

# ISO/TR 5602:2021-11 (E)

## Sources of error in the use of electrochemical impedance spectroscopy for the investigation of coatings and other materials

---

Contents	Page
<b>Foreword .....</b>	<b>v</b>
<b>Introduction .....</b>	<b>vi</b>
<b>1 Scope .....</b>	<b>1</b>
<b>2 Normative references .....</b>	<b>1</b>
<b>3 Terms and definitions .....</b>	<b>1</b>
<b>4 Error in the make-up of the measuring cell .....</b>	<b>1</b>
<b>4.1 Roughness of the surface .....</b>	<b>1</b>
<b>4.2 O-ring -- Considerations about the precise determination of the exposed area .....</b>	<b>3</b>
<b>4.3 Faulty cell make-up .....</b>	<b>7</b>
<b>4.3.1 Optically detectable leaks .....</b>	<b>7</b>
<b>4.3.2 Optically non-detectable causes .....</b>	<b>7</b>
<b>4.4 Reference electrodes .....</b>	<b>9</b>
<b>4.4.1 General information on the distance between the reference and working electrodes .....</b>	<b>9</b>
<b>4.4.2 Shielding .....</b>	<b>11</b>
<b>4.4.3 Air bubble in the reference electrode .....</b>	<b>11</b>
<b>4.4.4 Poisoning of the reference electrode .....</b>	<b>11</b>
<b>4.4.5 Bleeding of the reference electrode .....</b>	<b>11</b>
<b>4.5 Counter electrodes .....</b>	<b>11</b>
<b>4.5.1 Relative sizes .....</b>	<b>11</b>
<b>4.5.2 Reactive counter electrodes .....</b>	<b>11</b>
<b>4.6 Gas inclusions in the measuring cell .....</b>	<b>11</b>
<b>5 Faults caused by electronics incl. shielding .....</b>	<b>12</b>
<b>5.1 Faraday cage .....</b>	<b>12</b>
<b>5.2 Extended cable (without active shielding) .....</b>	<b>15</b>
<b>5.3 Cable breaks .....</b>	<b>16</b>
<b>5.4 Contact resistances between metallic contacts and the working electrode/counter electrode .....</b>	<b>17</b>
<b>5.5 Inductivities .....</b>	<b>18</b>
<b>5.6 Measurement range switching .....</b>	<b>19</b>
<b>5.7 Scattering signals in power supply .....</b>	<b>20</b>
<b>5.8 Insufficient signal-to-noise ratio .....</b>	<b>22</b>
<b>5.9 Influence of peripheral devices .....</b>	<b>22</b>
<b>6 Parameter selection, measurement range limits .....</b>	<b>24</b>
<b>6.1 Open-lead test .....</b>	<b>24</b>
<b>6.2 Note on dummy cells - ISO 16773-3 .....</b>	<b>24</b>
<b>6.3 Unsuitable amplitude .....</b>	<b>24</b>
<b>6.4 Insufficient frequency range .....</b>	<b>26</b>
<b>6.5 Repetition rate for subsequent measurements .....</b>	<b>27</b>
<b>7 Non-stationary measurement conditions .....</b>	<b>28</b>
<b>7.1 General .....</b>	<b>28</b>
<b>7.2 Temperature fluctuations .....</b>	<b>29</b>
<b>7.3 Electrolytic conductivity .....</b>	<b>31</b>
<b>7.4 Swelling .....</b>	<b>31</b>

7.5	<b>Drifting OCP</b> .....	31
7.6	<b>Corroding working electrode</b> .....	33
7.7	<b>Reactive counter electrodes</b> .....	33
7.8	<b>Gas formation at the counter electrode</b> .....	33
8	<b>Design and selection of equivalent circuit diagrams</b> .....	34
8.1	<b>Constant phase element</b> .....	34
8.2	<b>Multiple possibilities for the selection of equivalent circuits</b> .....	35
8.3	<b>Warburg impedance</b> .....	37
9	<b>Significance of measurement values from equivalent circuits</b> .....	37
9.1	<b>Measurement uncertainty</b> .....	37
9.2	<b>Plausibility analysis</b> .....	38
10	<b>Interpretation of the measurement values of various coating systems</b> .....	39
10.1	<b>Pre-treatment</b> .....	39
10.2	<b>Film thickness and measurement surface</b> .....	40
10.3	<b>Number of layers</b> .....	41
10.4	<b>Conditioning</b> .....	45
10.5	<b>Generic type of binder</b> .....	45
11	<b>Presentation of data</b> .....	45
	<b>Annex A (informative) Calculation of the coating capacitance</b> .....	48
	<b>Annex B (informative) Further information on the influence of the double-layer capacitance</b> .....	49
	<b>Annex C (informative) Estimation of the order of magnitude of an apparent capacitance caused by corrosion</b> .....	50
	<b>Bibliography</b> .....	52