InfrastructureTek™
CONSTRUCTION TECHNOLOGIES




SENSOR FAILURE ANALYSIS

Key Considerations for Assessing the Operational Lifespan of a Sensor System:

To evaluate the operational lifespan of a sensor system, the following factors should be carefully examined, along with appropriate testing:

- Failure analysis of all electronic components (FIT/MTBF)
- Possibilities for sabotage (EMP)
- Failure probability (Data-Retention) of the storage medium used
- Prevention of water ingress (capillary suction) into the interior of the system
- Mechanical robustness of the sensor
- Susceptibility of transmission
- Data security
- Declaration of conformity

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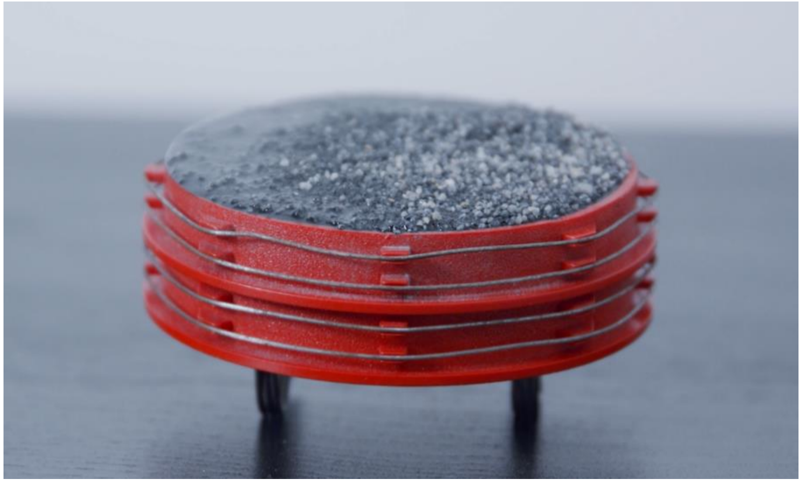
1. FAILURE ANALYSIS OF ALL ELECTRONIC COMPONENTS (FIT/MTBF):

The **FIT value (FIT = failure in time)** describes the failure rate of technical components, particularly electronic ones. Using FIT values for individual components makes it possible to calculate the failure probability of complex devices. In systems without redundancies, the failure of a single component can lead to the failure of the entire device. Therefore, a device's total failure rate is determined by its components' combined failure rates.

The corrosion/moisture sensor's FIT method yielded a value of 23.0. Converting this to the MTTF value (Mean Time to Failure, the average operating time until failure) indicates **a lifespan of over 200 years for this sensor.**

To further increase reliability, the following measures have been implemented:

- ***Redundant system across 2 wire levels***: to ensure continued operation in the event of a failure in one wire path.



- ***Signal amplifier checks*** before data transmission to verify proper functionality.

It is important to note that the values or results mentioned in this document do not affect the warranty/guarantee periods.

Source: IMS Fraunhofer Institute

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2. POSSIBILITIES FOR SABOTAGE (EMP):

Electronic components can be destroyed by electromagnetic pulses (EMP), which can be generated either by machinery or deliberately. To assess this risk, tests were conducted using a power level of 5.1 joules over a time period of less than 1 millisecond. *No negative results were observed during the testing.*

Source: IMS Fraunhofer Institute

3. LIGHTNING INFLUENCE

Electronic components installed in exposed environments, such as bridges, open decks, or marine structures, are at risk of being directly struck by lightning or impacted by voltage surges in nearby reinforcement areas caused by a lightning strike. The corrosion and moisture sensors are mounted directly on the reinforced concrete in this context. A pulse-like current flowing through the reinforcement grid generates rapid changes in the magnetic field around the steel reinforcement, which induces a current in the transponder coil.

Due to the absence of specific normative requirements, testing was conducted following generally accepted literature guidelines. A current surge of 50 kA was applied during these tests, with *no negative outcomes observed.*

Source: IMS Fraunhofer Institute

4. STANDARD INFLUENCES (EMC) FOR THE OVERALL SYSTEM

Electronic systems are subject to interference from various sources, which can affect their performance. The main interference factors include:

- ***Inherent immunity (internal EMC):*** The system's ability to resist internal electrical disturbances.
- **External immunity (external EMC):** The system's resilience to electromagnetic interference originating from external devices.
- ***Interference emission levels:*** The amount of conducted or radiated interference emitted by the device or system.

Tests conducted in compliance with standards EN 1326-1, EN 61326-1, EN 300300-1-V1.7.1, and EN 300300-1-V1.7.1 showed *no negative results.*

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Source: IMS Fraunhofer Institute

5. PREVENTION OF WATER INTRUSION (CAPILLARY ABSORPTION) INTO THE INTERIOR OF THE SYSTEM

Moisture and water can severely disrupt or damage electronic systems. Water molecules, with a size of 25 nanometers, can penetrate electronics unless preventive measures are taken. They are encapsulated in resin to protect electronic assemblies, typically made from long-chain molecules. However, this does not prevent capillary absorption along wires, as manufacturing processes often create grooves ranging from 20 to 100 micrometers. In the "CorroDec 2G" system, water intrusion along the individual wire entries into the sensor housing is blocked using specialized nanotechnology, which acts as a water barrier.

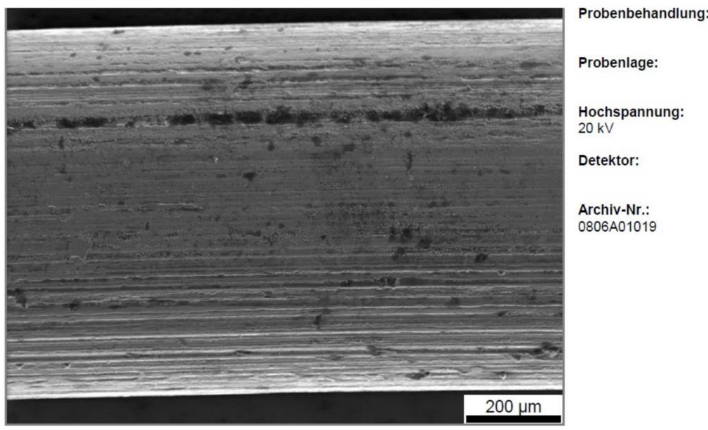

Abb. 8: Probe 3,
Oberfläche Draht 3

6. MECHANICAL DURABILITY OF THE SENSOR

Once installed, sensors are subject to high mechanical loads, including the direct passage of vehicles such as cars and trucks. The following load assumptions are considered:

- Car: 10 kN / 20 cm^2
- Truck: 96 kN / 40 cm^2 (contact area of the tire)

In tests, the sensors withstood loads of 400 kN/cm^2 without damage. Additionally, the impact on the structural integrity of the concrete (such as weakening due to static loads) was considered. Proper installation, ensuring that sensors are mounted parallel to the concrete surface, is essential for long-term durability.

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7. DATA SECURITY

Data security is critical in any sensor system. Measures are in place to prevent unauthorized access, manipulation, or theft of sensitive information. This includes encryption protocols, access control mechanisms, regular security audits, and adherence to relevant data protection regulations. Continuous monitoring and updates are also implemented to address emerging threats and vulnerabilities, ensuring ongoing data security.

Source: IMS Fraunhofer Institute

8. FAILURE PROBABILITY (DATA-RETENTION) OF THE USED STORAGE MEDIUM

Smart sensor systems perform various tasks, including acquiring and analyzing data, transmitting information, running internal checks, and measuring temperature. These tasks are controlled by internal software (firmware). Beyond the processor, the most important component is the storage unit, which holds the operating system.

Even individual memory locations must retain information (so-called Data Retention) to ensure an extremely long lifespan. Manufacturers conduct extensive tests to ensure data retention, and the results are shared with customers through datasheets. The data retention warranty is typically over 40 years, with regular data readouts ensuring accuracy over time.

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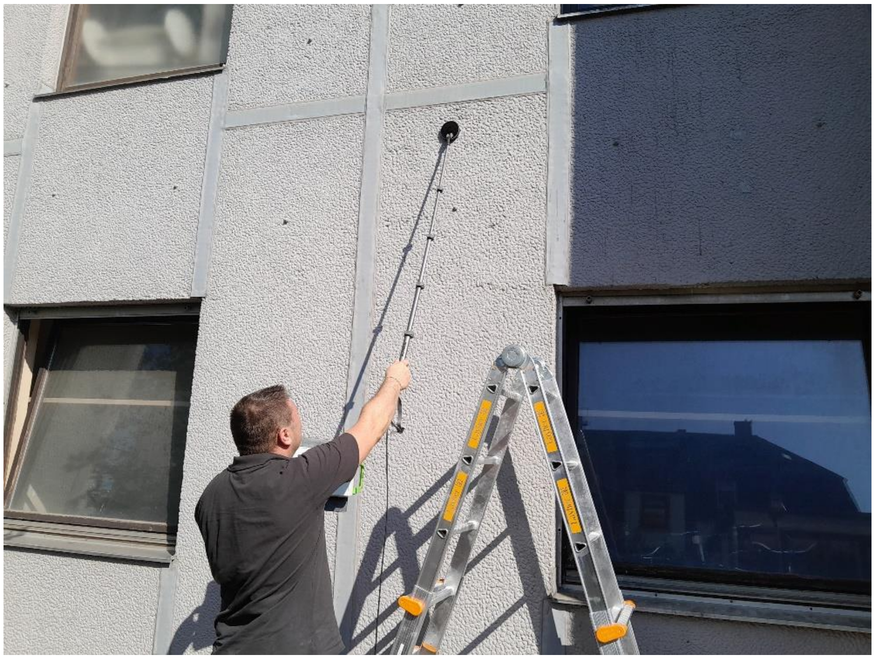

Source: Texas Instruments

9. INFLUENCE ON TRANSMISSION

The sensor system uses an extremely low frequency for data transmission, significantly reducing susceptibility to interference. Tests have been conducted to assess various conditions:

Test Condition	Influence
Steel reinforcement (connection with wire tie)	Low influence
Steel reinforcement (welded connection)	High influence
Operation underwater	Moderate influence
Operation under metal-coated sealing	Limited communication
Operation adjacent to another RFID Reader	Very high influence
Embedded in concrete	No influence

Note: Susceptibility can be further reduced by separating the communication components from the sensor itself through special design modifications.

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Source: IMS Fraunhofer Institute

DECLARATION OF CONFORMITY

In accordance with EC Decision No. 765/2008 and 768/2008 on the "General Principles of CE Marking," the manufacturer or importer declares that the product complies with the relevant requirements set out in the harmonization regulations of the European Community regarding its affixing.

Specifically, for the "**Corrosion Sensor"** and "**Moisture Sensor**" products, the following standards are applicable:

- ESD Compliance according to EN 61326-1
- Immunity to Interference according to EN 61326-1
- Emission of Interference according to EN 300330-1-V1.7.1

Source: IMS Fraunhofer Institute, Infrasolute

For more information or inquiries, please visit our website, WWW.INFRASTRUCTURETEK.COM, or contact us directly through LinkedIn or info@infrastructuretek.com

infrasolute
smart infrastructure monitoring

Note: All of the aforementioned tests have been conducted, validated, and utilized by our business partners at Infrasolute in Europe for over 10 years before entering the U.S. market.

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Ihr Zeichen	Ihre Nachricht vom	Unser Zeichen	
		GvB	Duisburg, 25. September 2014

Abschätzung der Lebenserwartung der elektronischen Schaltung "Betontransponder"

Sehr geehrter Herr Seuss,

im Rahmen des ZIM-Projekts „Entwicklung eines technologisch neuen Sicherheits- und Überwachungssystems für Korrosion an Beton- und Schachtbauwerken mit erstmaliger Fernabfrage" (kurz Betontransponder) wurde eine Abschätzung der Lebenserwartung der elektronischen Schaltung durchgeführt. Betrachtet wurde dabei der Teil des Systems, für den Fraunhofer IMS verantwortlich ist: die Leiterplatten des Betontransponders, also die komplette elektronische Schaltung. Nicht betrachtet wurden Einflüsse der Verkapselung, wie Vergussmasse und Gehäuse, die ggfs. durch mechanischen Stress Einfluss ausüben könnten.

Die Untersuchung gliedert sich in 2 Punkte:

- einer Abschätzung der Ausfallrate nach dem FIT-Verfahren (Failure in Time), die die Betriebsbedingungen wie Temperaturwechsel und auftretende Ströme auf Bauteil und Leiterplattenebene berücksichtigt und
- einer Betrachtung des Datenerhalts von Speicherzellen.

FIT-Verfahren

Dem FIT-Verfahren liegen die folgenden Normen zugrunde:

- Bauelemente FIT und Applikationsbedingungen: SN_29500
- Leiterplatten FIT: IEC TR 62380

Das FIT-Verfahren wurde mit den folgenden Parametern durchgeführt:

- durchschnittliche Temperaturschwankungen 30 °C
- Anzahl der Temperaturwechsel im Jahr 365
- Durchschnittstemperatur 25 °C
- Spannung der BE (Durchschnitt über Alle) 3,3 V
- Strombelastung der Gesamtschaltung 4 mA

Eine Eigenerwärmung des Systems durch den elektrischen Betrieb wird nicht berücksichtigt, da die auftretenden elektrischen Leistungen minimal sind und zu keiner signifikanten Erwärmung führen.

Das FIT-Verfahren lieferte die folgenden Ergebnisse:
Gesamtausfallrate:

- Feuchtetransponder 17,2
- Korrosionstransponder 23,0

Die Ausfallrate entspricht aufgrund der extrem niedrigen Aktivzeiten dem des Ruhezustandes. Dieser geht von Bauelementen, die in der Norm nicht spezifiziert sind von 0.1 (=Kondensator) aus. Damit ergibt sich insgesamt eine sehr niedrige FIT Rate für das System. Die Umrechnung in den MTTF Wert (Mean Time To Failure = mittlere Betriebsdauer bis zum Ausfall) ergibt für beide Transpondertypen eine Dauer von über 200 Jahren.

Datenerhalt
Die Betrachtung des Datenerhalts von Speicherzellen bezieht sich auf die Herstellerangaben des Bausteins, in dem die Speicherzellen enthalten sind. Um auch eine niedrige Ausfallrate zu für die Speicherzellen zu erzielen, wurde die FRAM-Technologie verwendet, die laut Hersteller folgende Zeiten für den Datenerhalt erfüllt:

- Betrieb bei 25 °C Datenerhalt 100 Jahre
- Betrieb bei 70 °C Datenerhalt 40 Jahre

Diese Angaben sind entnommen aus: http://www.ti.com/lit/an/slaa526a/slaa526a.pdf

Somit kann aufgrund der statistischen Angaben eine Gesamtlebenserwartung von über 40 Jahren abgeschätzt werden.

Mit freundlichen Grüßen

Dr. Gerd vom Bögel

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WE STRONGLY BELIEVE IN DEVELOPING TECHNOLOGIES THAT PROMOTE SUSTAINABILITY AND RESILIENCE TO SAFEGUARD THE BUILT ENVIRONMENT.

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