products with rated voltages from 6 kV (Um = 7.2 kV) up to 30 kV (Um = 36 kV) for use in fixed installations.

This standard is the most commonly used for MV cables, offering the potential to cover a wider design scope, including:

- ✔ Armoured and un-armoured option
- ✔ Tape armouring option STA & ATA

Whilst a low-smoke halogen-free (LSHF) option is not included, this standard is still commonly used. The general design is assessed by the main standard except for the mechanical tests for inner sheath, separation and outer sheath, as these are performed as per type ST8 of IEC 60502-1 and fire tests including IEC 60332 series, IEC 61034 and IEC 60754 are applicable.
IEC / EN 60754
Is designed to determine the halogen acid gas content and is particularly important because it was developed as a result of concerns raised by cable users over the amount of acid gas released when insulating, sheathing and other materials catch fire.

IEC / EN 60332
Small scale single cable and large scale bunched cable testing of flame propagation of vertically mounted samples.

IEC / EN 61034
Measures smoke density of cables burning under defined conditions. This standard is particularly relevant to assessing visibility in and around areas where smoke is released into the air as a result of the cables igniting in a fire scenario.

BS 6622
One of the main MV standards, particularly focused on general armoured cables with thermosetting insulation for rated voltages from 3.8/6.6 kV to 19/33 kV. Designed to operate at maximum, continuous conductor temperatures of 90°C, with short circuit temperatures of 250°C.

The standard includes single- and three-core cables using stranded copper, solid or stranded aluminium conductors. The cable insulation is typically either cross-linked polyethylene or cross-linked ethylene propylene rubber. The design also includes a metallic screening layer of copper wire, copper tape, a metallic armour of aluminium or galvanised steel wire. Finally, the oversheath will typically consist of a polyethylene or polyvinyl chloride compound.
Specialist knowledge and understanding of Internationally recognised standards and specifications

BS 7835
Another one of the main standards, this standard offers a variation for armoured cables with thermosetting insulation for rated voltages from 3.8/6.6 kV to 19/33 kV with a need for lower levels of smoke and corrosive gas emissions, when exposed to fire tests. Typically, the standard is applicable where cable products are used in fixed indoor installations: networks and industrial applications.

The standard includes similar ranges to the BS 6622, the only differences being in the inner sheath, separation and oversheath, which must consist of a low-smoke halogen-free material.

BS 7870 series
These standards apply to LV and MV polymeric insulated cables for use by generation and distribution utilities. The series outlines the specifications for distribution cables with extruded insulation of rated voltages of 11 kV to 33 kV.

BS 7870-4.10 – is specific to single-core cables only, with an oversheath made of one of the following compounds:

- Medium density polyethylene (MDPE) compound type DMP 5 (Type A cables), or
- Thermoplastic compound type DMZ 4 for cables with a need for low emission of smoke and corrosive gases when affected by fire (Type B cables)

The standard also specifies the requirement for cables laid up in a triplex formation at 11kV.

BS 7870-4.11 – is specific to single-core 33 kV lead alloy sheathed cables.

BS 7870-4.20 - works to the same criteria outlined above for BS 7870-4.10 but applies to the three-core 11 kV cable variation.
Specialist standards

MV cable products are widely used in specialist sectors including rail, marine, mining, oil gas and petrochemical, to name a few. In these specialist applications there are a range of internationally recognised, national or customer specific standards available in the market.

For example, HD 620 is a widely used standard offering insulation varieties including:

<table>
<thead>
<tr>
<th>Material</th>
<th>Single-core</th>
<th>Single-core Pre-assembled</th>
<th>Three-core</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEPR (hard grade ethylene propylene rubber)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>XPLE (cross-linked polyethylene)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>EPR (ethylene propylene rubber-insulated)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
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</table>
Cable testing

Complete cable assessment

As with all recognised standards for cable products, a collective standard is referenced for the approval, such as those outlined above. MV cable products require in-depth testing to assess not only each individual component, that makes up the cable, but also, tests to assess the final and complete cable itself. A type test includes electrical, mechanical, material, chemical and fire testing.

The make up of a type test

A type test is conducted to prove the characteristics of the cable product, in line with the standard and on products in their ready to sell to end user conditions.

All of the test information that follows forms a central part of the type test, some tests however must also be conducted on an on-going basis by the cable manufacturer. The test programme therefore is categorised in to three main testing groups:

- **Type tests** – a sequential testing requirement to enable the issuing of a complete approval. The tests include comprehensive, whole cable electrical testing and tests of individual material components

- **Samples tests** – these tests should be conducted on a representative number of samples, as per the agreed quality plan

- **Routine tests** – these tests should be conducted on every length of cable produced. Whilst they will be tested as part of the type test approval the manufacturer should ensure their operations are set up to facilitate maintained and on-going testing
Cable testing

**MV Type Test**

### Electrical

**Partial discharge test** – is designed to determine the discharge presence, magnitude and to check that the magnitude does not exceed a specified value, at a specific voltage. The results of these tests can vary depending on the length of cable being tested, therefore the IEC 60270 / EN 60885-3 standards set out the parameters to ensure controlled conditions.

Type test cable lengths must be 10-15 m. At the heart of the test system sits the HV test transformer, which is coupled with the voltage and partial discharge (PD) measuring systems. The test and transformer equipment is situated in a shielded enclosure to ensure any electrical noise or interference from the surroundings and circuit are cancelled.

Over 85% of disruptive failures in MV systems are partial discharge related. Specifically where there has been poor workmanship during jointing activities. The release of energy, therefore, is a precursor to breakdown, as it provides evidence that the cable is starting to deteriorate, which will lead to faults and failures later down the line.

**Bend tests** – are vital to understanding the bend radii and they are conducted to examine that the cable will bend as required, in line with the standard, without damage. This test is particularly relevant to the installation practises which the end user will need to undertake to position MV cable products within complex power generation systems.

This preliminary test is performed at the start of the sequential testing, to put stresses similar to those caused in installation and to precondition the sample. The cable sample is bent around a test cylinder, as defined in the standard, for at least one complete turn. It is then unwound and repeated, but this time the bend of the cable direction is reversed. Three cycles of this process are conducted.

A partial discharge test is conducted post bend test to assess the impact on the cable.
Tan delta (δ) testing – also known as dissipation factor, these tests are conducted to determine the quality of the insulation within the cable product. They are non-destructive. As the cable starts to age, the cable insulation is one of the first areas to be affected. As this happens the resistance decreases and is a key indicator of defects, including moisture or air pockets, water trees, electrical trees and a range of other issues.

This test can be repeated on cable products in service to also assist in assessing life expectancy in order to plan or predict maintenance or replacement cycles, and avoid unnecessary outages. Testing is conducted in relation to:

- **Temperature** – the cable sample is heated, by passing current through the metallic screen or by current loading the conductors. Measurement is at temperatures no less that 95°C and not greater than 100°C.
- **Voltage** – should be at least 2 kV and the cable should be heated by 5-10K above the maximum conductor temperature expected during normal operation.

Heat cycling – is designed to assess how a cable product will respond to constant temperature change in service. This is particularly important in applications where, for example, equipment may go in to standby-mode based on generation demands.

The test involves the passing of current through the conductor for 8 hours, the conductor temperature is again maintained between 95°C and 100°C for at least 2 hours during the heating period. After the 8-hour cycle, a period of 3 hours is allowed for natural cooling, down to a temperature within 10 K of the ambient temperature – this cycle is repeated 20 times.

After the final cycle the sample is subjected to a PD test to ensure that it still meets the standard criteria, in line with the requirements outlined earlier.
Cable testing

**Impulse voltage testing** – is designed to mimic the effect of lightning strikes. Typically, overhead cables are at risk of being struck by lightning. In this scenario the lightning strike will multiply the applied voltage which creates the impulse voltage. The test is designed to assess that the cable product can withstand this type of surge.

In accordance with the IEC 62067, 60840 and 60502-2 for cables, the test system generates lightning impulse, chopping and switching voltages. This test is also carried out at a temperature between 95°C and 100°C. Cable samples must be pre-heated to the temperature before the test starts and the temperature must be maintained throughout the test.

**Voltage test for 4 hours** – during this test voltage is applied at 4Uo as per the standard(s), and results should show no breakdown of insulation.

This final test is conducted to confirm the electrical integrity of the cable following the preceding range of sequenced tests.

**Adherence of screens at short circuit temperature** – this test is conducted on samples with a cross-sectional area of up to 185mm². The sample is PD tested and then one of the cores is subjected to a short circuit current. The cable sample is then cooled to ambient temperatures and PD testing is carried out again to ensure the discharge magnitude is no greater than the standard allows.

The short circuit temperature can sometimes cause separation between the layers of XLPE and semi-conductor which causes a void, allowing partial discharge. The test is designed to assess if the cable will be affected in this way, which will bring the cable design in to question if it fails.
Low voltage – electrical tests

Conductor resistance
Is used to determine the DC resistance of the cable's conductors. The lower the resistance the more efficient the cable will be through lower losses. Also a routine test conducted as part of a manufacturers production control checks.

Screen resistivity
During this test the semi-conductors are tested to ensure that the resistivity is suitable for the voltage rating of the cable, as per the standard's requirements.

Mechanical

Separation sheath material test
The separation sheath forms a protective layer when the underlying metal layer and the armour are of different materials. The separation sheath is checked to ensure that the two dissimilar metals are totally separated, in order to avoid the risk of reaction or corrosion which could cause problems later in service.

Insulation and oversheath material testing
Assesses the insulation's mechanical properties and condition to ensure it has been properly processed and meets the required standards before and after accelerated aging. Separately, the oversheath is subjected to the same mechanical assessment, plus in the case of halogen free sheaths, assessment of flame propagation, smoke emission and acid gas generation.

Compatibility test
This test ages a sample, of the complete cable, over a duration of 7 days in an air oven at 100°C. The compatibility test is designed to assess for any interaction between materials. As it ages them as a complete cable the test ensures that materials will remain compatible with one another.
Cable testing

Shrinkage test
This test is applied to PE materials, the test is important because it gives an insight into how the materials may perform, or impact other components in the cable construction.

Shrinkage means that the material pulls back. This characteristic makes it very critical, that should it occur in the insulation or sheath, how much of the conductor is exposed. If the material shrinks by a significant amount this increases the risk of a short circuit. If the sheath pulls back from a splice or termination the cable can then also be exposed to dirt and moisture which will again impact the cable.
The experts in fire testing, offering complete cable assessment aligned with the CPR requirements

Corrosive and acid gas
Measurement of gas emissions released when cable samples are burned, simulating a fire scenario and all non-metallic parts are assessed.

Abrasion test
A low carbon steel angle is loaded with force as per the standard, then dragged horizontally along the cable for a distance of 600mm, the test is repeated in the opposite direction, 25 times each way.

Armours
Different tests should be performed to verify the quality of any armouring material. The tests depend on the material type (galvanized steel or aluminium) and also depend on the armour type (wires or tapes).

Dimensions should be measured in all cases to ensure it complies to the standard, to ensure that the armours will provide the required level of mechanical protection for the cable. Additionally, the maximum gap or spacing between armour tapes, weight of zinc coating for galvanized steel armouring, and tensile strength of aluminium wires is measured.

Fire testing
The flame propagation test is conducted on multiple cable lengths, as per IEC / EN 60332-3-24 Cat C. The cable samples are bundled together for the main type test and are mounted vertically on the ladder to be burned. The char length is then measured to assess and understand the maximum distance of fire spread. Manufacturers are required to conduct testing to BS EN 60332-1-2 as part of their ongoing sample testing programme.

Smoke emission test
The smoke test is again completed on complete cable samples in accordance with IEC / BS EN 61034. The smoke generated must not result in a lower transmittance level than the relevant value specified. This test is also repeated as part of the manufacturers required sample testing.
It is the responsibility of the manufacturer to declare production so that a representative number of samples are tested on a frequency agreed and documented in their quality plan.

Many of the tests have been outlined in the main type test sequence, however periodic testing allows on-going quality surveillance activity to ensure product consistency:

- Conductor – material, construction, screen application, circularity of cores, assembly of three-core
- Insulation – hot set, thickness, concentricity, screen application, screen cold strip-ability
- Screens and armours – metallic screen application, armour wire measurement (resistance as per national regulation or standard)
- Sheath – separation sheath and overall thickness
- Fire & smoke – flame propagation on single cable BS EN 60332-1-2, smoke emissions
Routine tests

It is the responsibility of the manufacturer to ensure these tests are completed and integrated in their production line processes.

Spark test – is an inline voltage test, designed to capture faults at the manufacturing stages. This test is particularly important to ensure that any design faults or quality issues can be identified and corrected in the manufacturing process. The test is designed to ensure quality is maintained and to ensure efforts, materials and time are not wasted on product that does not meet the quality required.

Conductor resistance – is used to determine the DC resistance of the cable’s conductors. The lower the resistance the more efficient the cable will be through lower Watt losses.

Copper wire screen resistance – screens are included in cable designs to add a layer of protection. If the cable were to be cut or damaged once in service the screen is designed to trigger the fuse and in turn the circuit breaker to stop the flow of current, which could cause serious harm to those operating connected machinery if it fails. The screen is not included in the design as a mechanical protection, it is in fact included to drain or conduct electric field noise away from the capacitive charging current, inducing circulating current down to earth. This is to reduce interference with the surrounding electrical cables and systems.

Partial discharge – is used to determine the quality of the cable and can be indicative of weak areas or those where potential failures could arise. Partial discharge is a local dielectric breakdown, often this will appear prior to any visible component breakdowns, such as cracking in cable insulation.

Cable markings – are assessed for their accuracy, clarity and consistency. Whilst some may argue this is not an important test, cables with markings that do not meet the quality requirements raise cause for concern on the quality of the overall product. Often, this is linked to the authenticity of a product.
Ensuring that cables are compatible with end application requirements is critical. It is therefore, very common that private or utility project specifications will incorporate special requirements, designed to take into consideration the conditions within which these cables are expected to operate.

Many of these design features have been led by technological advancements, placing the manufacturers and end users at the cutting edge of producing and using the very best cable designs available. Protecting credibility and reputations for quality at the highest levels in industry.

**Tree-retardant XLPE**

Enabled through permanent polymer modification technology, retardancy to water treeing is built into the cross-linked polyethylene (XLPE). The enhanced properties of this insulation offer superior reliability and longer performance in high-stress cable designs.

At the compound level, a series of in-depth tests are undertaken to verify and prove the characteristics, including testing prior to use in cable construction, simulated long-term accelerated aging and breakdown testing, voltage life tests on 6.6kV up to 66kV, accelerated water treeing and tree growth rate on cables, as well as sampling of field aged cables.

**Water protected cables**

Underground cables are prone to many sustained outdoor conditions, including extremely dry, hot and cold weathering, contact with wildlife and, in this specific scenario wet or waterlogged environments. It is this last point where the special requirement for water penetration tested, or water protected cables comes to the fore.

Impacts to performance and premature life-shortening are key side effects of excessively wet or moisture filled conditions. Once permeated, water will migrate through the cable, potentially causing corrosion and chemical reactions.

MDPE sheathing is recommended as part of the BS 7870 series as being generally more resistant to water. The addition of swellable fillers: yarns and tapes work to block water, and copper screens, copper earthing work to reduce the use of materials prone to corrosion, such as steel and aluminium that are more likely to erode. Water penetration test as per IEC 60502-2 Annex F.

**External conductive layer**

Whilst underground cables are more reliable than overhead cables, the costs, time and efforts to repair cables often buried under soils or concrete structures is high. For this reason, ensuring the reliability of MV cables is extremely important. An additional conductive layer typically a carbon-black material or a graphite coating is applied at the same time as the oversheath. It is added to the design in order to facilitate commissioning testing and in-service routine testing, to ensure that the outer sheath is free from cuts.
Rigorous examination of production processes alongside product testing

Scheme F – PCR requirements

This scheme aims to manage the certification processes required to deliver type test approvals for cables designed to operate at medium voltage (6kV to 33kV).

Surveillance
Following the initial type test approval on-going surveillance of compliance is required to ensure consistency of quality.

As part of the scheme on-going samples must be saved by the approved manufacturer, referred to as the licensee in the BASEC Product Certifications Requirements (PCR) document, for selection by a BASEC representative.

Sample selection
Separate samples based on the construction of the cable, production volumes and the tests required to maintain the MV type test approval are detailed in the PCR document.

The sharing of this data is vital as it provides input into the development of sample selection packs. Sample selection information is shared with the manufacturer prior to planned surveillance audits so that they can plan to keep the samples required for testing aside.

Frequency of testing
Whilst it is recommended that the sequential type test approval should be conducted every 3 years to re-validate approvals, each test also has a frequency requirement. Tests in the PCR are denoted as follows to guide on the required frequency of testing:

- F100 – on every sample
- F50 – on 50% of samples
- F25 – on 25% of samples
- F5 – on 5% of samples
- 1/3 – once every 3 years
- Man – on every product by manufacturer

Test locations
The PCR also denotes where the test should be conducted, based on the size of samples and availability of testing equipment:

- a – at place of manufacturer
- b – if not at place of manufacturer, licensee owned laboratory
- o – if not at licensee owned laboratory, may be at BASEC laboratory
- d – at BASEC laboratory only
About us

The laboratory

MV cable testing, at BASEC’s strategic partnership laboratories, is conducted using the highest quality equipment. BASEC employees include expert test technicians, auditors and technical managers who hold years of experience gained from real cable manufacturing facilities from around the world.

Key equipment

To complete testing schedules in line with the standard’s requirements, a range of equipment must be used, detailed below are some key summaries of the equipment and their roles in the test processes:

- **HV test AC transformer** – used predominantly for insulation testing, many cable manufacturers are familiar with this test apparatus as it is often used in development and routine testing conducted in-house

- **Tan delta (δ) measuring bridge** – used to measure dissipation factor: tan δ the way the material absorbs or disperses energy, capacitance: electrical charge, and power factor: power that can be used in the circuit versus that resulting from the interaction of the current and voltage circuit

- **Faraday cage** – this is an enclosure used to block electromagnetic fields. Shielding the test sample from static electrical fields and radiation which is naturally present. The cage works to cancel out noise or interference, so that electrical testing can be conducted in a controlled environment

- **End termination systems** – are used to connect the sample to the test equipment. Specific to the test voltage, there are two main types of end termination, including:
  - **Oil termination systems** for medium voltage cables being tested up to 100 kV
  - **Water termination systems** for both medium and high voltage cables, for voltages 75 kV to 800 kV. Using a closed, water circuit conditioning unit which works to extract heat losses produced during the testing
State-of-the-art test equipment and facilities:

- HV test AC 100kV/150kV transformer oil-filled metal tank & oil-air bushing
- Switchgear cubicle power connection
- Compensation reactor
- Voltage measurement system
- Partial discharge system
- Tan delta (δ) – standalone capacitance measuring bridge
- Shielded Faraday cage
- Advanced control & data recording
- Impulse voltage generator with automatic earthing
- Water and oil insulated end termination system
- High-current heating system
The fault rate in cable products destined for underground applications is lower than that of overhead cables.

However, there are still a number of reasons why cable does not perform as required in service, detailed below are some of the common issues industry professionals often report to BASEC:

- Incorrect handling or storage of cable products prior to installation
- The majority relate directly to the quality of installation. Often laying, installation errors or use of incorrect rollers or pulling equipment are found to be the cause of cable damage, leading to problems or failures in service
- Poor base quality of cable termination systems
- Poor cable joints are often a weak link in the system
- Aging cable infrastructures and systems, which makes them more likely to fail, due to reduced reliability or operational efficiency

Benefits of BASEC

- Complete testing solutions
- Experts in rigorous cable testing and certification
- Testing to meet increasing consumption and demand
- Verification of cable design and construction
- Independent, third party assessment outside of the manufacturer’s facilities
- Type test report and approvals publicly listed and permitting the use of BASEC markings
About us

BASEC is the **expert in cable** certification, testing and the awarding of triple standard accredited management systems approvals: ISO 9001 for quality, ISO 14001 for environment and ISO 45001 for health & safety. Established in 1971, BASEC works in partnership with cable manufacturers around the world and their end users, as the preferred testing and certification provider.

To evidence the highest levels of quality and safety, BASEC delivers certification to industry recognised standards and specifications, including International IEC, European EN, British BS and local requirements. BASEC offers a range of services from **full certification** of single or full product ranges, to **one-off** and **type testing** of LV, MV and speciality cable products. Recognised in both the UK via UKAS NB 2661 & Europe via INAB NB 2851, for accredited CPR fire testing.

BASEC supports you across all major sectors, including: construction & electrical installation, utilities, transportation: rail, power distribution, renewable energy: solar, nuclear, oil, gas and petrochemical, fire and security and infrastructure.

BASEC continues to invest in increased regional presence and laboratory equipment to support the industry faster and better. When quality matters, choose BASEC as your trusted partner.