CORRGUARD® LCS

Specialty Metalworking Fluid Additive for Improved Corrosion Control and Aluminum Staining Performance

ANGUS offers a variety of specialty additives marketed under CORRGUARD® brand name for use in water-dilutable metalworking fluids. With decades of formulating expertise and cutting-edge technology, we provide additive solutions to improve overall performance and fluid life. CORRGUARD LCS is a primary amino alcohol (TRIS AMINO™, 2-amino-2-hydroxymethyl-1,3-propanediol) with high water solubility and low toxicity. CORRGUARD LCS provides exceptional benefits of corrosion control, is compatible with aluminum alloys and provides excellent pH stability. CORRGUARD LCS is the new additive that formulators can rely on to help reduce or eliminate metal staining of aluminum workpieces, while providing a stable pH during machining.

Suitable fatty acids and amines

Water-dilutable metalworking fluids include soluble oils, semi-synthetic fluids and synthetic fluids and are indispensable for metal cutting, forming, grinding, rolling, etc. Formulators are constantly searching for fluids and additives that are multi-metal compatible. Typically, fluids contain a variety of functional additives, such as biocides, emulsifiers, corrosion inhibitors, pH boosters, extreme pressure agents, lubricity additives and many others. As the auto and aerospace industries move toward more advanced materials to achieve improved fuel economy, the demand of lightweight aluminum alloys is significantly increasing. However, traditional metalworking fluids tend to severely stain metals if the pH is high, above 9, especially for aluminum alloys. Metalworking fluid formulators target the pH of fluids between 8.5-8.8 for aluminum alloys to minimize the staining (Canter, N. Tribology and Lubrication Technology, 68(9), 11-22, 2012).

Fatty acids and their derivatives, such as salts, esters and amides are commonly used in metalworking fluids. They provide corrosion inhibition towards metals, improve emulsion stability and enhance lubricity. In an earlier patent by ANGUS US 8,168,575, aqueous metalworking fluids comprised of C_{12-20} fatty acids (linear/branched/cyclic, saturated/unsaturated, or mixture) and neutralizing agents (amine, alkanolamine or caustic) inhibit the corrosion on ferrous metals, as well as the staining of aluminum or other non-ferrous metals. ANGUS extended the study to TRIS AMINO™ (TA), triethanolamine (TEA) and other amino alcohols. Metalworking fluids comprised of TA-neutralized fatty acids provide excellent corrosion control and aluminum alloy compatibility.
In general, the pH of aqueous metalworking fluids is higher than 7. The acidic components are neutralized by the basic components such as amines, alkanolamines, caustic or their mixtures in the fluids. The molar ratio of neutralizing groups to carboxyl groups can vary greatly, with the basic components typically present in excess to build pH. Any fatty acid that is compatible with other components and of the general formula \(\text{CH}_3(\text{CH}_2)_n(\text{COOH})_n\) can be used in practice. The structure can be linear, branched or cyclic with mono-, di-, tri- or other polycarboxyl groups. Both saturated and unsaturated fatty acids can be used. The suitable fatty acids include, inclusive of those listed in our earlier patent US 8,168,575, in particular:

- 2-Ethylhexanoic acid (2-ethylcaproic acid)
- Octanoic acid (caprylic acid)
- Decanoic acid (capric acid)
- Neodecanoic acid
- Lauric acid
- Myristic acid
- Palmitic acid
- 2-Hexyldecanoic acid
- Stearic acid
- Isostearic acid
- Oleic acid
- Linoleic acid
- Linolenic acid
- Arachidonic acid
- Ricinoleic acid
- 2-Cyclohexene-1-octanoic acid
- 5-Carboxy-4-hexyloctanoic acid
- Chaulmoogric acid
- cis-11-Eicosenoic acid
- Phytanic acid
- Pristanic acid
- 4,8,12-Trimethyltridecanoic acid
- Tall oil fatty acid
- Coconut fatty acid
- Sebacic acid
- Dodecanedioic acid
- 5(or 6)-Carboxy-4-hexyl-2-cyclohexene-1-octanoic acid
- Citric acid
- Lactic acid
- And mixtures thereof

The neutralizers can be primary, secondary and tertiary amines and alkanolamines. Diamines, cyclic amines and caustics can also be used. The suitable neutralizers include, inclusive of those listed in our earlier patent US 8,168,575, in particular:

- Monoethanolamine (MEA)
- Diethanolamine (DEA)
- Triethanolamine (TEA)
- Monoisopropanolamine (MIPA)
- Diisopropanolamine (DIPA)
- Trisopropylamine (TIPA)
- 2-(2-Aminoethoxy)ethanol (AEE, or DGA)
- N-Butylethanolamine (BEA)
- N-Butyldiethanolamine (NBDEA)
- Dicyclohexylamine (DCHA)
- 2-Amino-2-methyl-1-propanol (AMP)
- Monomethyl 2-Amino-2-methyl-1-propanol (MMAMP)
- Dimethyl 2-Amino-2-methyl-1-propanol (DMAMP)
- 2-Amino-1-butanol (2-AB)
- 3-Amino-4-octanol (3A4O, or CORRGUARD EXT)
- 2-Amino-2-methyl-1,3-propanediol (AMPD)
- Dimethyl 2-amino-2-methyl-1,3-propanediol (DMAMPD)
- 2-Amino-2-ethyl-1,3-propanediol (AEPD)
- Dimethyl 2-amino-2-ethyl-1,3-propanediol (DMAEPD)
- Tris(hydroxymethyl)aminomethane (TRIS AMINO, TA)
- Tris(hydroxymethyl)dimethylaminoethane (DMTA)
- Lithium hydroxide (LiOH)
- Sodium hydroxide (NaOH)
- Potassium hydroxide (KOH)
- Caustic alcohol (e.g., C_2H_5OH)
- Caustic carbonates (e.g., K_2CO_3)
- Caustic phosphates (e.g., Na_3PO_4)
- And mixtures thereof

Biocides can be formulated in the concentrate or added into the diluted fluid tankside. With increasing concern over environment, health and safety, formulators are moving away from formaldehyde-condensed biocides such as triazines, morpholines and oxazolidines, especially in countries with more stringent regulatory requirements. Non-formaldehyde-release biocides include isothiazolinones, phenolics, pyrithiones, carbamates, etc. Nevertheless, the benefit of TA is applicable to MWFs with different biocides. The suitable biocides include, inclusive of those listed in our earlier patent US 8,168,575, in particular:

- 2,2',2''-(Hexahydro-1,3,5-triazine-1,3,5-triyl)triethanol (Triazine)
- N,N'-Methylenebismorpholine (MBM)
- 3,3'-Methylenebis(5-methyloxazolidine) (MBO)
- 1-(3-chloroallyl)-3,5,7-triaza-1-azoniadamanate chloride (CTAC)
- (Ethylenedioxymethyl)dimethanol (EDDM)
- 1,2-Benzisothiazolin-3-one (BIT)
- 2-Methyl-2H-isothiazol-3-one (MIT)
- 2-Octyl-2H-isothiazol-3-one (OIT)
- N-Butyl-1,2-benzisothiazoline-3-one (BBIT)
- Mixture of CMIT/MIT
- 2-Phenoxyethanol
- Biphenyl-2-ol
- Sodium 2-biphenylate
- Potassium 2-biphenylate
- Sodium pyrithione
- 3-Iodo-2-propynyl-n-butylcarbamate (IPBC)
- 2,2-Dibromo-2-cyanoacetamide (DBNPA)
- And mixture thereof

**Lower corrosion on ferrous metals**

In the corrosion control study of cast iron chips, TA-neutralized fatty acids showed superior performance over TEA-neutralized ones. Examples of fatty acids such as 2-ethylhexanoic acid, neodecanoic acid and oleic acid are shown in Figure 1 and 2. In the case of neodecanoic acid, TA-neutralized fluid showed excellent corrosion control, while TEA-neutralized one lost corrosion control completely.

**Figure 1** Cast iron chips corrosion control result of amine-neutralized fatty acids

![Cast iron chips corrosion control](image1)

**Less aluminum staining**

Aluminum alloys are prone to turn blackish during mechanical processing due to corrosion. Harsh alkalinity tends to result in a more severe corrosion on the surface of aluminum. Using same amount of neutralizer, the pH of TA-neutralized fatty acid solution is higher than TEA-neutralized ones, resulting from the lower molecular weight and higher pKₐ value of TA (Table 1). TA-neutralized fatty acid solutions demonstrate better aluminum compatibility with much less severe staining towards aluminum alloys, albeit of a higher pH. Examples of aluminum alloy staining result – ADC12, A1050, A6061 and A7075 are shown in Figure 3, 4, 5 and 6, respectively.

**Table 1** pH of amine-neutralized fatty acids at 23°C

<table>
<thead>
<tr>
<th></th>
<th>2-Ethylhexanoic acid</th>
<th>Neodecanoic acid</th>
<th>Oleic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA</td>
<td>8.60</td>
<td>8.70</td>
<td>9.88</td>
</tr>
<tr>
<td>TEA</td>
<td>8.60</td>
<td>8.25</td>
<td>9.57</td>
</tr>
</tbody>
</table>

*Aqueous solution of fatty acid (2,000ppm) and amine (6,000ppm).*
Figure 3  Aluminum alloy ADC12 staining result of amine-neutralized fatty acids

<table>
<thead>
<tr>
<th>2-Ethylhexanoic acid</th>
<th>Neodecanoic acid</th>
<th>Oleic acid</th>
<th>Unexposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Aluminum coupons were half-immersed in the fluids at 40°C for 2 hours.

Figure 4  Aluminum alloy A1050 staining result of amine-neutralized fatty acids

<table>
<thead>
<tr>
<th>2-Ethylhexanoic acid</th>
<th>Neodecanoic acid</th>
<th>Oleic acid</th>
<th>Unexposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Aluminum coupons were half-immersed in the fluids at 40°C for 2 hours.

Figure 5  Aluminum alloy A6061 staining result of amine-neutralized fatty acids

<table>
<thead>
<tr>
<th>2-Ethylhexanoic acid</th>
<th>Neodecanoic acid</th>
<th>Oleic acid</th>
<th>Unexposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Aluminum coupons were half-immersed in the fluids at 40°C for 2 hours.

Figure 6  Aluminum alloy A7075 staining result of amine-neutralized fatty acids

<table>
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<tr>
<th>2-Ethylhexanoic acid</th>
<th>Neodecanoic acid</th>
<th>Oleic acid</th>
<th>Unexposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Aluminum coupons were half-immersed in the fluids at 40°C for 2 hours.
**Improved pH stability**

TEA is known to be prone to degradation and release ammonia into the environment. It will become yellowish and darker during storage. TA is more resistant to oxidative degradation than TEA because there is no hydrogen on the carbon for elimination in TA. The higher stability, and resulting lower oxidative losses, provides a more stable pH as compared to TEA. Thus, Metalworking fluids comprised of TA will often have a longer fluid life. Example of 1% aqueous solutions of TA and TEA are shown in Figure 7. The solutions were pumped with air at a flow rate around 45 liters per hour and their pH values were recorded. Due to its higher basicity, the solution of TA developed a slightly higher pH initially. The pH of TA solution dropped slightly slower than TEA, and provides a better buffering upon the continuous exposure to the air.

**Figure 7** pH stability of 1% amine in aqueous solution

![pH Stability](image)

* Aqueous solution of amine (10,000ppm)

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**Product Stewardship**

ANGUS encourages its customers to review their applications of ANGUS products from the standpoint of human health and environmental quality. To help ensure that ANGUS products are not used in ways for which they are not intended, ANGUS personnel will assist customers in dealing with environmental and product safety considerations. For assistance, product Safety Data Sheets, or other information, please contact your ANGUS representative at the numbers provided in this document. When considering the use of any ANGUS product in a particular application, review the latest Safety Data Sheet to ensure that the intended use is within the scope of approved uses and can be accomplished safely. Before handling any of the products, obtain available product safety information including the Safety Data Sheet(s) and take the necessary steps to ensure safety of use.