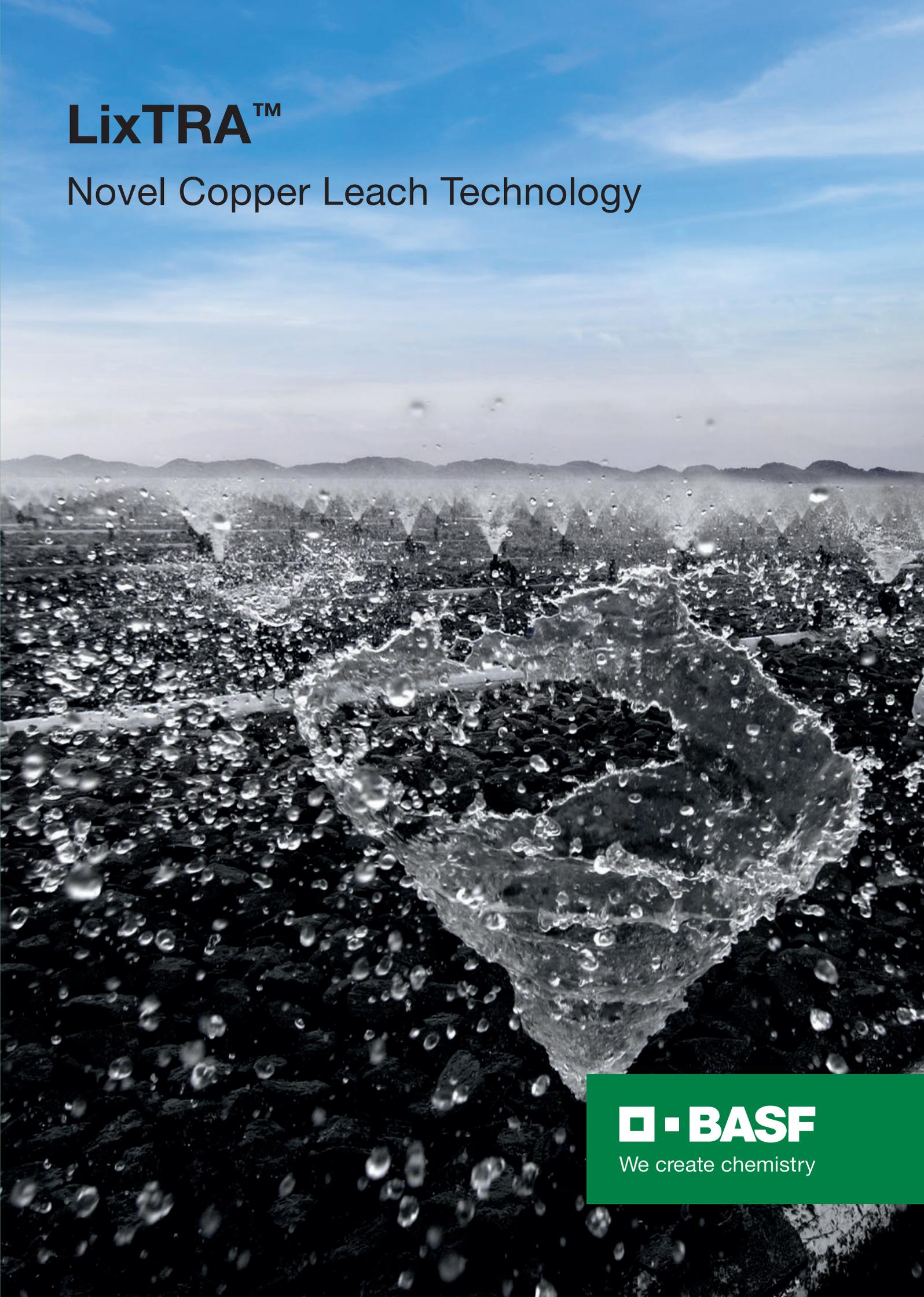


LixTRA™

Novel Copper Leach Technology



 **BASF**

We create chemistry

BASF's Mining Solutions at a glance

BASF's Mining Solutions business offers a diverse range of mineral processing chemicals and technologies to improve process efficiencies and aid the economic extraction of valuable resources.

Our offer includes products and solutions to the global mineral processing industry along with expert advice and technical support. Our global team is driven by a common goal to provide the best sustainable solution to meet our customers' processing needs. With technical representation in over 100 countries, BASF's technical support is provided on a global, regional and local basis.

Our chemical and process expertise includes reagents, equipment, process technologies and know-how. All of which are focused on hydrometallurgy, solid liquid separation, tailings management, materials handling, flotation and grinding.

In hydrometallurgy BASF supply copper SX reagents marketed under the LIX® tradename, which encompasses ketoximes, aldoximes and formulated blends thereof. This broad range of reagents and formulations allows BASF to supply its customers with optimized solutions tailored to meet the needs of their specific process.

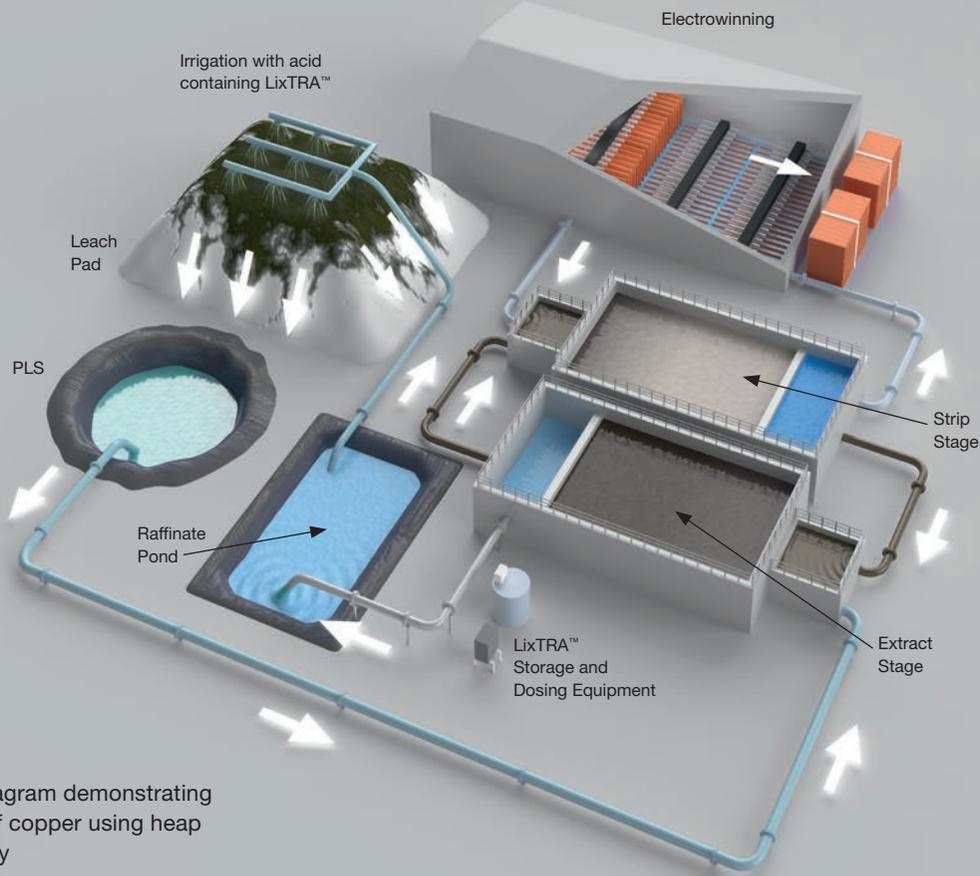
BASF technology developed to increase metal recovery from heap and dump leach processes



The ever-increasing demand for minerals and metals is driven by macroeconomic factors such as global population growth, industrialization, rapid urbanization and higher standards of living.

This poses a major challenge for the mining industry, especially when faced with depleting ore grades and more complex ore mineralogy, while at the same time required to meet increasingly stringent environmental and operation compliance. The industry is therefore in need of new sustainable extraction techniques to maintain or improve mineral and metal recovery.

To meet these challenges in the copper industry, BASF Mining Solutions have developed **LixTRA™** Technology for Heap and Dump leach processes. **LixTRA™** provides the industry an opportunity to increase metal recovery, reduce mining costs and extend the life of mine in an environmentally sound and sustainable manner.



Process flow diagram demonstrating the extraction of copper using heap leach technology

History

Heap leaching copper from oxide and secondary sulfide ores has been practiced commercially since the late 1960's. This methodology is mostly used for low-grade ores and involves the following basic processing steps: Mining, Crushing, Leaching, Solvent Extraction (SX) and Electrowinning (EW). Depending on ore characteristics other techniques such as Grinding and Agglomeration can also be employed.

Process

Heap and Dump leaching are processes used to extract metals such as copper, gold, nickel and uranium from their ores by placing the ore on a pad in the form of a heap. A heap leach encompasses a level of comminution while a dump leach is run of mine (ROM), where the ore is moved directly from mining to lixiviation. In the copper industry, irrigation takes place whereby a lixiviant (dilute sulfuric acid) is sprayed over the ore and dissolves the available copper. The resultant Pregnant Leach Solution (PLS) containing the dissolved copper, is collected from the bottom of the pad and passed through further processing steps. These include Solvent Extraction to purify and concentrate the metal containing solution and Electrowinning to produce high quality finished copper metal, known as cathode.

Background

BASF supplies reagents to help improve process efficiencies for all the major mineral processing steps apart from leaching; an area historically devoid of advanced chemical technologies. Previously, use of chemical additives in leaching applications were avoided due to either poor copper recovery or the lack of compatibility with downstream processes.

Future

BASF is a market leader in copper SX reagents and has been providing the mining industry advanced chemistry and technical expertise for over half a century. With this experience, BASF fully understand the importance and implications of ensuring the healthy operation of all associated processes.

The key research focus in the development of **LixTRA™** was therefore to identify all hydrometallurgical processes a leaching aid would impact and determine the sensitivity of those processes.

Based on various static and dynamic testing programs BASF targeted chemistry which would be universally compatible with the following:

- ◆ Typical heap leach bacteria & archaea
- ◆ Solid liquid separation
- ◆ Solvent extraction
- ◆ Electrowinning

Based on extensive Research and Development, novel **LixTRA™** Copper Leach Technology now offers the industry its first leaching additive that is compatible with the entire **Leach → SX → EW** process.

Benefits of using LixTRA™

Fig. 1a: Industrial Column Leaching – Oxide Ore

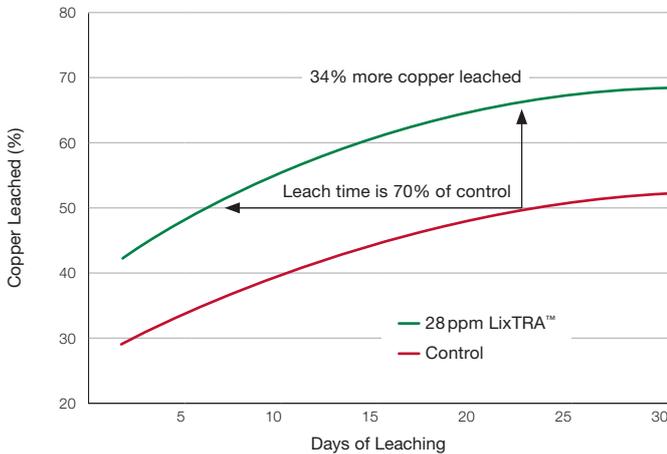


Fig. 1b: Industrial Column Leaching – Secondary Sulfide Ore

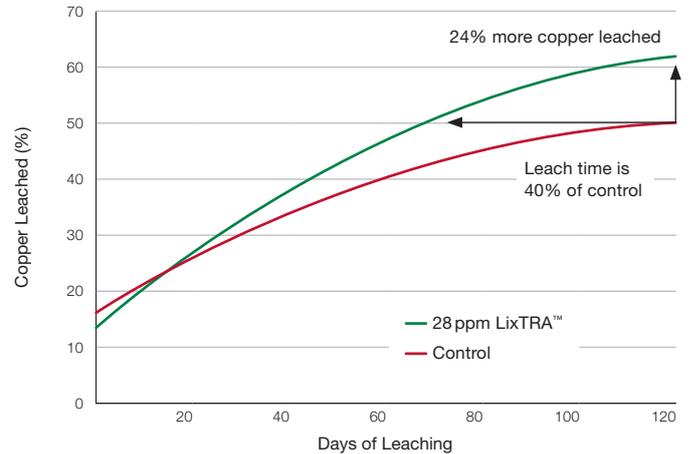


Fig. 1c: Large Scale Heap Testing – Mixed Oxide/ Primary Sulfide Ore

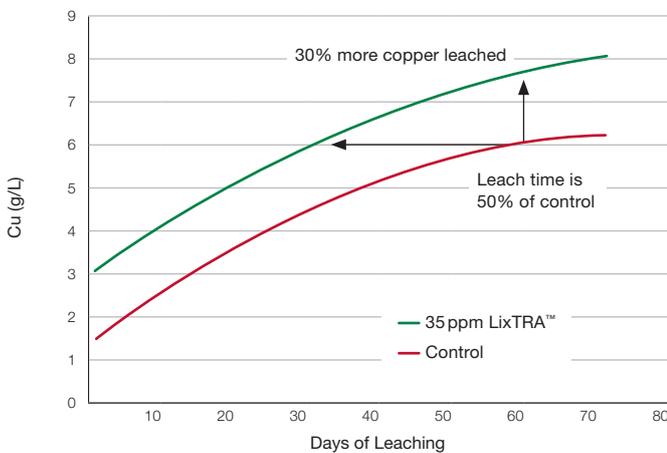
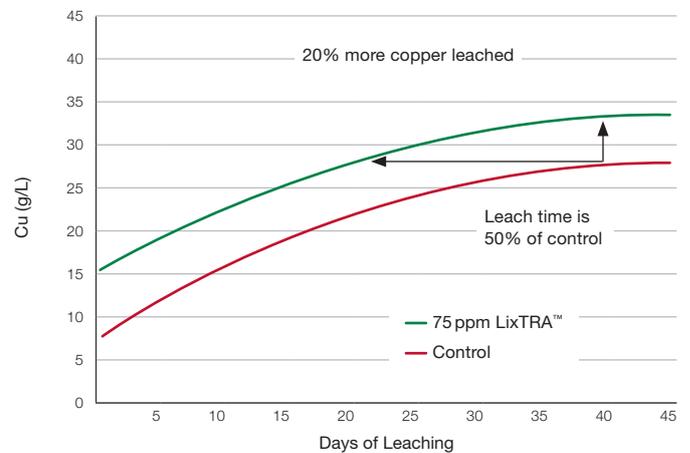


Fig. 1d: Column Testing – Agglomerated Mixed Oxide and Sulfide Ore



Results

From Figure 1 (a-d) the beneficial effect of using LixTRA™ can be observed when leaching; a) an oxide ore b) a secondary sulfide ore, c) a mixed oxide/primary sulfide ore and d) an agglomerated mixed oxide/sulfide ore compared to a control (lixiviant alone).

As can be seen, the addition of LixTRA™ not only significantly increases copper recovery, but also significantly increases the rate of copper recovery when compared to the control.

LixTRA™ therefore offers the following benefits to a mine:

- ◆ Increases rate of copper leaching; improving cash flow
- ◆ Reduces operating costs per ton of cathode; increasing profitability
- ◆ Opportunity to mine less ore to achieve the same production quota; reducing mining costs
- ◆ Extends life of mine; increasing return on investment

Compatibility

In order to evaluate chemical compatibility, both batch testing and continuous circuit testing was conducted to determine the effect on the kinetics of extraction/stripping and phase disengagement times. As can be seen from the data in Table 1, Figure 2a and 2b there were no adverse effects on solvent extraction.

Biological compatibility was also determined. Tests were conducted with sulfur and iron oxidizing bacteria as well as

heterotrophic bacteria to ensure that **LixTRA™** does not negatively affect the biological respiration necessary to convert secondary or mixed sulfide copper to copper sulfate in solution.

Biological species relevant to various mining sites were inoculated with **LixTRA™**. The results of this testwork showed that after a short conditioning period most of the biological species maintained typical populations.

	Dynamic Circuit Fresh Organic	Dynamic Circuit 8 hour Run 0 ppm Dose	Dynamic Circuit 40 hour Run 15 ppm Dose	Dynamic Circuit 80 hour Run 15 ppm Dose	Batch Testing Blank	Batch Testing 50 ppm Dose	Batch Testing 20 ppm Dose
E_{30} [Cu] (g/L)	4.69	4.75	4.73	4.80	4.72	4.69	4.69
E_{300} [Cu] (g/L)	4.77	4.81	4.78	4.87	4.75	4.73	4.72
S_{30} [Cu] (g/L)	1.67	1.68	1.67	1.70	1.64	1.64	1.65
S_{300} [Cu] (g/L)	1.64	1.66	1.64	1.69	1.63	1.63	1.63
Extraction Kinetics	98.3%	98.8%	99.0%	98.6%	98.3%	98.8%	99.0%
Strip Kinetics	99.0%	99.4%	99.0%	99.7%	99.0%	99.4%	99.0%
Org Continuous Break (s)	60	55	40	35	75	80	75
Aq Continuous Break (s)	85	90	90	90	95	85	95

Table 1. Chemical compatibility data for batch and dynamic circuit testing

Fig. 2a: Kinetics – Dynamic and Batch Testing

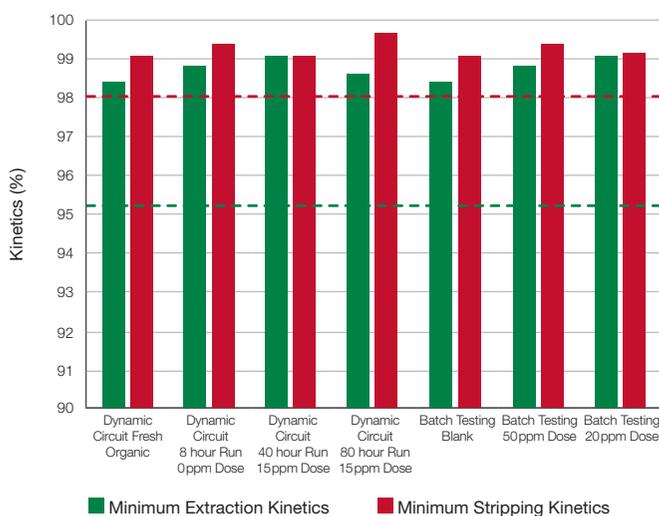


Fig. 2b: Phase Break Times – Dynamic and Batch Testing

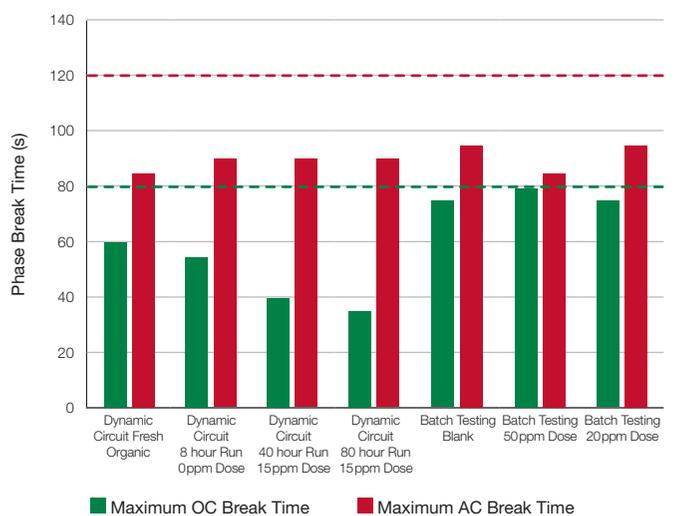


Fig. 2a Extraction and Strip Kinetics compatibility data and Fig. 2b Phase Break compatibility data for batch and dynamic circuit testing

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Product Information

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