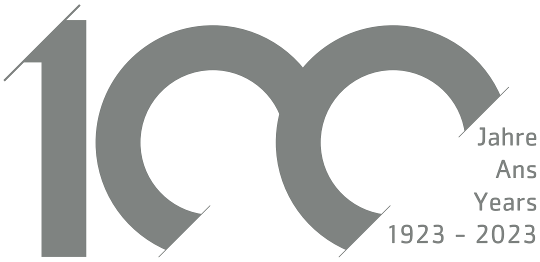
SGK®

100 years of corrosion protection

A review of the activities and the evolution of SGK



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Introduction

The Swiss Society for Corrosion Protection SGK celebrates its 100th anniversary this year. An overview is given of the founding, past and current activities of the association.

As a result of the electrification of railway lines in Switzerland, there was repeated damage to infrastructure installations due to direct current interference. With the founding of the Corrosion Commission in 1923, a neutral and independent body was created in Switzerland to deal with stray current problems and the inspection of DC railways. In the course of time, the range of activities has expanded to include a wide variety of areas, such as cathodic corrosion protection or corrosion of steel in concrete. The Corrosion Commission has compiled a small body of guidelines summarising the current knowledge for corrosion protection in certain areas of civil engineering, transport infrastructure and wastewater treatment, which is now recognised as a technical rule. The SGK office has developed into a modern service provider for corrosion protection, which, in addition to consulting, control and routine examinations, also carries out research work on a larger scale and develops new test methods. The resulting knowledge is passed on in the sense of technology transfer through publications and training courses.

Historical development of the SGK

In 1888, the Vevey-Montreux-Chillon tram line was the first electrified railway in Switzerland to operate at 600 V DC. This was followed in 1900 by the first kilometres of the electrified Aigle-Leysin line with 1500 V DC, and in 1901 the first section of the Montreux Bernese Oberland Railway (MOB) went into operation from Montreux to the village of Les Avants. Other railways followed, such as the electrification of the Bernina line (Fig. 1) or the ESB (Fig. 2). The electrification of the railways not only reduced the dependence on coal from abroad, but also strengthened the Swiss electrical engineering industry (Fig. 3). It is therefore hardly surprising that a whole series of railways and also SGK members from the electrotechnical sector are also celebrating their 100th anniversary in these years. However, this technical progress and the operation of DC railways were not without consequences for thirdparty structures: the traction currents led to strong corrosive influences and damage to buried metallic infrastructure. As a result, as early as 1914, the first negotiations took place between the Swiss Association of Gas and Water Experts SVGW and the Association of Swiss Secondary Railways VSS to investigate the effects of stray currents caused by DC railways on the water supply network. In 1916, a joint commission was formed, which also included representatives of the Swiss Electrotechnical Association (SEV). This commission drew up two fundamental reports on corrosion caused by earth currents of electric railways and on the methods of investigation of corrosion conditions on electric railways [1, 2]. Based on these reports, guidelines on protective measures against the effects of stray currents were drawn up in 1920, which were recommended by the associations concerned to their members for compliance. The most important recommendations of these guidelines concerned the limitation of the voltage difference between the rails and the affected structures to 0.8 V as well as the specification of requirements for the longitudinal conductivity of the rails and in particular of the butt joints. For the influenced structures, the installation of insulating joints was recommended in the first instance, for pipelines every 20-25 m, and drainages to divert stray currents in the second instance.

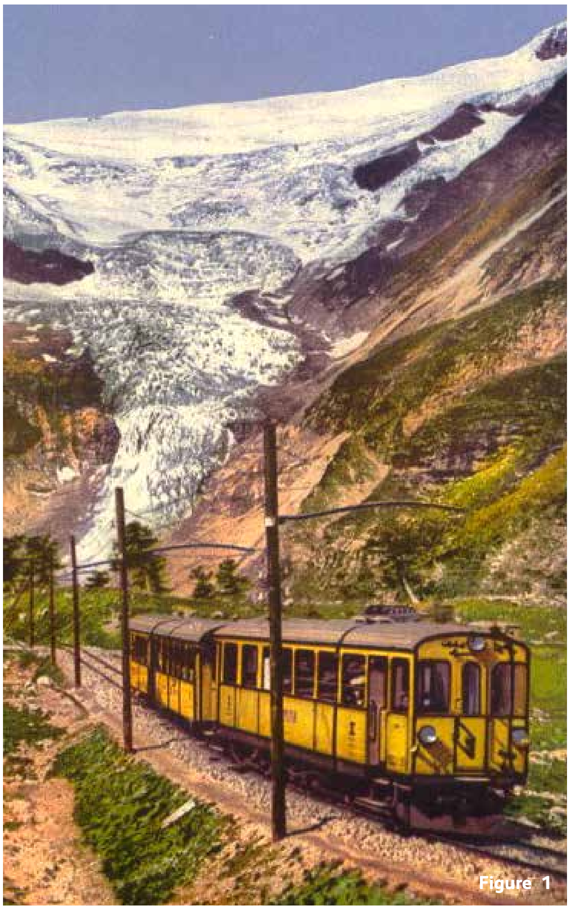

Figure 1

Electrification of the first sections of the Bernina line around 1908 (https://de.wikipedia.org/wiki/Berninabahn)

Figure 2

The electric narrow-gauge railway (ESB) Solothurn-Worblaufen in the opening year 1916 (Source: RBS)

Figure 3

Tram line 6 around 1930 in Geneva with a catenary constructed by Furrer und Frey AG (© furrerfrey.ch/Willy Riesterer)

In 1923, the Corrosion Commission was formed, a permanent joint commission of the above-mentioned organisations and the Chief Telegraph Directorate (OTD). Prof. J. Landry from the ETH Lausanne was elected as the first president of the Corrosion Commission. The actual birth of the SGK can be seen as the creation of a control body within the framework of the Corrosion Commission. Its primary tasks were to carry out general investigations of corrosion conditions and regular inspections in accordance with the guidelines drawn up by the Corrosion Commission. [3, 4]. The most important aspects of the work of the Corrosion Commission and the inspection body were regularly published in the Bulletin of the SEV until 1963.

In the initial phase, the work of the inspection body primarily comprised the inspection of DC railways in accordance with the guiding principles and the inspection of stray current influence on cables and pipelines in the area of influence of railways. Seven years after its foundation, 21 railways had already been inspected. One of the main tasks was to walk the tracks, visually inspect the rail connectors and carry out resistance measurements in case of doubtful connectors. In 1930, 21240 rail joints were measured. In the following years, the extent of the periodic inspections was continuously reduced due to the improvements achieved and ended in 1963 with the systematic introduction of welded rails. Subsequently, more special investigations were carried out, such as the investigation of corrosion damages, measures to improve the stray current conditions and current measurements in lead sheathed cables, as well as fundamental corrosion investigations on electrolytic corrosion in the ground [5] were carried out. In the process, various topics were addressed for the first time that are still relevant today. As early as 1936, possible problems with the use of the water mains as earth electrode were discussed, in 1945 indications of the involvement of galvanic elements as a cause of damage in pipelines were found, and in 1950 potential measurement technology was introduced. In 1956, recommendations were issued that lightning protection systems in contact with pipelines made of steel or cast iron should not be made of copper in order to avoid galvanic elements. In 1961, it was suggested to keep external currents away from tanks by installing insulat. Further on, various corrosion problems in domestic installations were investigated and more and more investigations were carried out on tank installations and in connection with earthing systems. In the process, previously unknown or unnoticed stray current effects were also recognised, namely the carry-over of stray currents via the rail network of AC railways and neutral conductors of the electrical network operators. In the 1950s, initial experience was gained with the method of cathodic corrosion protection (CP). This was applied for the first time in 1950 for the internal protection of hot water tanks, in 1953 for tank installations, in 1958 for the protection of a steel bridge in a reservoir and in 1959 for pipelines. For the execution of the measurements, own measuring devices were built or assembled. For example, as early as 1938, a device for automatically recording current-voltage diagrams was developed, and in 1951, a car was purchased and equipped as a measuring van. The already high recognition of the professional competence of the members of the Corrosion Commission at that time is also reflected in orders from abroad, which were handled between 1937 and 1940 in Athens, Palestine and Belgrade. From 1940 onwards, in addition to the member fees to finance the Corrosion Commission, industrial subsidies were also paid by interested companies.

A profound change in the activities of the Corrosion Commission took place in 1963 and 1979 under the leadership of Dr. R. Petermann and the then President of the Corrosion Commission, Professor E. Baumann (ETHZ). This period saw, among other things, the construction of two large oil pipelines, the development of the Swiss natural gas network with cathodically protected high-pressure pipelines and the publication of the Technical Tank Regulations TTV, which declared CP for buried steel storage tanks to be mandatory for most applications. This led to intensive work on questions of application and assessment of the effectiveness of CP. The experience and knowledge gained in this process were incorporated in 1969 in the C1 guidelines for project planning, execution and operation of CP of pipelines. Particularly worth mentioning are the instant off potential measurement introduced in 1968 as a criterion for assessing the effectiveness of CP and the development of a measuring system and standard test procedure for checking the effectiveness of the CP of small tank installations. These were the basis for a guide published in 1977 by the Federal Office for the Environment within the framework of water protection measures and the guideline C5 for project planning, execution and operation of the CP of underground storage tanks made of steel. In connection with the development of the high-pressure natural gas network, intensive cooperation developed with the Federal Pipeline Inspectorate FPI, for which the Corrosion Commission carried out measurements from 1968 onwards. However, the effort required for this soon exceeded the Corrosion Commissions personnel capacity, so that the periodic measurements were carried out by the FPI itself from 1972 onwards. From then on, the Corrosion Commissions activities shifted to consulting tasks and the investigation of special problems. The SGK is still active today as a corrosion protection expert for the FPI.

The changeover from grey cast iron to ductile iron pipes for water pipes in the 1960s and the regulations on equipotential bonding in domestic installations issued by the SEV in 1985 also had a major impact. The construction of extensive reinforced concrete foundations and air raid shelters in combination with equipotential bonding led to galvanic corrosion and much damage to relatively new water pipes. This damage was exacerbated by less careful pipe bedding, as a result of the greatly improved mechanical properties of ductile iron pipes, in heterogeneous soil. The problems of pipeline bedding, the quality of pipe insulation and formation of galvanic elements with the reinforcement of reinforced concrete structures and the preparation of Guideline C2 on corrosion protection of buried metallic installations, published in 1976, formed another focus of the activities of the Corrosion Commission.

From about 1973 onwards, there was a clear shift from control to advisory activities and the investigation of damage cases. In addition to the focal points already mentioned, corrosion cases in domestic installations, such as underfloor heating and hot water systems, as well as in sewage systems were dealt with in particular. This development continued steadily under the leadership of Dr. F. Stalder as head of the office (1980-2006) and Prof. H. Böhni (1978-2007) as president of the Corrosion Commission, which by 1983 had been transferred to the Swiss Society for Corrosion Protection (SGK).

Through the close relations with the Institute for Building Materials, Materials Chemistry and Corrosion IBWK of the ETHZ, headed by Prof. H. Böhni, the SGK always had the latest scientific bases for working out practical solutions to the corrosion problems from industry. This high level of competence led on the one hand to a strong increase in demand for the services, and on the other hand to the opening up of new fields of work and the possibility of carrying out development and research work. A milestone in this respect was the move to the Technopark in 1993, where CorrTech, a laboratory belonging to the IBWK, could be used within the framework of a collaboration to carry out joint research projects and laboratory work for the SGK. As a result, the number of staff at the SGK increased from two to six. Over time, this laboratory activity developed into an indispensable part of the SGK‘s activities, so that after Prof. Böhni‘s retirement, an own laboratory was set up by SGK. This laboratory is specially equipped for carrying out electrochemical investigations and, in addition to handling research projects, also provides valuable services for material-technical clarifications, investigations in the field of corrosion of steel in concrete and the investigation of damage cases from industrial applications. The most important new fields of work were reinforced concrete structures, anchors and prestressed cables as well as water and sewage systems. International projects became increasingly important. Extensive investigations were carried out for the construction industry in Germany on the durability of post installed rebar connections. These led to the development of a test method that gained international recognition and was accepted by EOTA for European approval. [6]. Furthermore, research projects were carried out for the German gas industry. In addition to these laboratory activities, field investigations were also carried out on CP in Saudi Arabia (Figure 4) and Iran.

Figure 4

Investigations at a pumping station in Saudi Arabia

Under the current leadership of Dr. M. Büchler as Managing Director (since 2006) and under the presidency of M. Lörtscher (2007-2015), it was possible to further expand the activities of the SGK. In particular, M. Lörtscher's indepth experience in the area of railways, traction power supply and railway infrastructure as well as earthing has led to a strengthening in the area of railway technology and stray currents (Fig. 5). This was followed by orders for direct current railways investigations in Australia (Fig. 6) and India (Figure 7). Furthermore, the profound competence of SGK in the field of CP resulted in the technical management of three DVGW research projects lasting several years by the SGK. These research projects led to the development of the technical rule DVGW GW 28. With the increasing importance of international standardisation, Dr. M. Büchler took over the function as convenor of ISO TC 156 WG 10 for the CP of buried and immersed structures in 2012. In parallel to these research projects on CP, the SGK built up comprehensive training courses. From 2015 to 2017, the SGK was presided by R. Wendelspiess. In his function as head of the FPI, the cathodic corrosion protection was further intensified and the SGK chaired a European working group to further develop the CP protection criteria. In 2017, SGK staff member Dr U. Angst took over as professor at ETH Zurich and subsequently became president of the SGK. After an interruption of 10 years, the direct connection of the SGK to the ETH was thus restored with Prof. U. Angst. Important synergies could be used again, which further strengthened the function of the SGK as an interface between industrial application of corrosion protection and the university. Currently, 9 people are employed at the SGK. With two electrical engineers, two materials engineers, two civil engineers and one mechanical engineer, the SGK is able to deal with the most diverse aspects of corrosion and corrosion protection, but also earthing, railway engineering and protection of persons. The international recognition of the expertise but also the neutral position between influencing and influenced plant operators leads to a strong international commitment, as projects in France, Germany, England, Holland and Spain but also South Africa, Australia and Israel show.

Figure 5

Recording the stray current distribution on the SBB network in Ticino

Figure 6

Stray current investigations in Gold Coast (Australia)

Figure 7

Measurements on the metro in Bangalore (India)

The modern SGK

Purpose and organisation of the SGK

The SGK aims to promote corrosion protection in the technical and scientific field in Switzerland in general and among its members in particular. It is an independent, innovative organisation active in the field of corrosion protection, which promotes and conducts the transfer of technology from science to practice and represents the interests of its members in national and international bodies. In addition, it offers services related to corrosion protection, which it provides as a neutral non-profit organisation in a market-oriented and cost-covering manner.

According to the Swiss Civil Code (ZGB), the SGK is an association with its registered office in Zurich. It has been certified according to ISO 9001 since 2005. The main organs of the SGK are the General Assembly, the Board of Directors and the Office, which carries out the tasks of the SGK. To deal with corrosion-related problems and to carry out studies, the Board of Directors forms a permanent expert group, the Corrosion Commission. It has no legal personality of its own. The Corrosion Commission draws up guiding principles for the prevention of corrosion damage.

The high level of expertise, the international contacts via the standards committees, but above all the constructive cooperation within the members in the framework of working groups has contributed significantly to the success of the SGK. With the foundation of a neutral expert body to deal with corrosion problems 100 years ago, the essential basis for later success was created: Influencers and influenced sat down at the same table, exposed the technical problems and created a common strategy for solving them. Even today, the discussions in the working groups are always constructive and solution-oriented. There is no question that water, gas, electricity, railways and roads are essential components of the Swiss infrastructure and that conflicts of interest between those who influence and those who

are influenced cannot always be ruled out in individual cases. Of course, the technical rules must be complied with and the costs of solving problems that nevertheless arise must be shared between the parties involved in accordance with Guideline C4.
This constructive type of cooperation is rare internationally. Accordingly, the SGK's task in foreign assignments often consists of informing and training the companies involved in order to identify constructive approaches to solutions for stray current interference issues.

Guidelines, national and international bodies

In order to enable the application of the current knowledge in practice and thus prevent damage, the SGK has issued a total of 7 guidelines, which are revised and adapted to the current regulations and standards as required. The guidelines C1, C2, C3, C4 and C5 have been recognised in Switzerland by the legislator as recognised state of technology [7].
The SGK has always maintained national and international relations with various specialist bodies and takes an active part in their activities. As early as 1927, it represented Switzerland in the CCI (Comité Consultatif International des communications téléphoniques à grande distance) and in 1929 became a member of the CMI (Commission Mixte Internationale pour les expériences relatives à la protection des lignes téléphoniques). Since 1972, it has been a member of CEOCOR, the European Study Committee on Corrosion and Corrosion Protection of Piping Systems. Its annual congresses are of a very high technical standard and the latest findings are always presented. The open and constructive discussion culture has also led to the fact that all European and international standards relevant to the CP have emerged from working documents of the CEOCOR. Three employees of the office were elected as sector and commission presidents in this organisation and Dr. M. Büchler currently holds the presidency.
For 20 years, SGK staff have also been active in national (SIA) and international standardisation (CEN, CENELEC and ISO). There, relevant findings from the SGK's research work have been incorporated directly into international standards.

Knowledge transfer

A major endeavour of the SGK is to transfer the latest findings and solutions in the field of corrosion and corrosion protection into practice and make them publicly accessible. This is done through lectures, publications in technical journals, the issuing of guidelines, the holding of training courses and participation in various working groups. Since 1980, more than 300 SGK publications have appeared. In addition to annual publications, about 10 lectures are held at national and international events. In addition, the members of the SGK are informed about the latest technical findings, normative developments and the activities of the SGK at the annual general assembly.

Training is also very important for the transfer of knowledge. In 2006, a first standard concerning the competences of CP personnel was published, which was transferred into an ISO standard in 2017 and thus regulates the requirements for skilled personnel worldwide. [8]. The SGK developed training/preparatory courses for the areas of soils and reinforced concrete, which are offered in German, French and English since 2008. The high quality of the courses also leads to large participation from neighbouring countries and training courses lasting several days have already taken place in Belgium, Netherlands, England and Australia. In addition to these specific courses on CP, the SGK also runs a wide range of tailormade training courses for companies and associations, which take into account the specific requirements and the respective boundary conditions, such as the training of the railway personnel of the Sofia Metro (Bulgaria) for the practical execution of the periodic control measurements of the stray current protection.

Data collection and evaluation

The metrological recording of temporally varying influence has always been a central competence of the SGK. The development and construction of suitable measuring equipment as well as its application under partly demanding conditions has shaped the work in the past and contributed significantly to the technical know-how. Technical progress with digital data acquisition and processing has thus also significantly changed SGK‘s working environment. In 1995, after the application of a new deck seal, monitoring equipment was installed for the first time on the Europabrücke bridge in Zurich to track the influence of the drying out of the bridge on the corrosion rate. These procedures were continuously refined and led to the development of various sensors at SGK for use in the continuous monitoring of reinforced concrete structures. With the development of the competence to handle large amounts of data, not only a greatly improved evaluation of reinforced concrete structures became possible, but also a deeper understanding of the damage mechanisms taking place and the identification of relevant influencing factors. [9].

The findings from the remote monitoring were used within the framework of a DVGW research project to develop a Smart CP System, which determined the influencing situation of pipelines in real time and regulated the respective optimal operating conditions of CP with active control. Within the framework of a joint working group of the CEOCOR and the EFC (European Federation of Corrosion), new approaches for evaluating the effectiveness of CP were developed. These enable automated monitoring even with combined AC and DC influence.

Research and development

The core competence of SGK is the metrological recording and assessment of corrosion problems. This results in direct access to current issues, which sometimes arise as a result of new technologies. 100 years ago, these were interference problems as a result of DC railway operation, at the end of the 1980s there was damage to cathodically protected pipelines due to AC interference, and in recent years the increased use of renewable energies based on solar energy has led to interference issues due to DC leakage currents from inverters. Furthermore, there are unresolved issues related to high voltage DC transmission as well as the addition of hydrogen to methane and its effect on the durability of pipelines. In recent years, the SGK has dealt with the issue of AC and DC interference in extensive research projects and has contributed significantly to the development of the corresponding standards. Currently, the focus is on the contribution of hydrogen as an energy carrier to the formation of cracks in pipelines. However, the SGK is also intensively investigating the contribution of hydrogen formed by CP to the damage of pipelines or prestressed tendons. This involves both the development of a fundamental understanding of the relevant chemical and physical influencing factors and the identification of objective assessment criteria for the evaluation of a possible hazard.

Areas of activity of the SGK

The SGK's activities cover all corrosion problems of metals in aqueous media. It deals primarily with buried infrastructure such as pipelines in the ground, but also reinforcing steel in concrete, stainless steel in waste water, brass in drinking water or track systems in tunnels. But also special issues such as the resistance of dental implants, cleaning agents in the food industry or cracking in steam generation systems are dealt with. In the following, an overview of the most important fields of activity of the SGK is given.

Underground installations

Stray currents

The first edition of the stray current guideline C3 of the SGK, which was created in 1979, has been continuously updated and expanded. An essential component of stray current protection measures is to avoid the spreading of stray currents by consistently separating the current return of the railway from the earthing of the grid operator. In addition to the metrological assessment of the stray current load of a structure before its construction, the design of protective measures and the control of the execution/effectiveness of protective measures, e.g. the demanding verification of the separation of the earthing systems as primary protection from stray current interference, formed the main activities of the SGK in this field.


Figure 8

Detection of the stray current hazard radius of a direct current track

From 2001, a new method for measuring the electrical insulation of the rails was introduced, which was used for acceptance measurements of newly constructed track systems. This made it possible to estimate the critical radius of influence of tracks, which allowed for the first time to calculate the influence of stray currents in the planning phase. Another important aspect was the development of an evaluation method for determining the corrosion risk of cathodically protected systems affected by stray currents [10]. These findings and the associated measurement methods have been directly integrated into the international rules and regulations [11] and subsequently in the new C3 guideline published in 2022.

AC Corrosion

In 1987, corrosion damage caused by alternating currents occurred for the first time on a Swiss gas pipeline [12]. This new type of corrosion resulted in extensive investigations on gas pipelines, which showed that many Swiss gas pipelines are affected to a greater or lesser extent by alternating currents (Fig. 9). The damage mechanism was investigated in extensive research work at national and international level. The breakthrough came in 2003, when the SGK was able to scientifically explain the corrosion mechanism [13]. Only the knowledge of the underlying processes allowed the conception of new protective measures and the elaboration of protection criteria, which were verified in further research projects and adopted in the international standards [14]. These findings were complemented by two essential observations: It is technically impossible to prevent AC corrosion. However, the maximum possible depth of corrosion attack can be limited. These findings have been incorporated into the technical rule DVGW GW 28 B1 and are currently also being adopted in the revision of guideline C1.

Figure 9

High-pressure gas pipeline under AC influence.

Cathodic protection

In the 1990s, the SGK was heavily involved in the standardisation of terms, requirements and measurement methods, which until then had been handled very differently in the various countries. Within the framework of the CEOCOR, it was significantly involved in the development of generally accepted guidelines, which later served as the basis for the European and international standards.

The findings from AC corrosion research also have consequences for the evaluation of the effectiveness of CP (Fig. 10) and the optimum operating conditions. Contrary to earlier expectations, it has been shown that AC corrosion is favoured by high levels of CP, which is why the corrosion hazard was reduced in many plants by adjusting the protection to less negative on-potentials. This inevitably led to conflicts with ensuring the effectiveness of CP. As a result, numerical models were developed by the SGK that correctly depicted the actual chemical, physical and electro-chemical effects and their interaction. Their contribution on the assessment of effectiveness were discussed and published internationally [15]. This made it possible to create the basis for evaluating the effectiveness of CP even in the case of combined AC and DC interference [10]. These concepts will be of great importance with the increased use of DC high-voltage transmission lines and the increased use of inverters in connection with alternative energies. These latest approaches are currently being incorporated into the revision of Directive C1.

Figure 10

Checking the effectiveness of CP on a pipeline

Tank farms

The SGK was intensively involved in the elaboration of the European standard for the CP of buried steel storage tanks [16]. This experience enabled the C5 guideline to be reissued in 2018, with the scope extended to include tanks for water and biogas.

Since 1983, SGK has been responsible on behalf of CARBURA for the corrosion protection of large tank farms with compulsory fuel storage (Figure 11). These are periodically inspected for the risk of stray currents and galvanic currents. The possible protective measures such as the formation of galvanic islands, cathodic corrosion protection, installation of insulating joints and spark gaps are always coordinated with the earthing concept of the installation. This also ensures the requirements for personal safety and explosion protection.

Tracks and earthing systems

It is characteristic of the SGK's activities that not only the effects of electrical interference on third-party structures are investigated. Supporting railways with regard to corrosion protection of the railway infrastructure and minimising influences on third-party structures represent an essential activity. The fundamental understanding of return path and earthing requirements, as well as the development and optimisation of procedures to assess the expected interference in the design phase of railway installations, provides important support for the operators. As in the founding years of the SGK 100 years ago, regular inspections of railway installations are still an important activity. Of course, checking the bridging of rail joints is now only necessary in a few remaining ca-

Corrosion investigations in a tank installation ses of very old installations. Instead, checking the rail insulation as well as the functionality of the galvanic isolations is a central task for the implementation of the specifications of the C3 directive. The success of the SGK, especially in international railway projects, lies in the developed measuring and evaluation procedures as well as in the highly developed methods for locating insulation faults.

This competence is relevant in connection with the intensive investments in the railway infrastructure built in Switzerland around 100 years ago, but also in the development of public transport abroad, and continues to form an important area of activity for the SGK.

Water and wastewater treatment

Water production and distribution

With the increased use of stainless steels in water production, such as wells (Figure 13), corrosion problems have frequently occurred as a result of the formation of galvanic elements between pumps/fittings made of cast iron and stainless steel. As protective measures, the realisation of galvanic separations or the application of cathodic protection have proven successful here. Unfortunately, experience has shown that the measures taken often remain ineffective due to planning deficiencies and/or lack of acceptance inspections.

Another focus of the work in recent years has been investigations on underground water supply systems and the development of measures to reduce corrosion damage in the pipe network. A large part of this damage is due to the formation of galvanic elements between the water pipes and the rebars of reinforced concrete

Figure 12

Stray current measurements on the Bernina line structures. To solve this problem, it was necessary to move away from the water pipe as the earth electrode and to separate the domestic installation from the buried pipes, as is also recommended for existing buildings in SVGW Code of Practice W 1015 [19]. In close cooperation with the Federal Inspectorate for Heavy Current Installations (ESTI), solutions have been developed that simultaneously ensure personal safety and allow the use of pipes with high-quality, also electrically insulating, sheathing. In the city of Zurich, these corrosion protection measures have led to a reduction in the corrosion load of the water pipe network and to a decrease in pipe bursts from over 1000 in 1985 to about half today. [17].

Towards the end of the last century, degradation of cement mortar linings in the form of, mostly brown, stains and local softening was observed in many drinking water reservoirs. It could be shown within the framework of a research project that these effects are due to galvanic corrosion of the concrete [18]. This galvanic corrosion on a non-metallic inorganic material can be limited with the same protective measures that are applied to metallic materials: Protective current or galvanic separations.

Power plant facilities

Galvanic corrosion problems are not limited to the water supply, but also occur analogously in hydropower plants (Fig. 14). The problem of corrosion on pipelines (Fig. 15) as well as questions regarding the coating quality are therefore always important fields of activity.

Figure 13

Corrosion investigations in a well

Waste water plants

During Dr. R. Petermann‘s term of office, about 60 % of the Swiss wastewater treatment plants were built. Unfortunately, at that time it was not considered necessary to call in a corrosion expert for this purpose. This led to massive and expensive damage occurring after relatively short periods of operation, and the same mistakes being made repeatedly. In order to avoid this, or at least to reduce it, the SGK developed Guideline C6 on corrosion protection in wastewater systems, which was published in 1990. To ensure that the measures proposed in this guideline could be implemented in practice at an economically justifiable cost and that they met with the necessary acceptance, it was of decisive importance that the Swiss Federal Inspectorate for Heavy Current Installations (Eidgenössisches Starkstrominspektorat) drew up the ARA Directive in parallel with the C6 guideline. This deals


Figure 14

Investigation of galvanic corrosion at a run-of-river power plant


Figure 15

Evaluation of corrosion protection on a water pressure pipe with the associated electrotechnical and personal safety aspects. Particularly worthy of mention is the possibility, for corrosion considerations, of feeding electrically operated components that are mounted in an insulated manner via galvanic decoupling devices (Fig. 16).

Guideline C6 was a great success, with over 2000 copies sold. It enabled decisive improvements to be made in the planning, construction and equipment of the plants, not least with regard to the design and processing quality of stainless steels and coatings. This led to a significant reduction in damage. If major problems still occur today, this is mostly due to the lack of plantspecific corrosion protection concepts as well as the unclear definition of responsibilities and lack of coordination of the work. These points were taken into account in the last revision of the guideline by making appropriate additions. Today, practically no new plants are built, but mainly conversions or extensions are realised. Since in these cases the specific conditions in each plant are different, the development of plant-specific solutions is of particular importance. The guideline also provides the necessary basics for this, although it is recommended that a corrosion specialist be consulted for the preparation of an overall concept. The concepts developed for wastewater plants are now also increasingly being used for anergy plants.

Checking the corrosion protection in a sewage treatment plant

Reinforced concrete

In close cooperation with the IBWK and the canton Grisons, potential field measurement for the non-destructive examination of reinforced concrete structures was introduced in Switzerland in the 1980s and brought up to the current state of the art. Today, potential field measurement is routinely used for condition assessment of the reinforcement of road bridges (Fig. 17). During the same period, the application of the CP for the repair of the carriageway slab of the San Bernardino Tunnel was also investigated. The knowledge gained in the process forms the basis for the C7 guideline for project planning, execution and monitoring of cathodic corrosion protection of reinforced concrete structures. The cathodic corrosion protection of reinforced concrete structures is rapidly gaining in importance today. This leads not only to an increasing number of CP projects, but also to important normative developments. Dr. M. Brem was involved in the revision of SN EN ISO 12696 [19] and various investigations are currently underway at the SGK to improve the assessment of the protective effect of the method in terms of measurement technology and to simplify implementation in application.

In addition to these now well-established procedures for condition assessment and repair, monitoring on numerous structures provides important findings for evaluating the effectiveness of protective measures by continuously recording data. Thanks to Dr. M. Brem‘s internationally recognised expertise, projects have been carried out in South Africa, France and Italy.

Figure 17

Condition assessment of a reinforced concrete bridge

Anchor and prestressed tendons

In the 1980s and 1990s, the corrosion protection of ground and rock anchors was decisively improved by measures to separate the anchors from the reinforcement of concrete structures and the use of plastic ducts (Figure 18). During the construction of the Stadelhofen railway station, however, it was found that the corrosion protection did not initially meet expectations as a result of careless installation. The SGK then developed measuring methods and criteria for checking the installation quality, which were generally accepted and are prescribed in today‘s standards and guidelines [20]. The corrosion protection of micropiles, which are increasingly used for economic reasons, has been the subject of laboratory and field tests. In this context, the use of stainless steels as an alternative material has been introduced in recent years, in addition to the long-term monitoring of existing structures.

In areas exposed to stray currents, prestressed tendons are insulated from the reinforcement of structures, especially bridges. During construction, however, unwanted contacts with the reinforcement occur time and again. To locate such contact points, the SGK has developed methods in recent years that have proven very successful in practice.

Figure 18

Corrosion investigation on the anchors of a pile wall

Other infrastructure and industrial facilities

Tunnels

The SGK carried out various investigations in railway and road tunnels. In the Furka base tunnel, severe cross-section losses were found on the rails after only 5 years of operation. The reasons for this were found to be water ingress and the associated high relative humidity, the presence of a DC track occupancy control and an unexpectedly high chloride input. This led to the realisation that in railway tunnels with car transport, there is a strongly increased corrosion load due to the thawing of snow containing deicing salt, which must be taken into account through suitable material selection and design adjustments.

In road tunnels, the focus was on corrosion phenomena on the suspensions of intermediate ceilings, hydrant lines and fixtures in the carriageway space (Figure 19). The „standard qualities“ of stainless steel that are still often used are in most cases not sufficiently resistant. For safety-relevant components, it is therefore necessary to use higher alloyed stainless steels or alternative materials. This circumstance is taken into account in SIA 179 [21]. Based on the evaluation of experiences in Swiss road tunnels, a risk-based choice of components was proposed in a research project of the SGK. Another problem point is often the extinguishing water systems, especially the hydrant lines and their supply lines. Various corrosion damages have occurred here, especially due to contact with the tunnel reinforcement and earthing systems. This corrosion could have impaired the functionality of the systems in an emergency.


Figure 19

Corrosion investigation on the intermediate ceiling of a road tunnel

Materials

The laboratory facilities set up in 2004 have made it possible to work increasingly on materials issues. Various development and research projects on the optimisation of non-ferrous metal alloys, comparative investigations within the framework of approvals of alternative materials for drinking water pipelines with press-fit connections as well as with regard to the possible applications of various stainless steels as reinforcing steels were worked on. Furthermore, the SGK developed the corrosion test for post installed reinforcing steels in extensive laboratory tests. [6]. This procedure has been transferred into internationally recognized regulations.

For materials testing and quality control, the SGK developed the ec-pen, a tool that was awarded the Swiss Technology Award in 2001 and enables electrochemical tests to be carried out quickly and easily on any practical components and on site. [22]. The ec-pen has been used by the SGK with great success in recent years for quality testing of welded constructions and custom-made products produced in stainless steel. A great advantage is that this test allows for a direct assessment of the corrosion resistance of finished components and installations. It has been shown that it was often severely impaired by production-related surface and structural changes and as a result of insufficient post-treatment. The ec-pen can also be used to objectively assess the effectiveness of post-treatment measures such as pickling or electropolishing and optimisations in welding processes.

Coatings

SGK has two employees trained and certified as coating inspectors. Its activities primarily include the condition assessment of coated steel structures, the preparation of recommendations for repair measures and the implementation of quality assurance measures on the object. On behalf of the SVGW, it also carries out external inspections for cast iron pipes with PUR internal coatings. Furthermore, there is close cooperation with the Swiss Federal Railways on questions concerning corrosion protection.

Outlook

It is the SGK‘s task to always be at the cutting edge of knowledge and technology in order to continue to offer its members and customers optimal advice. Research work to develop basic principles and measurement methods will therefore continue to be given high priority in the future in order to meet the challenges of the energy turnaround, the expansion of public transport and the sustainable use of resources. The prevention of external corrosion is not only relevant for the functional safety of pipelines and containers of substances hazardous to water and thus for environmental protection. Rather, effective corrosion protection also ensures preservation of the functionality and thus contributes significantly to the sustainability of the infrastructure. This is important for economic reasons. However, the use of efficient repair procedures is also relevant with regard to the careful use of resources.

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