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TECHNICAL WRITING AND PRACTICAL INSIGHTS OF UNDERGROUND CABLE DUCT SEAL

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Abstract: Underground (UG) basements in infrastructure facilities such as electrical substations are highly vulnerable to water ingress due to continuous exposure to groundwater and environmental moisture, particularly at cable penetration points. Cable sealing systems play a vital role in ensuring long-term watertightness and protecting structural and electrical assets. However, their effectiveness depends largely on accurate cable-per-sleeve calculations and proper coordination between civil and electrical works during construction. This article highlights the importance of sealing in UG basements and discusses construction-stage responsibilities, common planning gaps, and associated risks. Drawing insight from a UAE substation project, it demonstrates how miscalculation of cable entries per sleeve led to unsuitable sealing arrangements, procurement delays, and additional costs. The article emphasizes that effective sealing relies on early coordination, accurate cable planning, and disciplined execution to avoid rework and improve overall project efficiency [1], [2], [6].

Index Terms— Underground basements, cable sealing, mechanical seals, sleeve-wise cable calculation, water ingress, substation construction.

I. INTRODUCTION

Underground (UG) basements are essential components of infrastructure facilities such as electrical substations, pumping stations, and utility buildings. These basements typically accommodate power cables, control cables, earthing systems, and associated services that penetrate through retaining walls, floors, and duct banks. Due to their belowground location, UG basements are continuously exposed to groundwater pressure, soil moisture, and environmental humidity. One of the most common sources of post-commissioning defects in such facilities is water ingress through cable and service penetrations [1], [2].

Cable duct sealing systems are a critical line of defense against leakage at penetration points. When correctly planned and executed during construction, proper seals ensure long-term water tightness, protect structural elements, and significantly reduce future maintenance requirements. However, insufficient coordination between civil and electrical works often results in improper sealing arrangements, leading to avoidable delays, increased costs, and operational risks [2], [3].

II. IMPORTANCE OF PROTECTING UG BASEMENTS FROM LEAKAGES

Leakage in UG basements is not limited to visible water flow; even minor seepage or moisture migration can have long-term consequences. Persistent damp conditions can accelerate corrosion of embedded steel, cable trays, supports, and earthing components. Electrical cables exposed to moisture are at increased risk of insulation degradation, termination failures, and reduced service life [9].

From an asset management perspective, uncontrolled water ingress results in repeated maintenance interventions, temporary repair works, and unplanned shutdowns. Over time, moisture-related deterioration may compromise the structural integrity of concrete walls and slabs. Effective cable sealing at the construction stage therefore plays a vital role in protecting both the functional and structural performance of UG basements throughout the project lifecycle [7], [8].

III. ROLE OF MECHANICAL SEALS IN UG BASEMENT CONSTRUCTION

Mechanical seals are engineered systems designed to close the annular space between cables or pipes and the surrounding concrete penetration. Unlike temporary sealing materials, mechanical seals are designed to withstand hydrostatic pressure, accommodate minor movements, and maintain sealing performance over extended periods. In UG basements, mechanical seals are commonly applied at cable entry walls, duct bank terminations, floor penetrations, and pipe sleeves [3], [4].

The effectiveness of a mechanical seal depends not only on the product itself but also on accurate input data and proper installation. Seal performance is directly influenced by factors such as cable quantity, cable diameter, sleeve size, wall thickness, and installation sequence. These parameters must be clearly identified and coordinated during construction [3], [4].

IV. Construction-Stage Actions During Basement Duct Works

During the construction of UG basements and associated duct banks, contractors are responsible for ensuring that sealing requirements are integrated into the civil works. This includes correct positioning and alignment of ducts, provision of sleeves or block-outs at penetration points, and maintaining adequate tolerances for seal installation [2], [4].

Civil works executed without considering mechanical sealing often result in misaligned ducts, insufficient sleeve diameters, or congested.

V. Surveying Cable Layout in Line With Approved Drawings

Accurate surveying of cable layouts is a key prerequisite for effective mechanical sealing. Contractors must verify the number; size Accurate surveying of cable layouts is a key prerequisite for effective mechanical sealing. Contractors must verify the number, size, and grouping of cables based on approved cable routing and termination drawings. Assumptions regarding cable quantities or diameters frequently lead to incorrect seal selection [2], [6].

By confirming cable layouts before finalizing duct work and seal procurement, contractors can ensure that penetration sizes are adequate and that sealing systems can accommodate both current and future cable requirements. This proactive approach minimizes rework and avoids late-stage design changes [2], [3

VI. Avoidance of Late Ordering and Customized Mechanical Seals

Mechanical seals, particularly those requiring factory customization, are subject to procurement lead times. Late identification of sealing requirements often results in urgent orders, premium costs, and construction delays. In some cases, standard sealing systems become unusable due to inaccurate initial assumptions, forcing the use of special or non-standard products [3], [4].

Early calculation of sealing requirements allows sufficient time for procurement, delivery, and installation without impacting critical project milestones. It also enables cost control by avoiding unnecessary customization [2], [3]

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VII. Practical Insight From a UAE Substation Project

In one UAE substation project, civil construction works were completed entirely in accordance with the approved drawings; however, deficiencies later emerged due to inaccurate cable entry planning by the contractor. During the electrical installation phase, it was identified that the contractor had miscalculated the number, size, and configuration of incoming and outgoing power and control cables per sleeve. Detailed sleeve-wise cable surveys were not adequately carried out during the design coordination stage, and assumptions were made regarding cable quantities and diameters. As a result, the ordered cable sealing systems were unable to accommodate the actual cable configuration required for installation. Consequently, the originally planned cable sealing arrangement became unworkable, as standard mechanical sealing systems could no longer be installed within the available duct and sleeve capacity provided during civil construction. Customized sealing solutions had to be engineered and procured, leading to extended procurement lead times, delays in cable pulling activities, and additional costs. This case demonstrates how sleeve-wise cable calculation errors can result in major setbacks to project delivery [1], [6], [9].



Fig. 1. Customized mechanical sealing system



Fig. 2. Standard mechanical seal with multiple cables

VIII. Lessons Learned and Best Practices

The long-term performance of UG basements depends strongly on early planning, accurate design inputs, and effective coordination between civil and electrical disciplines. Mechanical sealing systems, while often treated as secondary components, are in fact critical elements that safeguard structural integrity, electrical reliability, and asset longevity. Civil works executed strictly in accordance with approved drawings do not guarantee constructability if electrical requirements—particularly cable quantities, diameters, and sleeve-wise arrangements—are inaccurately assessed. Mechanical sealing effectiveness is governed not only by product selection but also by the quality of coordination and verification carried out during construction [1], [2], [6].

IX. Proactive Measures

Mechanical sealing requirements must be embedded into the construction planning process from the outset. Contractors should conduct detailed sleeve-wise cable surveys based on approved routing and termination drawings before finalizing basement duct works. Cable quantities, diameters, grouping, and allowances for future provisions should be jointly reviewed by civil and electrical teams to confirm sleeve adequacy. Treating mechanical sealing as an engineered system rather than a finishing activity, combined

with early calculation of sealing needs and effective site supervision, significantly reduces the likelihood of water ingress, rework, and late-stage disruptions [2], [3], [4].

X. Conclusion

This article underscores the critical role of mechanical sealing systems in ensuring the long-term watertightness and durability of underground basements in infrastructure facilities. Mechanical sealing systems are essential for ensuring the long-term watertightness and durability of underground basements. Water ingress issues are more often rooted in inaccurate cable planning, insufficient coordination, and premature execution of civil works rather than product failure. Accurate cable-per-sleeve calculations, early interdisciplinary coordination, and disciplined construction-stage verification are critical to achieving effective sealing performance, minimizing rework, controlling costs, and reducing long-term maintenance burdens in underground substation facilities [1], [2], [9].

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