

Electrical Conductivity as an Indicator for Early Warning Detection Systems in Chemical Reactors

Giuseppe Andriani¹, Gianmaria Pio², Chiara Vianello¹, Paolo Mocellin^{1,3}, Ernesto Salzano²

¹ Università degli Studi di Padova, Dipartimento di Ingegneria Industriale, Via Marzolo 9, 35131 Padova, Italia.

² Università di Bologna, Dipartimento di Ingegneria Civile, Chimica, Ambientale e dei Materiali, Via Terracini 28, 40131 Bologna, Italia.

³ Università degli Studi di Padova, Dipartimento di Ingegneria Civile, Edile e Ambientale, Via Marzolo 9, 35131 Padova, Italia.

Abstract:

In chemical reactor safety, Early Warning Detection Systems (EWDS) are essential tools for preventing runaway reactions by anticipating the onset of uncontrolled exothermic events, traditionally through continuous temperature monitoring. However, in industrial applications, thermocouples often suffer from delayed response times, and their placement is critical to accurately detecting potential onset conditions. These limitations can reduce the effectiveness of safety protocols, particularly in rapid runaway scenarios that exceed sensor response times or occur in insufficiently monitored areas. As an alternative, monitoring the electrical conductivity of solutions—especially when ions or charged species are released during an uncontrolled reaction—may offer a faster and more reliable indicator. Examples of exothermic reactions that generate ions and present runaway risks include the decomposition of organic and inorganic compounds, as well as bulk chemical production, such as strong acid manufacturing (e.g., sulfuric acid), saponification of fatty acids, and neutralization reactions. Within this context, the proposed methodology could be scaled to industrial applications by integrating more sensitive, reliable, and rapid control instruments (e.g., conductivity probes) to closely monitor reaction environment and prevent hazardous loss of control.

Using this surrogate variable, EWDS can achieve enhanced responsiveness and reliability. This study introduces an alternative approach to EWDS in chemical reaction engineering, shifting the focus from temperature monitoring to the analysis of electrical properties in reactive liquid systems. The theoretical framework for this approach is presented, laying a foundation for future experimental validation.

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Corresponding author: Paolo Mocellin

E-mail: paolo.mocellin@unipd.it