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ERROR PREVENTION IN AUTOMOTIVE PRODUCTION.

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ERROR PREVENTION IN AUTOMOTIVE PRODUCTION – THE OFTEN UNDERESTIMATED ROLE OF PROTECTIVE PLUGS AND CAPS

Executive Summary

In automotive production, efficiency, process reliability and component quality are top priorities. Simple components such as protective plugs and caps are often given too little attention – despite potentially serious consequences. Contaminated fluid systems, damaged threads or faulty electrical connections can lead to production downtime, rework and customer complaints.

This white paper uses typical sources of error and practical examples to demonstrate how protective solutions make a decisive contribution to error prevention and provides hands-on recommendations for design engineers and quality assurance specialists.

1. INTRODUCTION: SMALL PARTS, BIG IMPACT

Quality assurance in the automotive industry is optimised down to the smallest detail. Nevertheless, errors continue to occur, often originating in the early stages of the production process. One frequently underestimated factor is missing or insufficient protection for sensitive components.

Components particularly affected include:

- Media-carrying lines (e.g. for thermal management)
- Threaded holes and sealing surfaces
- Electrical connectors (e.g. high-voltage or sensor components)
- Surfaces with tight tolerances or specific assembly requirements

Even the smallest particles, moisture or mechanical influences during storage, transport or production can cause failures. Protective plugs and caps provide a simple yet highly effective means of protection.

2. SOURCES OF ERROR WITHOUT ADEQUATE PROTECTION

Where can errors occur?

Errors can arise during transport, storage and at various stages of the production process of the components to be protected.

What types of damage can occur?

2.1 Transport Damage

- Impact and abrasion loads in mesh containers, on pallets or during handling
- **Consequences:** deformation, burr formation, damage to connectors and edges

2.2 Contamination

- Ingress of dust, dirt, metal chips, moisture or cleaning agents
- **Consequences:** sensor malfunctions, leakages, corrosion, electrical short circuits

2.3 Damage During the Production Process

- **Unintended painting or coating**
During painting or coating processes, open threads, sealing surfaces or connectors may unintentionally be exposed to paint, powder coating or protective media if they are not adequately covered.
- **Consequences:**
 - Paint or coating residues in threads prevent correct tightening of fasteners
 - Damage to thread flanks during re-tapping or cleaning
 - Increased assembly effort, up to and including scrapping of components
 - Impairment of sealing function on coated sealing surfaces

2.4 Damage During Further Processing

- **ESD-related damage to electronic components**
During subsequent processes such as assembly, testing or handling, electrostatic discharge may occur if electronic interfaces or connectors are not protected. Electronic assemblies, sensors, as well as high-voltage and low-voltage connector systems are particularly affected.
- **Consequences:**
 - Latent damage to electronic components (failure occurs later in operation)
 - Malfunctions of sensors or control units
 - Partial or complete failure of electronic assemblies
 - Increased field failure rates and difficult-to-trace complaint causes

2.5 Damage During Cleaning Processes

- **Ingress of liquids or cleaning chemicals into connectors**
During cleaning processes, for example after machining or before assembly, water or cleaning media can enter unprotected connectors, contact surfaces or open interfaces.
- **Consequences:**
 - Corrosion on contacts and conductor tracks
 - Impaired electrical conductivity
 - Contact problems up to complete electrical failure
 - Long-term damage due to moisture ingress (e.g. leakage currents, contact failure)

3. TECHNICAL REQUIREMENTS FOR PROTECTIVE SOLUTIONS

- **Material properties:** temperature, media and UV resistance depending on installation location
- **Ease of assembly:** suitable for manual or automated installation
- **Removability:** safe removal without residues or damage, if required with clearly defined and documented pull-off forces
- **Identification:** colour coding, grip tabs, safety features
- **Standards compliance:** compatibility with OEM requirements and ISO standards
- **Technical cleanliness:** e.g. no metallic particles >150 µm
- **Protection against electrostatic discharge (ESD)**

4. PRACTICAL EXAMPLES

Example 1: HV Connector in Vehicle Manufacturing

- **Problem:** A supplier reports an increasing number of failures in HV connectors after installation. Cause: moisture ingress during storage prior to final assembly.
- **Solution:** Use of a precisely fitting protective cap with circumferential sealing lip.
- **Add-on:** Heat-resistant plastic.
- **Result:** Failure rate reduced, no further complaints in series production, reduced rework

Example 2: Protection of Coolant Lines

- **Problem:** Particle and dust ingress during transport.
- **Solution:** Dust-tight protective plugs.
- **Add-on:** Venting function.
- **Result:** Reduced field failure rate, lower return costs.

Example 3: Thread Protection in Engine Assembly

- **Problem:** Damaged threads during transport and intermediate storage.
- **Solution:** Impact-resistant protective caps.
- **Add-on:** Colour coding for quick identification.
- **Result:** Avoidance of rework, smooth assembly processes

5. PRACTICAL RECOMMENDATIONS

- Carry out a **failure analysis** along the supply chain: where can contamination, damage or assembly errors occur?
- Review **material requirements:** temperature, media and UV resistance.

- Use **identification features** such as colours or grip tabs to increase process reliability.
- Integrate **sustainability solutions** (e.g. recycled-material-based series) to meet OEM requirements and sustainability targets.

6. EXPERT OPINION

“Protective elements are often treated as a secondary issue in the early phases of development and production processes. At the same time, they must meet requirements that come very close to safety-relevant components. These include temperature resistance in the engine compartment, ESD protection for electronically sensitive components, and compliance with common industry standards such as VDA and SAE.

In our experience, customers benefit particularly when protective components are considered at an early stage – for example during the design of high-voltage connectors or VDA/SAE-based quick couplings. This significantly reduces later process risks such as particle ingress, moisture or mechanical damage.

System diversity also plays an important role in the automotive industry. With an extensive standard range, high-voltage connectors as well as VDA and SAE interfaces can often already be covered with standardised protective caps and plugs, reducing development effort and simplifying procurement processes.”

Johannes Berling – Head of Project Engineering at Pöppelmann KAPSTO

7. KAPSTO SOLUTIONS

Pöppelmann KAPSTO offers a broad range of protective components for the automotive industry:

- **Standard range:** Over 4,000 protective caps and plugs, generally available ex stock
- **Custom solutions:** Individual developments for complex or highly specific applications
- **Sustainable series:** Products made from up to 100% PCR in the plastic used
- **Engineering support:** CAD data, material consulting, sampling, technical documentation
- **Precisely fitting protective solutions**, e.g. for high- or low-voltage applications from TE Connectivity, Hirschmann, or VDA applications
- **New:** Tool manufacturing in 6 days – from approval of article data to first samples from the machine

8. SEVEN EXAMPLE PROTECTIVE SOLUTIONS

HV-PROTECTION – GPN 380 Type B



- Protects connectors from manufacturers such as TE Connectivity (HVP 800), e.g. between battery, inverter and electric motor, against corrosion and mechanical damage
- Non-slip grip surfaces allow quick removal
- Can be mounted on both sides and features a functional design registered as a design patent
- Plastic used is made from post-consumer recycled material and is certified with the Blue Angel eco-label

VDA- Grip Cap – GPN 243



- Suitable for protecting VDA PS3 quick-connect fittings
- Fits versions with and without anti-rotation protection
- The grippy tab enables very fast assembly and removal
- Clamping via retaining ribs allows pressure equalisation and protects the fitting up to the chamfer
- Plastic used is made from post-consumer recycled material

QC Plug – GPN 245 Type B



- For protection of SAE Quick Connector couplings, based on SAE J2044
- Gentle and secure clamping on the internal sealing rings of the connector
- Suitable for pressure testing within certain limits
- Ring tab enables easy assembly and removal
- Also available as Type A without ring tab

Screw Caps with Sealing Ring – GPN 804



- Suitable for a wide range of thread types, including metric, pipe and American threads
- Equipped with a sealing ring made of nitrile butadiene rubber (NBR) to meet increased sealing requirements
- Knurled outer surface for easy manual installation

Grip Plugs – GPN 305



- Suitable for protecting hoses, bores and internal threads
- Handy grip tab allows easy removal; circumferential ribs and centring bars ensure a secure fit

HV Protection – GPN 395 Type A



- Protects connectors, e.g. in batteries, DC/DC converters, on-board chargers, power distribution units and HV distribution systems, against corrosion, mechanical damage and splash water in accordance with IPX4
- Non-slip grip surfaces allow quick removal
- Can be mounted on both sides and features a functional design registered as a design patent
- Plastic used is made from post-consumer recycled material

Contact Protection – GPN 366



- Designed to protect compact connector interfaces in the low-voltage range; also suitable for oval openings
- Handy grip tab enables quick removal; circumferential ribs ensure optimal clamping fit
- Prevents the ingress of liquids within certain limits

9. CONCLUSION: PREVENT ERRORS BEFORE THEY OCCUR

Protective plugs and caps are not just simple plastic parts – they are **key components in quality assurance**. Their targeted use helps eliminate **systemic sources of error in automotive production** before they lead to **downtime** or **warranty claims**.

KAPSTO supports you with a comprehensive product portfolio, many years of automotive experience and technical support – from development through to series supply.

CONTACT & FURTHER INFORMATION

More information at:

<https://www.poeppelmann.com/en/kapsto/Industries/Automotive.html>

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