# A comparative study on corrosion behaviour Evaluation techniques for Aluminium-Based PVD Coatings

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## Introduction

Coatings have been modified to improve their performance by using advanced techniques such as physical vapour deposition (PVD) which increases the lifetime and service quality of the coating system. Surface degradation mechanisms of passive films on aluminium and its alloys in aqueous solution have been carried out by salt spray test and electrochemical impedance spectroscopy (EIS). One of the widest uses of EIS is in evaluating the corrosion protection behaviour of coatings on corrodible metal surfaces. The EIS method is a well-established technique and a powerful tool to determine a quantitative numerical value of corrosion damage of coatings, investigate the mechanisms of the electrochemical reactions of the corrosion process, and measure the dielectric and transport properties of various coating systems to explore coating defects. Although, the test itself is rapid, periodic long-term EIS testing (for comparison with other techniques) can take days or weeks (and sometimes months) to obtain good results. Therefore, the results must be obtained in short times are needed to provide a faster indication of corrosion behaviour in the coated metal surfaces. Hollaender et al. l [1, 2, 3] developed a rapid electrochemical test (AC-DC-AC) which combines EIS measurements with cathodic polarisation DC measurements for testing coated metal surfaces in food packaging. The AC-DC-AC test has been used and adopted by Suay and co-worker in liquid paints coated steel surface successfully [1, 3].

## Benefits

- Companies producing coatings often need to evaluate the actual corrosion behaviour of new coatings before their use in large-scale production. It's highly desired to have a rapid evaluation technique that can estimate the corrosion behaviour of PVD Al-based coatings at least as reliable as during their immersion in salt spray test (that gives just qualitative results) and immersion in 3.5% NaCl solution at different exposure times by electrochemical impedance spectroscopy (EIS) test which gives quantitive result but in long period of times.
- Obtaining meaningful results from AC-DC-AC test in very short times (almost 1day) than EIS tests is practicable for manufactures, hence it not necessary to wait for completion of outdoor tests.

## Methodology

## Corrosion Behaviour Evaluation Techniques

### *Salt Spray Testing*

The most commonly used accelerated test is the salt spray test, which is defined by the ASTM B-117 standard. SST can offer many benefits, including a controlled corrosive environment with a standardised protocol for conducting the exposure and evaluating the results, multiple materials can be used in the test. However, salt spray tests can only provide qualitative and this in itself requires a trained observer to provide accurate and reliable interpretation. Evaluation by SST methods also does not always yield rankings that agree with those found in actual field exposure; this has led such testing to be criticised as being almost uninterpretable to many 'real life' situations.

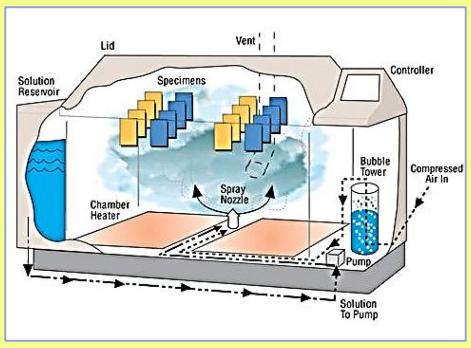


Figure1. Typical salt spray test cabinet

### *Electrochemical Impedance Spectroscopy EIS*

EIS provides valuable information with regard to the details of corrosion rate, electrochemical reactions, and detection of localised corrosion. However, EIS data can be interpreted through the construction of an equivalent circuit (EC), which is an assembly of electrical elements that describe the physical and electrochemical corrosion behaviour of the coating/substrate interface. EIS tests are normally performed using small amplitude ac signals (usually of the order of 10mV) over a wide range of frequencies ($10^{-2}$ Hz to $10^{5}$Hz); hence the adoption on of the term of "impedance spectroscopy". The impedance response of the system is a complex number that is defined by ohm's law:

$$Z(\omega) = \frac{V(\omega)}{I(\omega)} = Z'(\omega) + jZ''(\omega)$$

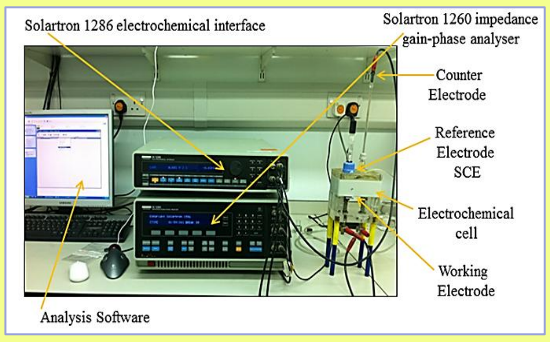


Figure2. EIS electrochemical Instrument and cell

### *AC-DC-AC Test*

AC-DC-AC test measures the quality of the coating and its adhesion by subjects the coating to sequence of cycles consist of a combination of AC and DC measurements.

(I) **AC step:** for monitoring the electrochemical properties of the coating using EIS test.

(II) **DC step:** applying constant cahtodic voltage (-2V) for promoting $H_2$ evolution that can lead to physical delamination and $HO^-$ ions flow through the coating that promote the delamination coating degradation.

(III) **OCP step:** the processes that were accelerated after the applied potential DC were allowed to reaches again the steady.

(IV) **AC step:** For monitoring the electrochemical properties of the coating using EIS after coating damaged.

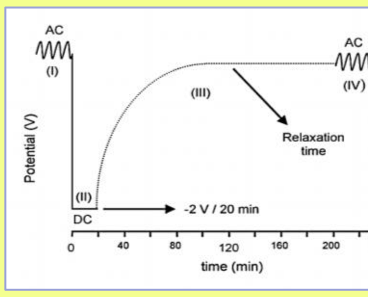


Figure3. AC-DC-AC schematic diagram vs. time

1. García, S.J. , and Suay, J., *A comparative study between the results of different electrochemical techniques (EIS and AC/DC/AC): Application to the optimisation of the cataphoretic and curing parameters of a primer for the automotive industry.* Progress in Organic Coatings, 2007. 59(3): p. 251-258.
2. Bierwagen, G.P., Allahar, K.N., Su, Q. , and Gelling, V.J., *Electrochemically characterizing the ac–dc–ac accelerated test method using embedded electrodes.* Corrosion Science, 2009. 51(1): p. 95-101.
3. Allahar, K.N., Bierwagen, G.P. , and Gelling, V.J., *Understanding ac–dc–ac accelerated test results.* Corrosion Science, 2010. **52**(4): p. 1106-1114.

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