






Corrosion Monitoring Sensor for Hot Dipped Galvanized Steel Applications in Geological Protection Systems



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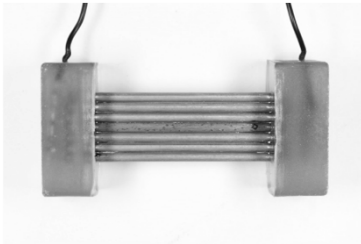
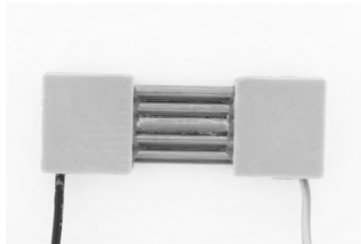
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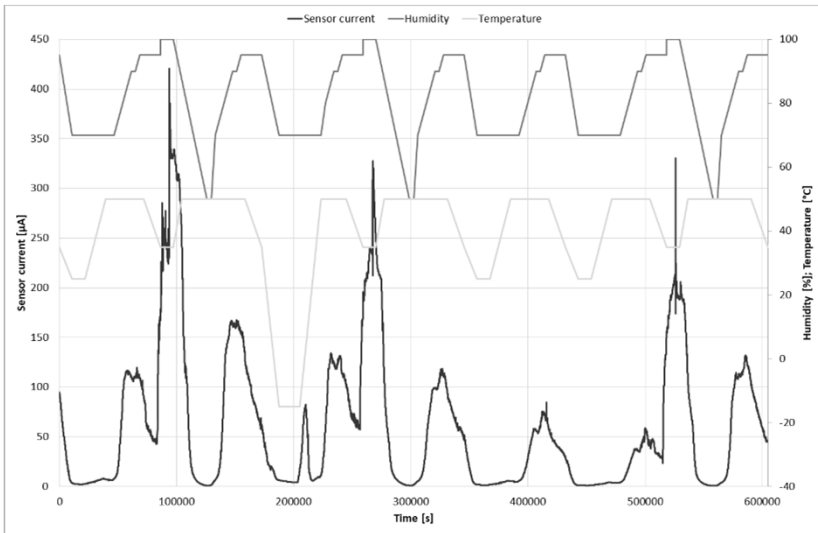
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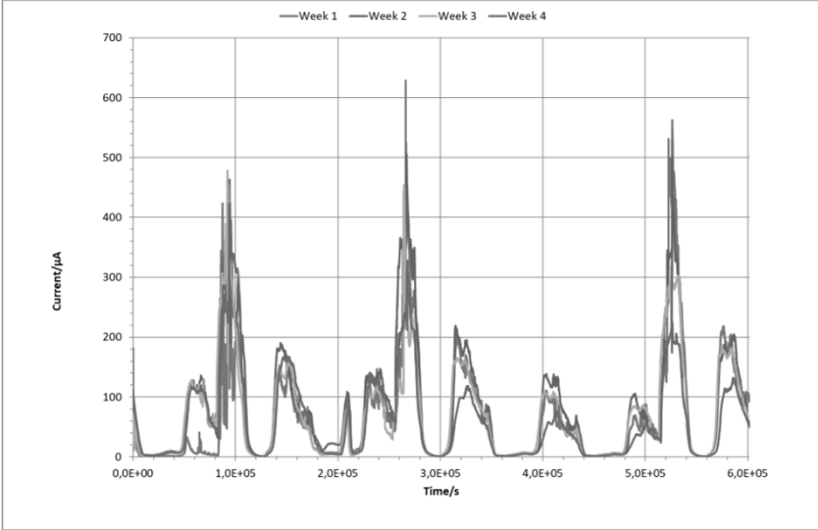
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Outline	<ul style="list-style-type: none"> • Introduction • Sensor concept • Laboratory Tests • Field tests • Data evaluation • Summary and Outlook 	
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Introduction	<ul style="list-style-type: none"> • High tensile steel wires are widely used in geological protection systems. • The systems are often installed in areas with poor access for inspection and maintenance. • A digital monitoring system is being developed to record movements in the system, for example rockfall events or filling of nets. • Another function is to measure the corrosivity in the installation area. 		
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Sensor Concept	<ul style="list-style-type: none"> • Requirements for the corrosion sensor: <ul style="list-style-type: none"> ➤ Measurement of corrosivity of hot dipped galvanized steel in installed area. ➤ Integration in a multi sensor concept. ➤ Long lifetime (>5 years). ➤ Robust and tough construction. ➤ Wireless data transmission. ➤ Easy and understandable interpretation of the data. ➤ Cheap in comparison to existing technologies. 		
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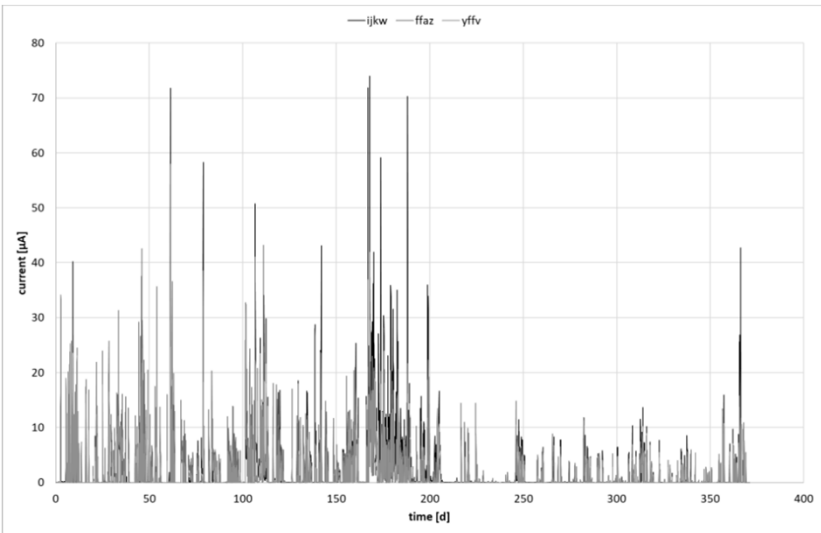
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Sensor Concept	<ul style="list-style-type: none"> • Principle of the sensor <ul style="list-style-type: none"> ➤ Galvanic couple between steel and zinc-aluminium coating. ➤ Anode: zinc coated steel wire; cathode: blank steel wire. ➤ Coupling through wetness → no direct contact between wires (distance <0,2mm). ➤ Measurement of the corrosion current of the coupling. ➤ Use of original wire, used in the protection products. 		
	<div style="display: flex; justify-content: space-around;">   </div> <p style="text-align: center; font-size: small;">WITg Konstanzerstrasse 19 CH-8274 Tägerwilen Fon: +41 (0) 71 666 4204 www.witg.ch info@witg.ch</p>		
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Laboratory Tests	<ul style="list-style-type: none"> • Tests in a climate test cycle in combination with salt spray test 		
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Laboratory Tests	<ul style="list-style-type: none"> • Tests in a climate test cycle in combination with salt spray test  <p style="text-align: center;">—Week 1 —Week 2 —Week 3 —Week 4</p> <p style="text-align: center;">Current/µA</p> <p style="text-align: center;">Time/s</p> <p style="text-align: center;">Slide 7</p> <p style="text-align: center;">WITg Konstanzerstrasse 19 CH-8274 Tägerwilen Fon: +41 (0) 71 666 4204 www.witg.ch info@witg.ch</p>		

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Laboratory Tests	<ul style="list-style-type: none"> • Tests in a climate test cycle in combination with salt spray test <ul style="list-style-type: none"> ➤ Measured current: calculation of mass loss by Faraday's Law. ➤ Reference specimens: gravimetric determination of mass loss. ➤ Two weeks (2 Testcycles): <table border="1"> <thead> <tr> <th></th> <th>Reference Wire (gravimetric)</th> <th>Sensor (calculated)</th> </tr> </thead> <tbody> <tr> <td>Mass loss [g/m²]</td> <td>45,2</td> <td>35,5</td> </tr> </tbody> </table>  <ul style="list-style-type: none"> ➤ Aggressive test → very high corrosion rate. ➤ Strong covering with corrosion products → no washing off by rain. <p style="text-align: center;">Slide 8</p> <p style="text-align: center;">WITg Konstanzerstrasse 19 CH-8274 Tägerwilen Fon: +41 (0) 71 666 4204 www.witg.ch info@witg.ch</p>				Reference Wire (gravimetric)	Sensor (calculated)	Mass loss [g/m ²]	45,2	35,5
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Field Tests	<ul style="list-style-type: none"> • Field test: <ul style="list-style-type: none"> ➤ Around 50 sensors at 20 locations in Europe. ➤ High corrosive areas (marine environment) and low corrosive areas. ➤ Reference wires beside the sensors. 		
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Field Tests	<ul style="list-style-type: none"> • Helgoland (Germany, North Sea), August 2019 to August 2020 		
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Field Tests

- Helgoland (Germany, North Sea), March 2020

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Field Tests

- Helgoland (North Sea), August 2019 to August 2020
- 3 sensors for one year.
- Calculated corrosion rate:

	Sensor 1	Sensor 2	Sensor 3
Mass loss [g/m ² *a]	11,3	9,7	11,5

- Reference wires (gravimetric evaluation):



Wire	1	2	3	4	5
Mass loss [g/m ² *a]	7,2	8,2	8,2	8,2	9,2

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Field Tests

- Helgoland (North Sea), August 2019 to August 2020
 - Under real conditions in the field, the corrosion rate from sensor is higher than from reference samples.
 - Only small amounts of corrosion products covers the sensor surface.





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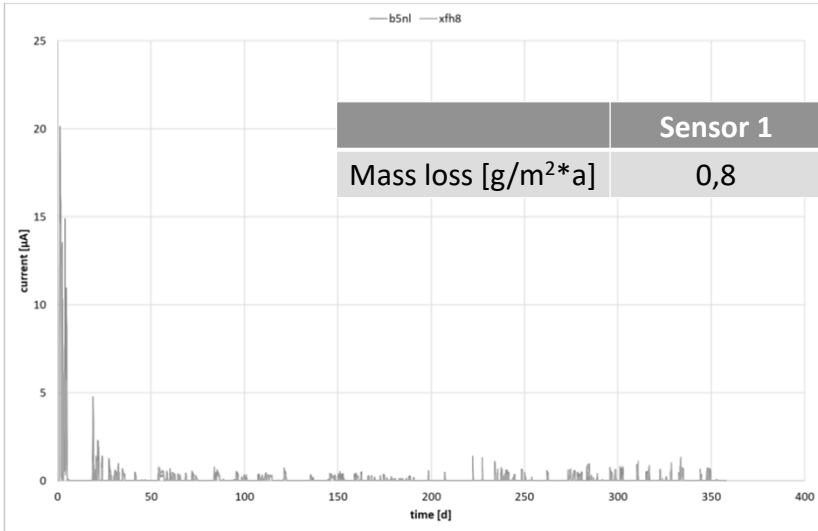
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Field Tests


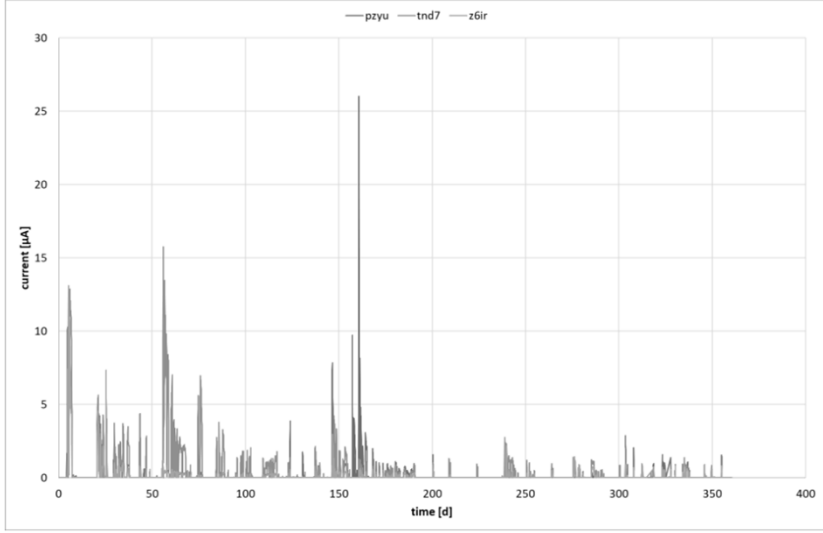
- Altstätten (Switzerland), September 2019 to August 2020


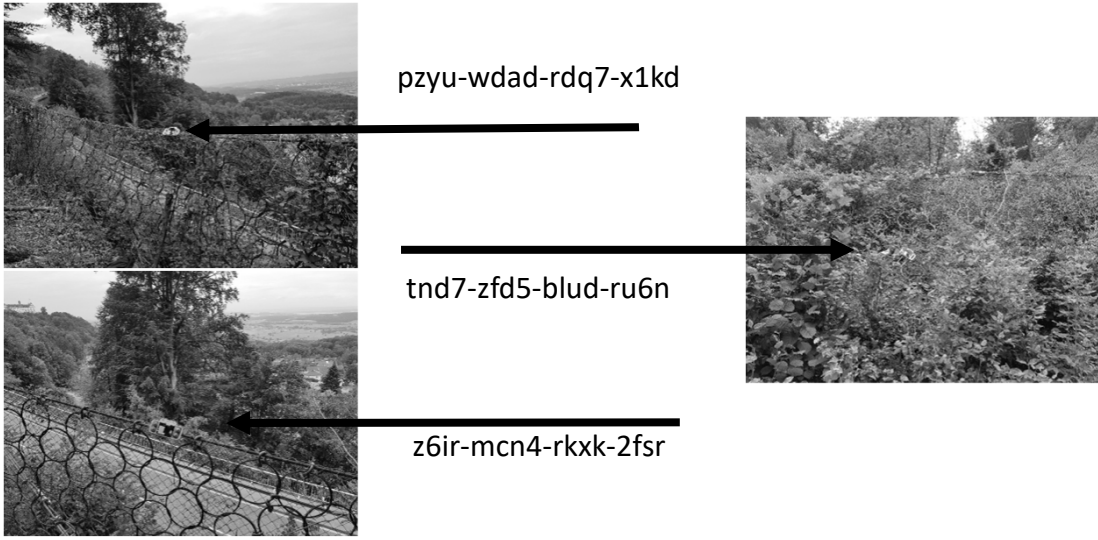




	Sensor 1	Sensor 2
Mass loss [g/m ² *a]	0,8	1,0



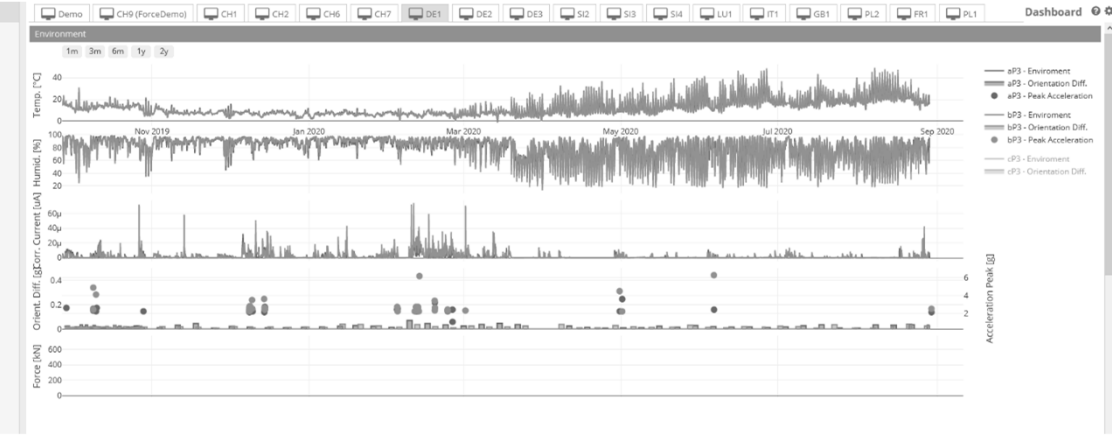
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<p>Field Tests</p>	<ul style="list-style-type: none"> Heiligenberg (Germany) - influence of vegetation on the microclimate  <p>Slide 15</p> <p>WITg Konstanzerstrasse 19 CH-8274 Tägerwilten Fon: +41 (0) 71 666 4204 www.witg.ch info@witg.ch</p>	

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Data Evaluation	<ul style="list-style-type: none"> • Calculation of corrosion rate by Faraday`s Law. • Classification of the results in corrosion classes, according to DIN EN ISO 9223. • Data from Sensor are visible in a dashboard. 		
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Data Evaluation	<ul style="list-style-type: none"> • Example dashboard – raw data 		
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Data Evaluation

- Example dashboard – evaluated data

Impact	Peak Value [g]	Date	Link
BP1 (Data)	4.9	24.08.1725	
BP1 (previous)	14.7	16.08.1800	
BP1 (Data)	2.4	21.08.0056	
BP2 (previous)	7.2	25.02.1719	
BP2 (Data)	7.7	23.08.0823	
BP3 (previous)	21.8	23.08.1624	

Alarm	Status	Date	Description
DC2AP2-data gap alarm (no data since 8...	Uncollected	21.08.2020 15:01...	
DK2AP1-acceleration alarm	Confirmed	02.07.2020 10:54...	
DK2AP1-acceleration alarm	Confirmed	19.05.2020 10:50...	
DC2AP3-acceleration alarm	Confirmed	03.04.2020 11:05...	
DK2AP1-data gap alarm (no data since ...	Normal	06.08.2020 00:31...	
DK2AP2-data gap alarm (no data since 8...	Normal	06.08.2020 00:31...	

Location (BP1)	Voltage [mV]	RIS [mV]	Corrosion Rate [g/m2/a]	Dr. entlastung [mV]
1.574 g/m2/a	1.574	314	Difference: 0.687 % Last updated: 07.08.2020 at 00:00	
Location (BP2)	Voltage [mV]	RIS [mV]	Corrosion Rate [g/m2/a]	Dr. entlastung [mV]
0.956 g/m2/a	0.956	850	Difference: 1.728 % Last updated: 07.08.2020 at 00:00	
Location (BP3)	Voltage [mV]	RIS [mV]	Corrosion Rate [g/m2/a]	Dr. entlastung [mV]
2.682 g/m2/a	2.682	850	Difference: 2.044 % Last updated: 07.08.2020 at 00:00	

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Summary and Outlook

- Sensor reacts sensitive to wetness and corrosive environments.
- Sensor reacts also to microclimate influence like vegetation.
- The concept allows a corrosion classification of the location.
- The dashboard allows an easy access to the raw and evaluated data.
- The measured corrosion rate is higher than gravimetric determined corrosion rate → more reference samples are necessary for determination of a correction factor.
- The next generation of prototypes is installed on different locations (including sensors for corrosion, temperature, humidity, acceleration, position and force).

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Thanks for your attention



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