**CORRGUARD®-95**

High Performance Amino Alcohol for Metalworking Fluids

Today’s metalworking-fluid formulators require raw materials that are easy and relatively safe to handle, provide multi-functional benefits and are of consistent high quality. CORRGUARD®-95 (2-amino-2-methyl-1-propanol with 5% water), a primary amino alcohol that has been used successfully in metalworking fluids for many years, possesses these attributes. CORRGUARD-95 corrosion inhibitor is a strong base with low molecular weight, and is a very efficient neutralizer of acidic ingredients such as carboxylic acids and phosphate esters.

The benefits of the unique chemical and physical properties of CORRGUARD-95 include:

- Cost efficient alkaline pH development and neutralization of acidic components
- Reduced microbial degradation
- Stable emulsions at high pH
- Enhanced performance of triazine biocides
- Minimal ammonia release
- Minimizes leaching of cobalt

**Key Performance Advantages**

- Extends fluid life
- Minimizes leaching of cobalt
- Cost effective
Typical Properties

The following are typical properties of CORRGUARD-95. They are not to be considered product specifications.

### Key Benefits

**Cost Efficient Alkaline pH Development**

Development and maintenance of alkaline fluid pH is an important factor in determining fluid performance and service life. Inadequate pH control can result in loss of fluid stability, corrosion of tools and parts, and increased opportunity for microbial degradation of the fluid. Proper pH control can help reduce end-user operating costs by minimizing fluid changes, waste disposal, and downtime.

CORRGUARD-95 corrosion inhibitor is the product of choice for developing and maintaining alkaline pH because it has high base strength, low molecular weight, and is less reactive with atmospheric CO₂ than other common amines. High base strength, along with low molecular weight, means less amine is needed to develop alkaline pH. CORRGUARD-95 may improve cost efficiency when used in combination with amines of lower base strengths and higher molecular weights, such as triethanolamine (TEA-99). This is particularly true with fluids formulated at pH 9 or above, where the 100-fold greater base strength of CORRGUARD-95 relative to TEA-99 is a major advantage. An example of this benefit is shown in Table 1 for a synthetic fluid. Replacement of 25 parts TEA-99 with 1.5 parts CORRGUARD-95/16 parts TEA-99 resulted in equal pH development in the diluted fluid.

### Table 1

Cost Efficient pH Development

Synthetic Fluid with CORRGUARD-95 vs. TEA-99

<table>
<thead>
<tr>
<th>Ingredients, wt %</th>
<th>TEA-99</th>
<th>CORRGUARD-95</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deionized Water</td>
<td>52.8</td>
<td>60.3</td>
</tr>
<tr>
<td>Inversely Soluble Ester [A]</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Chlorinated Fatty Acid [B]</td>
<td>9.2</td>
<td>9.2</td>
</tr>
<tr>
<td>Amine Carboxylate [C]</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Amino Alcohol</td>
<td>25.0</td>
<td>1.5/16.0</td>
</tr>
<tr>
<td>Biocide [D]</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

| pH @ 20:1 Dilution | 8.9 | 9.0 |

The low molecular weight of CORRGUARD-95 means more amine per unit weight is available for neutralizing acidic contaminants, such as byproducts of microbial growth, oxidation, etc. This is often referred to as reserve alkalinity. The relative amounts of reserve alkalinity for equal weights of CORRGUARD-95 and TEA-99 are shown in Figure 1. This shows the volume of 1N hydrochloric acid required to completely neutralize one pound (454 grams) of each amine. CORRGUARD-95 provides 60% more reserve alkalinity than TEA-99.

### Figure 1

Reserve Alkalinity

CORGUARD-95 vs. TEA-99

Amine retention and reactivity with atmospheric CO₂ in a circulating metalworking fluid system can significantly influence pH stability. Results of a 14-day aquarium study (Figures 2 & 3) reveal that CORRGUARD-95 corrosion inhibitor is well retained in a recirculating aqueous solution. In addition, CORRGUARD-95 is less reactive with atmospheric CO₂ than other strong amines, resulting in better pH stability.
Efficient Neutralization of Acidic Components

Many metalworking fluid ingredients must be neutralized to make them water soluble and to perform properly. Examples include phosphate esters, mono- and dicarboxylic acids, fatty acids, and boric acid. Neutralization efficiency is related to the combination of base strength and molecular weight of the neutralizer. Performance depends upon the types of neutralizers and acidic materials that are used.

CORRGUARD-95, with an effective molecular weight of ~95 as supplied (Active Ingredient = 89.1), is a much more efficient neutralizer than TEA-99 (molecular weight 149). ANGUS recommends use of combinations of these products to balance cost and performance.

Stable Emulsions at High pH

When formulating soluble oils, one of the main goals is achievement of a stable emulsion at the desired pH. It is often desirable to formulate emulsions at pH 9 or greater, and an amine that provides good stability at higher pH levels is required.

As shown in Table 3, it is often difficult to formulate a stable emulsion in the higher pH range with TEA-99; the soluble oil formula shown in Table 2 was used for this comparison. CORRGUARD-95 can be used alone or in combination with TEA-99 to provide stable emulsions at elevated pH.
Table 3
Stable Emulsions at Higher pH

<table>
<thead>
<tr>
<th>Amine System</th>
<th>pH</th>
<th>mL Cream @ 24 hours*</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEA-99</td>
<td>8.7</td>
<td>1/2</td>
</tr>
<tr>
<td>TEA-99</td>
<td>8.8</td>
<td>&gt;1/2</td>
</tr>
<tr>
<td>CORRGUARD-95/TEA-99</td>
<td>8.9</td>
<td>&lt;1/2</td>
</tr>
<tr>
<td>CORRGUARD-95</td>
<td>9.0</td>
<td>1/2</td>
</tr>
<tr>
<td>CORRGUARD-95</td>
<td>9.2</td>
<td>1/3</td>
</tr>
</tbody>
</table>

*on 50 mL emulsion

Resistance to Microbial Degradation

Microbial degradation of fluid components results in loss of performance and shortened fluid life. Recognizing this, metalworking fluid formulators have searched for more "bioreistant" materials from which to build their fluids.

However, the term bioreistant is often confused with the term biocidal. In order to clarify the issue, we define the term bioreistance as follows: A bioreistant material is one which, while it does not kill microorganisms, is not readily chemically decomposed by microbial attack. Simply put, a bioreistant material does not provide a ready food source for microorganisms. Under equal conditions, a fluid made from bioreistant ingredients will typically last longer than one made from biosupportive ingredients.

Several common acidic components were diluted to 5000 ppm in distilled water and neutralized to pH 9.5 with CORRGUARD-95 corrosion inhibitor or a blend of TEA-99 and KOH. These salt solutions were given a mixed inoculum of 106 Colony Forming Units (CFU)/mL bacteria and 104 CFU/mL fungi. The CORRGUARD-95 salts were all resistant to bacterial growth while the TEA salts were biosupportive as shown in Figure 5.

Figure 5
Biostability of Amine-Based Metalworking Fluid Additives*

In a similar test of four synthetic metalworking fluids without biocide, two based on TEA and two based on CORRGUARD-95, the fluids containing CORRGUARD-95 showed superior bioreistance to the TEA-based fluids. The data is shown in Figure 6.

Figure 6
Bacterial Resistance - Synthetic Metalworking Fluid

pH Stability in Microbially Contaminated Systems

The degree to which amino alcohols biodegrade in metalworking fluid formulations has an impact on the pH stability of the fluid. The more bioreistant the fluid components, the less microbial growth occurs, and hence fewer acidic byproducts are produced. In addition to its reserve alkalinity and efficient pH boosting properties, CORRGUARD-95 corrosion inhibitor, as a bioreistant amine, exhibits superior pH stability in the presence of microbial contamination. The data in Figure 7 shows pH stability of a synthetic metalworking fluid based on CORRGUARD-95 compared to that of the same fluid based on TEA/KOH. The fluids were dosed with a mixed inoculum of bacteria and fungi and then tested for pH change after 12 weeks. The results show that fluids containing CORRGUARD-95 exhibit superior pH stabilization as compared to fluids with TEA.

Figure 7
pH Stability – Synthetic Metalworking Fluids

*0.5% acid solutions neutralized to pH 9.5 and inoculated at start with mixed bacterial/fungal inoculum
Enhanced Performance of Triazine Biocides

Triazine biocide [hexahydro-1,3,5-tris(2-hydroxyethyl)-s-triazine] is an effective antibacterial agent in metalworking fluids, but does not normally control fungal growth except at very high use levels. CORRGUARD-95 has been shown to enhance the antifungal performance with triazine biocide. An example is shown in Figure 8 for the synthetic fluid formulations in Table 4. Fluid with the triazine/CORRGUARD-95 system resisted fungal growth for three weeks, while fluids containing triazine and TEA-99 or TEA/KOH failed at one week. CORRGUARD-95 is not a biocide and is not intended for use as an antimicrobial.

Figure 8
Triazine/CORRGUARD-95 Antifungal Benefits

![Graph showing weeks to fungal failure](image)

*Failure is 1000 CFU/mL

Table 4
Synthetic Fluid Formulations
(Triazine/CORRGUARD-95 Antifungal Study)

<table>
<thead>
<tr>
<th>Ingredients, wt. %</th>
<th>TEA-99</th>
<th>TEA-99/KOH</th>
<th>CORRGUARD-95</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deionized Water</td>
<td>73</td>
<td>71</td>
<td>79</td>
</tr>
<tr>
<td>Amine Carboxylate [I] 5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Inversely Soluble Ester [A]</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Amino Alcohol</td>
<td>0</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>KOH (45%)</td>
<td>–</td>
<td>2</td>
<td>–</td>
</tr>
<tr>
<td>Triazine [J]</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>pH @ 20:1 Dilution</td>
<td>8.8</td>
<td>9.6</td>
<td>9.7</td>
</tr>
</tbody>
</table>

This study also revealed fluids containing CORRGUARD-95 corrosion inhibitor that were microbially challenged released significantly less NH₃ than fluids containing ethanolamines (Figure 9). Although a small amount of NH₃ was released initially from the CORRGUARD-95 fluid, the quantity released over the 180-day test period was small compared with that released by ethanolamine-based fluids. Olin concluded that MEA, DEA, and TEA contribute to ammonia accumulation, while CORRGUARD-95 does not.

Figure 9
Ammonia Release Study

![Graph showing ammonia release over time](image)

Cobalt Leaching

Leaching of cobalt binder from cemented tungsten-carbide during the manufacturing of carbide tools introduces potential safety and environmental hazards:

- The presence of dissolved cobalt in machining fluids can create dermatitis and inhalation problems for workers handling these fluids.
- Environmental regulations may limit the discharge of heavy metals such as cobalt into waterways.

In carbide tool production, it is important to select fluid ingredients that do not leach (dissolve) cobalt from the tool material. Certain fluid components, such as amino alcohols and amine-based additives (e.g. amides and carboxylate salts), are more problematic than others.

Since amino alcohols can leach cobalt from cemented carbide, a laboratory study was conducted to compare the leaching properties of various products. A one percent solution of each amine was prepared in deionized water and the pH of each adjusted to 9.0 with acetic acid. The amine solutions were vigorously mixed for five days with carbide swarf. At the end of the test period, the fluids were filtered and the filtrates analyzed by atomic absorption for dissolved cobalt. The test results are shown in Figure 10. The solution with CORRGUARD-95 corrosion inhibitor had the least dissolved cobalt of all the amine solutions tested. In fact, CORRGUARD-95 leached only slightly more cobalt than deionized water with no amine (control). CORRGUARD-95 is therefore the amine of choice for fluids intended for carbide tool manufacturing.

Ammonia Release

Release of ammonia (NH₃) from metalworking-fluid systems can result in worker complaints and, in severe cases, evacuation and shutdown of operations.

A study by Olin Chemicals (now Lonza) showed that NH₃ release is associated with microbial degradation of triazine biocide, monoethanolamine (MEA), diethanolamine (DEA), and triethanolamine (TEA). NH₃ release occurs when fluid pH is adjusted upward, converting dissolved ammonium hydroxide (from microbial degradation) into its gaseous form.
Low Foam
Foam generation is undesirable because it results in loss of cooling and lubrication, and can create a mess in the plant. The addition of defoamers may result in concentrate stability problems and poor adhesion of coatings to finished parts.

Several types of fluid components (fatty acid soaps, non-ionic surfactants, etc.) can contribute to foaming. Studies have shown that the amine portion of various salts can significantly affect foaming potential. Test results with 0.5% solutions of amine salts at pH 9.5 are shown in Figure 11.

Figure 10
Cobalt Leaching Study

<table>
<thead>
<tr>
<th>Dissolved Cobalt (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Amine</td>
</tr>
<tr>
<td>14</td>
</tr>
</tbody>
</table>

Figure 11
Foaming Results
Cylinder Shake Test of Amine Salt Solutions

<table>
<thead>
<tr>
<th>Foam @ 5 Minutes, mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORRGUARD-95</td>
</tr>
<tr>
<td>36</td>
</tr>
</tbody>
</table>

Figure 12
Waring Blender Foam Results

Foamy salts can lead to foamy metalworking fluids. In a study of soluble oils containing tall oil fatty acid and various strong amines, the fluid with CORRGUARD-95 corrosion inhibitor generated the least foam (Figure 12). This test, using a “Waring Blender,” is very severe, simulating a high speed grinding application.
Summary

CORRGUARD-95 offers numerous benefits to metalworking fluid formulators. In cases where a particular benefit is desired, for example bioresistance or low cobalt leaching, ANGUS recommends formulating with CORRGUARD-95 exclusively. However, in many cases a balance of properties is desired. To achieve the desired cost/performance, the use of CORRGUARD-95 with weaker amines such as TEA may be preferred. Please contact your local ANGUS representative for technical assistance.

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.