

# METALWORKING ADDITIVES

**AKYPO®**  
**AKYPO® ROX**  
**AMIDET®**  
**FOSFODET®**

**Emulsion stability**  
**Lime soap dispersion**  
**Hard water stability**  
**Foam control**  
**Corrosion inhibition**  
**Extreme pressure and anti-wear**  
**Rinsing and cleaning**

ESSENTIALS FOR  
LONGER LIFETIME  
METALWORKING FLUIDS

THE TECHNOLOGY OF KAO SURFACTANTS IN METALWORKING FLUIDS

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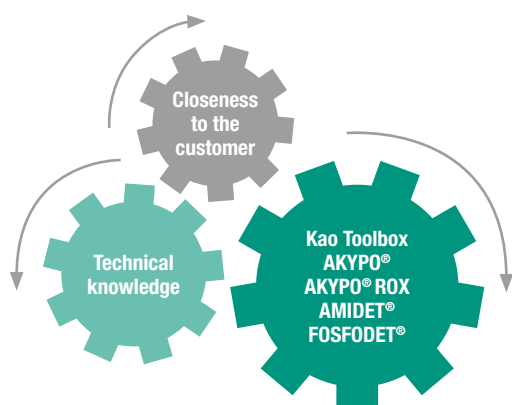
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# KAO SURFACTANT TECHNOLOGY

## KAO CORPORATION

Founded in 1887, Kao Corporation is a Japanese company with a long history of innovation. Today, more than 33,000 employees worldwide are satisfying customer needs around the globe.



## SUSTAINABLE, COLLABORATIVE DEVELOPMENT

Inspired by our corporate philosophy, the Kao Way, and the Yoki-Monozukuri concept that lies at its heart, we are committed to providing excellent products to our customers.

Our close relationship with our customers inspires us to integrate their needs into the concepts and extensive technical knowledge of our Research & Development and Marketing & Sales teams. Guided by the Kao Sustainability Statement, we aspire to design and distribute non-toxic and environmentally friendly products using renewable resources.

These principles are reflected in our standard product range, the Kao Metalworking Toolbox, as well as in the customized solutions we offer.

# METALWORKING APPLICATION

Kao Chemicals Europe provides key surfactant technology for modern metalworking formulations that are particularly indispensable for water miscible fluids. Our additive brands AKYPO®, AKYPO® ROX, AMIDET® and FOSFODET® feature these primary properties:

- Stable emulsions for various degrees of water hardness and a wide variety of conditions.
- Foam controlling emulsifiers, co-emulsifiers and solubilizers.
- Multifunctional stabilizers (highlighted in Kao Metalworking Toolbox summary of application benefits).
- Easy handling and formulating.
- Environmentally friendly.

These properties enable your formulations to successfully meet the increasing demands of your customers:

- Longer fluid lifetimes.
- Lower maintenance costs and increased productivity thanks to clean fluids.
- Formulations for high pressure and high speed machining.
- Improved lubricity and extreme pressure/anti-wear (EP/AW) performance for increased tool lifetimes.
- Mild labeling and environmentally friendly metalworking fluids.

## APPLICATION BENEFITS:

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PRODUCT GROUPS		CHEMICAL DESCRIPTION	Hard water stability	Electrolyte stability	Foam control	Emulsifier efficiency	Corrosion inhibition	Rinsing and cleaning	Extreme pressure/anti-wear
Anionic	AKYPO® LF	C <sub>4-8</sub> alkyl ether carboxylic acids	High	High	Low	Low	Low	Low	Low
	AKYPO® RLM/RO	C <sub>12-18</sub> alkyl ether carboxylic acids low ethoxylated	High	High	Low	Low	Low	Low	Low
	AKYPO® RO	C <sub>16-18</sub> alkyl ether carboxylic acids moderate to high ethoxylated	High	High	Low	Low	Low	Low	Low
	AKYPO® PO-EO	C <sub>16-18</sub> alkyl PO-EO ether carboxylic acids	High	High	Low	Low	Low	Low	Low
	AKYPO® RA	Alkyl amide ether carboxylic acids	High	High	Low	Low	Low	Low	Low
	FOSFODET®	C <sub>16-18</sub> alkyl PO-EO ether phosphate esters	High	High	Low	Low	Low	Low	Low
Non-ionic	AMIDET®	Ethoxylated alkyl amides	High	High	Low	Low	Low	Low	Low
	AKYPO® ROX	C <sub>16-18</sub> alkyl PO-EO alkoxyates	High	High	Low	Low	Low	Low	Low

Summary of the application benefits for the Kao Metalworking Toolbox product groups, highlighting the most relevant properties of our surfactants and their multifunctionality.

- Specially designed for respective performance
- High ■ Medium ■ Low □ Not relevant

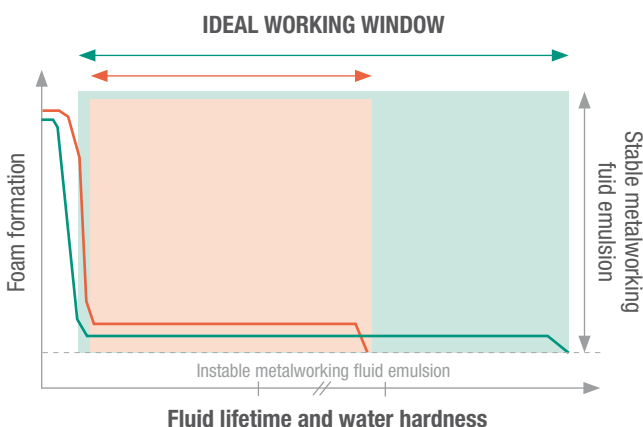
Range of products



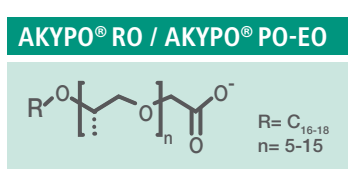
# HARD WATER STABILITY

## HARD WATER STABILITY EXTENDS THE LIFE OF METALWORKING FLUIDS

AKYPOs® are characterized by their outstanding tolerance in terms of water hardness and electrolytes. The addition of AKYPOs® allows to decrease the formation of foam even if the level of water hardness is low, and it also limits the formation of soaps and insoluble agglomerates throughout a wide range of water hardness levels. Ultimately, this extends the fluid's operating window, which leads to a longer fluid lifetime.

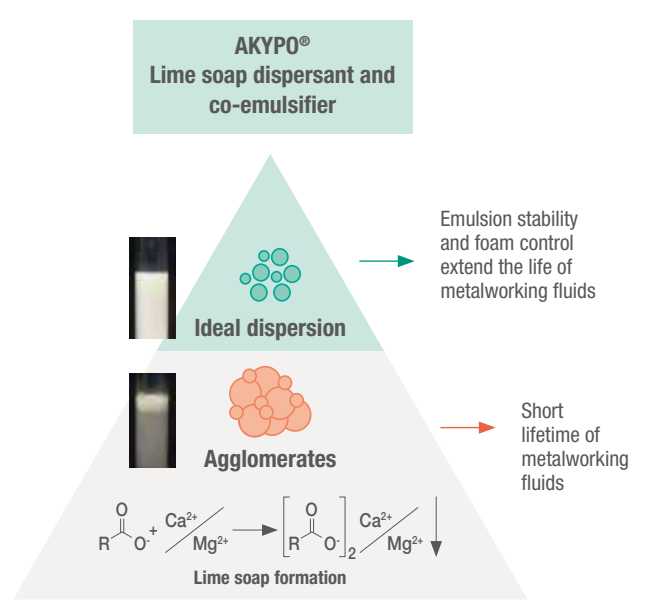


- Main emulsifier sulfonate, fatty acids, fatty alcohol ethoxylates + AKYPO® RO or AKYPO® PO-EO.
- Only main emulsifier sulfonate, fatty acids, fatty alcohol ethoxylates.



## DISPERSION POWER OF AKYPO®

The strength of AKYPO® is its extraordinary lime and metal soap dispersion power. This makes it possible to stabilize metalworking fluids under the extreme water conditions typically present in metalworking. Such common primary emulsifiers as fatty acids and sulfonates form soaps and insoluble agglomerates in combination with high loads of metal salts (calcium, magnesium, aluminum and sodium) resulting from natural water hardness and water treatment as well as the severe conditions characteristic of metalworking. The dispersion of soaps with AKYPO® prevents drag out of lubricity components and preserves the cleanliness and stability of fluids, resulting in less maintenance.

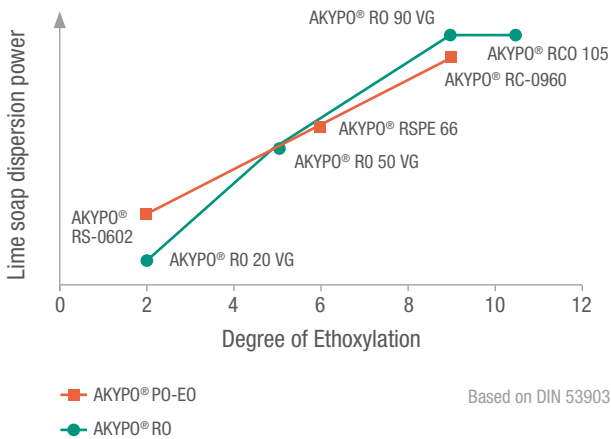


<p><b>Common primary emulsifier</b></p> <p>Fatty acids Coco, oleic, tall oil Sulfonate</p>	<p><b>Process water, water hardness, water treatment</b></p> <p>Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup>, ...</p>
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# ELECTROLYTE STABILITY

## SELECTING THE IDEAL AKYPO®

The lime soap dispersion power of AKYPO® increases with its degree of ethoxylation and this directly corresponds to achievable hard water resistance. This parameter thus indicates which AKYPO® is the best choice for achieving the desired level of calcium and magnesium dispersion for the fluid.

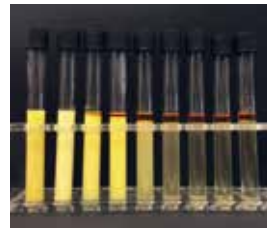


## LIGHT METAL TREATMENT

The worldwide goals to save energy and conserve resources is fueling demand for the treatment of light metal alloys. This treatment in particular leads to the formation of aggressive soaps.

The best resistance toward the formation of magnesium in soaps is attained by the addition of AKYPO® RO 90 VG.

Without AKYPO®



Mg<sup>2+</sup> concentration

With AKYPO® RO 90 VG

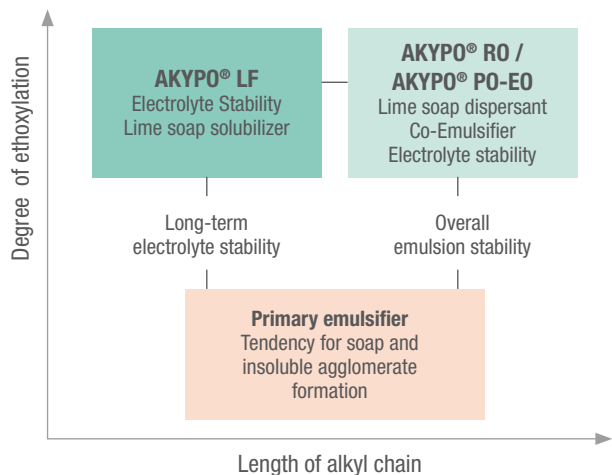


Mg<sup>2+</sup> concentration

Electrolyte scan with 10% metalworking formulation (colored) starting with demineralized water (0 ppm) and an increasing concentration of magnesium.

## ELECTROLYTE STABILITY AND SOLUBILIZATION

AKYPO® LF products will further enhance the electrolyte stability of your formulation and are beneficial for the solubilization of lime soaps.

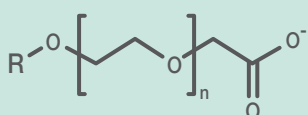


# FOAM CONTROL

## EMERGING NEED FOR FOAM CONTROL

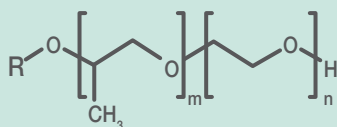
Today's metalworking industry is moving toward using greater operating pressures and pumping rates, which leads to the increased formation of foam. Due to additional regulations and limits on biocides, the industry has turned to alternatives such as using highly concentrated fluids. This approach enables maintenance of resistance to microbial growth, but typically leads to increased foaming. These trends make foam control a central issue, especially for modern metalworking fluid technology. The Kao Metalworking Toolbox offers a broad range of low foaming AKYPO® and AKYPO® ROX products that enable enhanced foam control.

### AKYPO® RO / AKYPO® LF



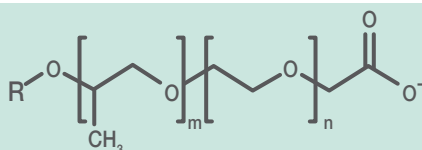
n= 2-10.5  
R= C<sub>16-18</sub>/C<sub>4-8</sub>

### AKYPO® ROX



m= 6  
n= 2-9  
R= C<sub>16-18</sub>

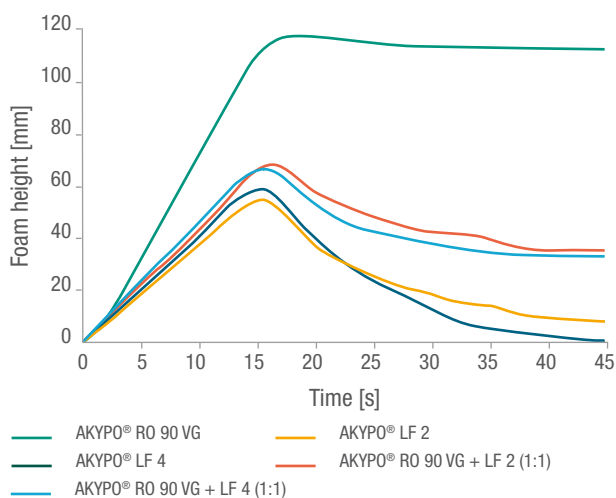
### AKYPO® PO-EO



m= 6  
n= 2-9  
R= C<sub>16-18</sub>

## FOAM CONTROL IN SOFT WATER

Foam formation is a well known problem, especially with low levels of water hardness. The addition of short alkyl chain AKYPO® LF allows to decrease foaming under soft water conditions.



The foaming behavior of a 5% metalworking fluid emulsion was tested at < 90 ppm (5 °dH) with a Krüss DFA100 Dynamic Foam Analyzer. The formulations included 2% AKYPO®.

AKYPO® LF 4 shows the most limited foam formation tendency combined with the fastest foam collapse rate, specifically when used in combination with AKYPO® RO 90 VG.

We recommend using the combination of both products to increase the fluid's longevity. To simplify the formulation process, we offer AKYPO® TEC AM VG, a blend of AKYPO® RO 90 VG and LF 4.

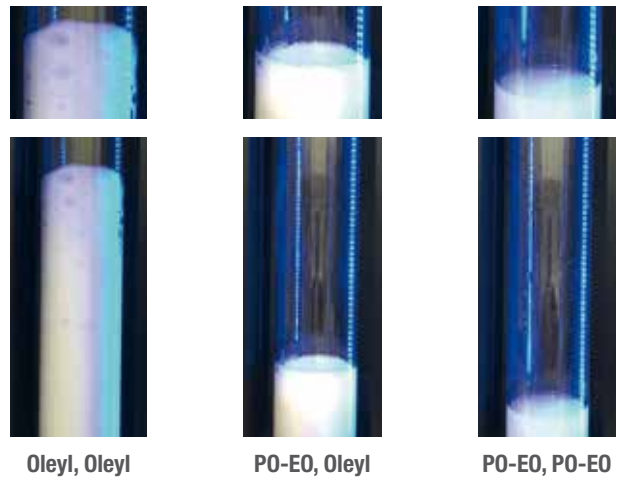


## ENHANCED FOAM CONTROL WITH MODERATE WATER HARDNESS

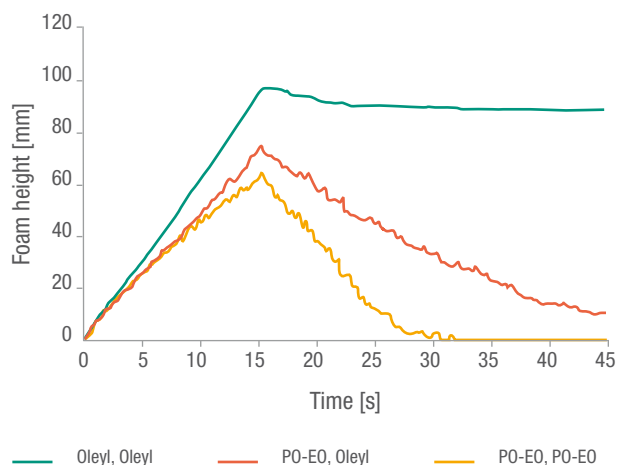
Emulsifiers based on saturated fatty alcohols, instead of unsaturated oleyl alcohol, and additionally modified by the insertion of a propylene oxide building block (PO) between the hydrophobic tail and the hydrophilic head are emulsifier with significantly reduced foam stability. These PO-EO emulsifiers represents an ideal combination of emulsification power and low foaming characteristics. Accordingly they offer formulators a powerful alternative to standard emulsifier chemistries.

The best foam control in combination with hard water stability is achieved through synergistic effects when the nonionic and anionic PO-EO (co-)emulsifiers are used together. Exemplarily this superior foam control performance is shown by modifying the emulsifier chemistry of a commercial formulation.

FORMULATION	NONIONIC (3%)	ANIONIC (2%)
Oleyl, Oleyl	Cetyl/Oleyl alcohol ethoxylate (5 EO)	AKYPO® RO 90 VG
PO-EO, Oleyl	AKYPO® ROX RS-0606N	AKYPO® RO 90 VG
PO-EO, PO-EO	AKYPO® ROX RS-0606N	AKYPO® RSPE 66



The images above show how fluid appears after exposure to 15 seconds of severe foam formation conditions followed by 15 seconds of foam collapse. The foaming behavior of a 5% metalworking fluid emulsion was tested at 200 ppm (11°dH) with a Krüss DFA100 Dynamic Foam Analyzer.



# CORROSION INHIBITION

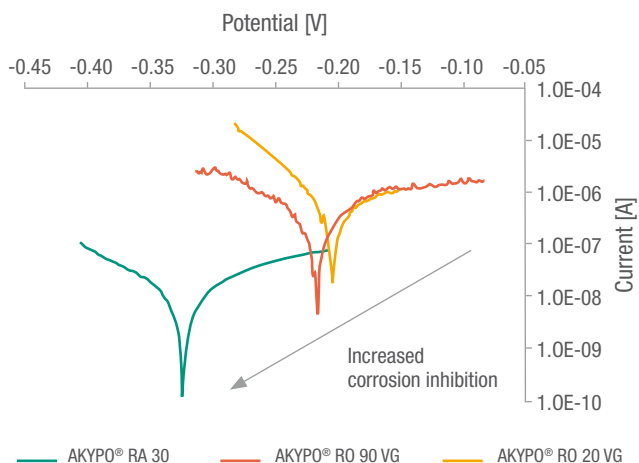
## AKYPO® SUPPORTS ANTI-CORROSIVE PROPERTIES

As ether carboxylic acid products AKYPOs® are multi-functional. AKYPO® RO 20 VG, with its low degree of ethoxylation, in particular supports anti-corrosion properties when used in combination with common corrosion inhibitors such as fatty acid alkanol amines.

## PROTECTING IRON

Since corrosion is an electrochemical issue, electrochemical test methods provide a powerful alternative to chip/filter paper tests. Linear sweep voltammetry (LSV) measurements allow direct, quantitative determination of corrosion rates by measuring corrosion currents. The formation of a hydrophobic layer on the metal surface inhibits corrosion reactions and is reflected in a decreased corrosion current. Due to its amide functionality, AKYPO® RA shows the best corrosion inhibition on steel. This is depicted in the LSV analysis of steel (St 37-2), which ranks the various AKYPOs® as follows:

**AKYPO® RO 90 VG < AKYPO® RO 20 VG << AKYPO® RA 30**

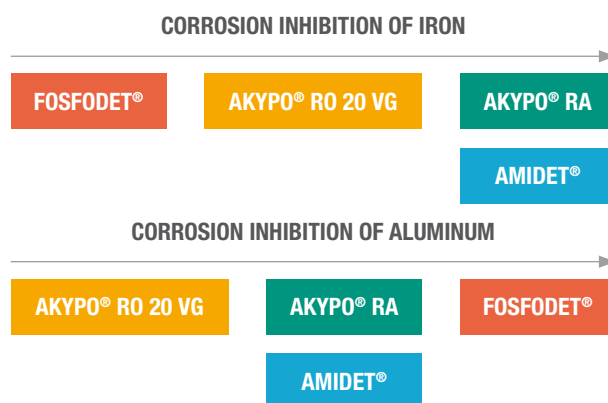


## PROTECTING LIGHT METALS

When it comes to staining, aluminum alloys present a different challenge in comparison with steel and other ferrous metals. Phosphorus chemicals such as alkylphosphonic acids or ethoxylated phosphate esters protect aluminum against corrosion but exhibit certain disadvantages for metalworking applications. This includes having limited hard water tolerance and a tendency to foam. Our newly developed FOSFODET® solutions overcome these disadvantages. These products combine an excellent light metal inhibition with significant low foaming characteristics and reasonable hard water tolerance.

## SELECTING THE IDEAL ANTI-CORROSION ADDITIVE

This summary of the Kao Metalworking Toolbox's anti-corrosive properties provides guidance for selecting the best product to achieve the optimal level of corrosion control that can be provided by a given metalworking formulation.





# SURFACTANT PROPERTIES

## EMULSIFIER EFFICIENCY

Hydrophilic-lipophilic balance (HLB) indicates emulsifier efficiency and is a concept that is often applied to formulations. Lipophilic products with low HLB values stabilize fluid concentrates, while hydrophilic products with increased HLB values are designed to stabilize the fluid emulsion. If desired, customers can also combine our products to achieve exceptional stability while dealing with a wide range of conditions.



The synergistic effects of AKYPO® ROX emulsifiers and AKYPO® PO-EO in particular improve lubricity and foam control properties, thanks to the polypropylene oxide building block placed between the alkyl and polyethylene oxide chain.

## WETTABILITY

Emulsifiers with low contact angles and surface tensions have the best wettability. Good wetting properties facilitate quick adhesion of performance additives to the metal surface, thus enabling improved lubricity and corrosion control in metal treatment. Solubilizing AKYPO® LF products, especially AKYPO® LF 4, are wettability modifiers. AKYPO® LF can strongly adjust drip off behavior, support washing and rinsing, and improve the removal of metal chips and fluid residues on metal. That makes AKYPO® LF an excellent additive also for metal cleaning applications.

	HLB LUMIFuge® (in-house method)	CONTACT ANGLE on steel (DC048) 0.1% in 1% NaOH	SURFACE TENSION [mN/m] 0.1% in 1% NaOH (static ring)	SOLUBILITY IN WATER neutralized	CLOUD POINT [°C] Hoffmann 5g in 25g BDG
<b>NONIONIC</b>					
<b>AMIDET®</b>					
AMIDET® TEC N	9	28.3	29.4	n.s.	57
AMIDET® TEC-111	9	33.1	29.9	n.s.	> 95
<b>AKYPO® ROX</b>					
AKYPO® ROX RS-0602N	4.5	n.s.	n.s.	n.s.	37
AKYPO® ROX RS-0606N	8	45.5	33.2	n.s.	59
AKYPO® ROX RC-0960N	11	38.8	31.8	s	68
<b>ANIONIC</b>					
<b>AKYPO® RLM/RO</b>					
AKYPO® RLM 25	5.5	29.1	28.3	n.s.	36
AKYPO® RO 20 VG	5	49.2	24.4	n.s.	34
<b>AKYPO® RO</b>					
AKYPO® RO 50 VG	9	46.9	30.7	s	56
AKYPO® RO 90 VG	11	55.6	35.2	s	68
AKYPO® RCO 105	11	50.6	35.3	s	72
<b>AKYPO® PO-EO</b>					
AKYPO® RS-0602	5	44.5	32.9	n.s.	30
AKYPO® RSPE 66	9	47.6	34.3	s	52
AKYPO® RC-0960	10	50.5	32.8	s	62
<b>AKYPO® LF</b>					
AKYPO® LF 1	11 - 14	53.5	34.8	s	54
AKYPO® LF 2	13 - 16	57.4	36.7	s	67
AKYPO® LF 4	12 - 15	65.7	45.3	s	63
AKYPO® LF 6	14 - 15	66.6	42.3	s	57
<b>AKYPO® Blends</b>					
AKYPO® TEC AM VG	n.a.	52.0	35.5	s	64
<b>AKYPO® RA</b>					
AKYPO® RA 30	9	44.3	32.6	s	52
AKYPO® RA 50	13	55.5	35.1	s	62
<b>FOSFODET®</b>					
FOSFODET® RS-0602	3	48.2	34.4	n.s.	58
FOSFODET® RS-0606	7	48.8	34.5	n.s.	63
FOSFODET® RC-0960	10	54.4	33.3	s	79

n.a. = not applicable; n.s. = not soluble; s = soluble

# TECHNICAL EXPERTISE

## EVALUATING QUALITY AND PERFORMANCE

In addition to standard chemical wet analyses, our company's analytical department uses various chromatographic methods, including HPLC, GPC, and GC-MS as well as spectroscopic measurements such as FTIR and UV-VIS. Our metalworking competence center in Emmerich, Germany, carries out the following tests for developing and improving our metalworking additive portfolio:

### FOAMING

- CNOMO foam test D655212.
- Blender test Waring® Xtreme.
- Krüss DFA100 Dynamic Foam Analyzer.
- Shaking cylinder test.
- Aquarium stone test (in-house method).

### EMULSION AND EMULSION STABILITY

- LUMIFuge®
- Dynamic light scattering, zeta potential.
- Hach Lange transmission.
- Electrolyte scan (in-house method).
- Stability of metalworking fluid in hard water (DIN 51367/8).
- Temperature stability test.

### CORROSION

- Chip/filter paper method (DIN 51360-2).
- Light metal test, immersion test.

### LUBRICATION

- Rheometer Anton Paar MCR 302 Tribocell.
- Tapping Torque Microtap Megatap II.
- Mahr Surf SD26 roughness measurement.
- Hund WETZLAR T100 microscope.

### BASIC SURFACTANT AND EMULSIFIER TESTS

- Krüss K100 Force Tensiometer (static surface tension, CMC, contact angle).
- Bubble pressure tensiometer (dynamic surface tension).
- Lime soap dispersing power (DIN 53903-1).
- Phase inversion temperature.



# FORMULATION GUIDE

## COLLABORATIVE INNOVATION

Kao Chemicals Europe is more than just a metalworking additive supplier! Our desire is to provide the very best in support and joint development to formulate excellent innovative metalworking fluids. We draw on decades of experience and our comprehensive technical expertise to develop multifunctional products that add value to our customer's metalworking fluids.

Our metalworking formulations range from classic boric acid based formulations to modern boron free semi synthetic fluids.

### CLASSIC METALWORKING FLUID FORMULATION

EXCELLENT HARD WATER STABILITY	% w/w
Mineral oil	49.1
Deionized water	5.5
Triethanolamine	18.4
Monoethanolamine	3.6
Boric acid	4.9
Tall oil fatty acid	4.3
Butyldiglycol	3.6
Cetly/Oleyl alcohol ethoxylate (2 E0)	5.0
Cetly/Oleyl alcohol ethoxylate (5 E0)	3.7
AKYPO® RO 90 VG	2.0

LOW FOAM AND HIGH HARD WATER STABILITY	% w/w
Mineral oil	49.1
Deionized water	5.5
Triethanolamine	18.4
Monoethanolamine	3.6
Boric acid	4.9
Tall oil fatty acid	4.3
Butyldiglycol	3.6
AKYPO® ROX RS-0606N	8.5
AKYPO® RSPE 66	2.0

## GUIDELINE FORMULATIONS

All companies that prepare metalworking fluids rely on their own know-how to develop their own formulations. The guidelines provided here are intended to serve as examples for various kinds of metalworking fluids that would benefit from the addition of AKYPO® and AKYPO® ROX. These formulations provide a framework for reformulation or as a starting point for new formulations. All formulations use an emulsifier package consisting of fatty alcohol ethoxylates (for example, AKYPO® ROX) and AKYPO®. The various combinations will provide you with an idea on how to achieve the ideal formulation for specific performance requirements (extreme hard water stability, low foam, boron free, etc.).

### BORON FREE FORMULATIONS

SOLUBLE OIL (BORON FREE)	% w/w
Deionized water	1.0
Amino alcohol Triethanolamine, monoethanolamine, other standards used in metalworking	4.6-5.3
Mineral oil	74.6-77.5
Tall oil fatty acid	9,5
Butoxypropanol	2.4-2.8
AKYPO® ROX PO-E0 Fatty alcohol alkoxyates	3.3-4.5
AKYPO® RO or AKYPO® PO-E0	1.7-2.3

SOLUBLE OIL (BORON FREE)	% w/w
Deionized water	43.8
Amino alcohol Triethanolamine, monoethanolamine, other standards used in metalworking	7.4
Mineral oil	21.1
Tall oil fatty acid	4.2
Butoxypropanol	3.2
AKYPO® ROX RS-0606N	12.1
AKYPO® RSPE 66	2.6
Dodecanedioic acid	3.2
Oleyl alcohol ethoxylated phosphate ester	2.5

The information in this document has been prepared on the basis of our current experience and knowledge, and every effort has been made to ensure this information is reliable. Statements and suggestions regarding possible fields of application or formulations for specific end products are derived from our experience and testing results with these products. The users of our products must carry out their own tests to determine the applicability and/or suitability of our products for any intended purpose. The user is responsible for ensuring that any proprietary rights and existing laws are observed; the publisher may not be held liable for any infringement on existing patents on the grounds of the information provided above.

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in harmony with nature.

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**OUR CHEMICALS, YOUR BUSINESS**

**kao**