CASE STUDY

Synergex™ T amine additive
as a replacement for DIPA and/or DGA in a semisynthetic metalworking fluid formulation

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Introduction

This case study was conducted to determine if Synergex™ T amine additive could be used as an effective replacement for diisopropanolamine (DIPA, CAS 110-97-4) or diglycolamine (DGA, CAS 929-06-6). Prior to developing a guide formulation, pH measurements were performed on 0.5% solutions of the four amines in deionized water.

Table 1. pH levels

Amine	pH
DIPA 85%	10.42
DGA	10.78
Synergex T	10.44
MIPA	10.91

Based on this data, the values for DIPA 85% and Synergex T are nearly identical. In addition, the values for DGA and MIPA (monoisopropanolamine, CAS 78-96-6) are similar. Therefore, Synergex T could be a suitable replacement for DIPA 85%, and MIPA could be used to replace DIPA. To understand the cost implications of these substitutions, current costs for these four amines were acquired from a toll blender of metalworking fluids in the U.S.A.

Table 2. Pricing for relatively small drum volumes in the U.S. (as of Q3 2022)

Amine	Cost/lb
DIPA 85%	$2.41
DGA	$3.05
Synergex T	$2.66
MIPA	$2.50

A formulation was developed to evaluate the performance properties that can be realized by replacing DIPA and DGA with Synergex T and MIPA. The formulations were as similar as possible to allow for a fair comparison.

Table 3. **Formulations**

Raw material	Description	Supplier	Formulation 503A	Formulation 503B	Formulation 503C
HyGold 100	100 SUS naphthenic oil	Ergon	40.0	40.0	40.0
Polartech® EA-700	Polymeric emulsifier	Afton	7.0	7.0	7.0
Altapyne® M-28B	High-rosin tall oil fatty acids	Sea-Land	2.0	2.0	2.0
TAS DL-960	Amide	ACC	4.0	4.0	4.0
Synative® AC LF-420	Nonionic emulsifier	BASF	5.0	5.0	5.0
AE-43	EO/PO alcohol	ACC	3.0	3.0	3.0
AKYPO TEC-AM	Ether carboxylate	KAO	1.5	1.5	1.5
Rhodafac® AS-010	Aluminum stain inhibitor	Solvay	1.0	1.0	1.0
Troyshield® FX40	Fungicide	Troy	1.0	1.0	1.0
DIPA 85%	—	Dow	5.0	—	—
DGA	—	Huntsman	2.0	2.0	—
Synergex T	—	Eastman	—	5.0	5.0
MIPA	—	Dow	—	—	2.0
Cola®Cor 232	Corrosion inhibitor blend	Colonial	6.0	6.0	6.0
DI water	Deionized water	—	40.0	40.0	40.0
TT50	Sodium tolyltriazole 50%	—	0.5	0.5	0.5
Triazine	Bactericide	Troy	2.0	2.0	2.0
Cost for amine portion of formulation (per pound)			$0.1815	$0.1940	$0.1833
Cost for amine portion of formulation (per gallon)			$1.49	$1.59	$1.50
Density = 8.2 lb/gal					

Figure 1. **The prototype concentrates**

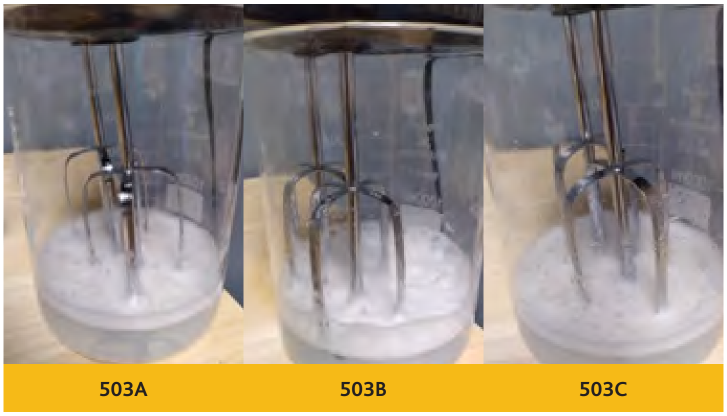
503A 503B 503C

All three samples are the same color and display the same stability in concentrate form. No defoamers were used to better differentiate between the foaming performance or gauge sample stability.

Foam testing

Foam testing was performed by preparing 200 mL of a 5% emulsion in 150 ppm water and blending in a kitchen mixer for five minutes. Although the foam is slightly more stable in 503B than in 503A, the difference is relatively small and is completely recovered in the formulation of 503C.

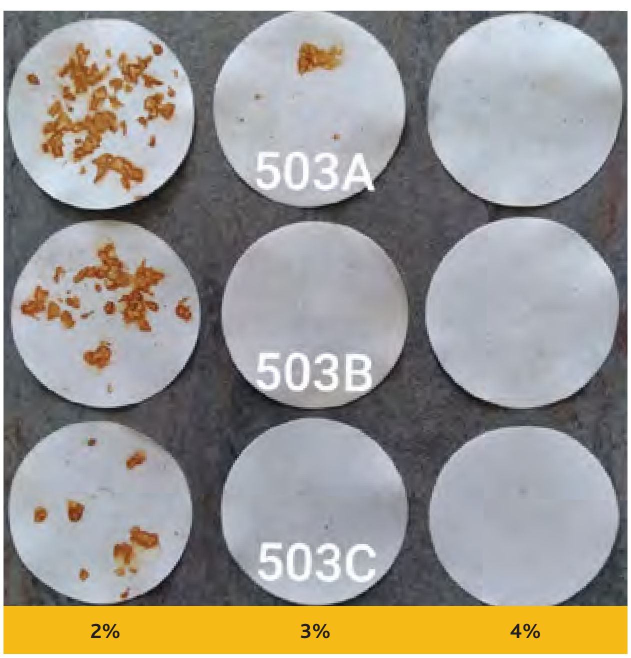
Figure 2. Samples 120 seconds after the completion of the foam testing



Cast iron chip testing

Cast iron chip corrosion testing was performed on both samples at 2%, 3%, and 4% in 200 ppm water. In the test, 2.5 grams of cast iron chips were added to a plastic Petri dish that contained a piece of filter paper. The chips were covered with the test fluid for five minutes and then drained. The Petri dishes remained covered for 24 hours and then were allowed to dry.

Figure 3. Cast iron chips after corrosion testing (top row is 503A, the middle row is 503B, and the bottom row is 503C)

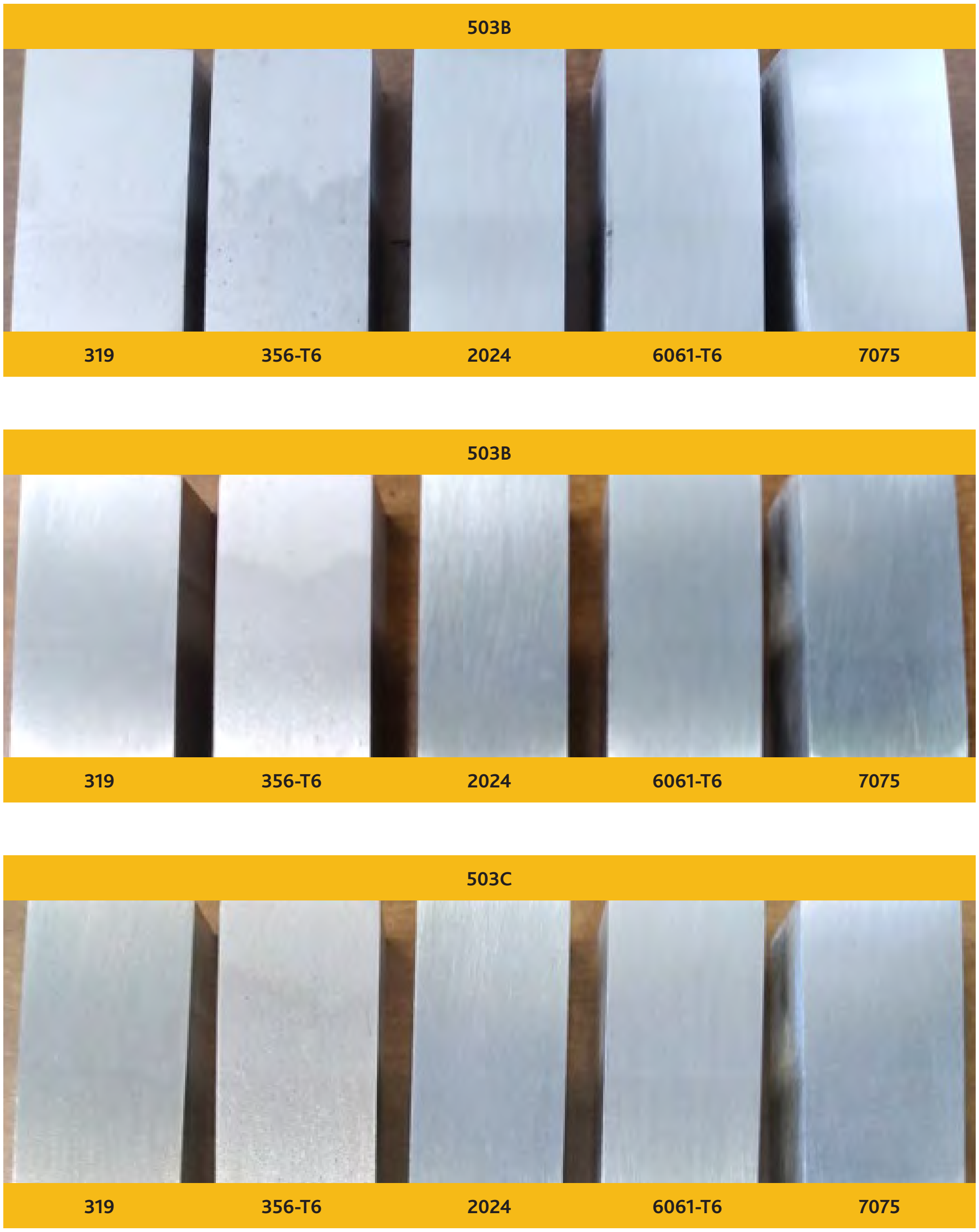


Aluminum stain testing

Aluminum stain testing was conducted by soaking five different aluminum specimens (319, 356-T6, 2024, 6061-T6, and 7075) for 24 hours in emulsions of the prototypes prepared at 5% in 150 ppm water.

There did not appear to be any significant differences in how the different amine combinations affected the amount of stain observed on the aluminum specimens. The aluminum stain profile did not get worse, even with the improvement in cast iron chip corrosion performance.

Figure 4. Aluminum specimens after stain testing



Results

The objective of this case study was to evaluate Synergex T as a replacement for DIPA and/or DGA. Based on the pH values of these amines when diluted in water, the value for Synergex T is very similar to that of DIPA but much lower than that of DGA. Therefore, the testing concentrated on the replacement of DIPA with Synergex T and not DGA. MIPA was selected to be used along with Synergex T to show how both DIPA and DGA could be effectively replaced.

The prototypes went together easily when DIPA was replaced with Synergex T and when DGA was replaced with MIPA. Therefore, a formulator should not have significant problems when using these replacements. pH readings of emulsions prepared at 5% in DI water showed that similar pH readings can also be obtained when making these changes. The foaming performance of the various prototypes varied slightly but not to a level of concern for the formulator.

Cast iron chip testing revealed that cast iron chip corrosion protection improved when making the switch from DIPA to Synergex T. More corrosion resistance was seen when DGA was replaced with MIPA.

Aluminum corrosion protection stayed constant when making the substitution from DIPA to Synergex T and again when DGA was replaced with MIPA. Even at a slightly higher emulsion pH, the two formulations were equal. Final raw material costs were also similar.

Conclusion

Given the fact that many formulators are trying to stay away from secondary amines, this data shows that Synergex T, a tertiary amine, is an effective replacement for DIPA. Synergex T also exhibits low odor and should help with biostability. To replace DGA, MIPA should be used in combination with Synergex T to produce similar pH values.

For more information on Synergex multifunctional amine additives, visit **eastman.com/Synergex** or contact your Eastman representative or your authorized Eastman distributor.

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