ACUMER® 3100 Terpolymer
For Control of Boiler Sludge

All boilers, regardless of pressure, need the highest quality water treatment program available. Even low-pressure boilers, which should have less stringent treatment requirements, frequently face inferior water quality, inadvertent higher cycles of concentration, unpredicted load swings and, occasionally, insufficient attention to the unit. High-quality treatment programs demand the best dispersant available – ACUMER 3100 terpolymer.

ACUMER 3100 water treatment terpolymer controls boiler deposits by keeping in suspension more of the harmful foulants that can accumulate in boiler tubes. This highly effective proprietary terpolymer controls both dried iron oxide and the more prevalent and difficult to control hydrated iron oxide in condensate return and well water. The unique features of ACUMER 3100 terpolymer and the corresponding benefits they provide in boiler service are presented below.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Your Benefit</th>
<th>Your Customer's Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior inorganic particulate dispersant,</td>
<td>Helps keep surfaces clean for maximum heat transfer and corrosion resistance</td>
<td>Reduced downtime, lower fuel and maintenance costs.</td>
</tr>
<tr>
<td>especially for iron oxide and hydroxyapatite.</td>
<td>through effective boiler sludge control.</td>
<td></td>
</tr>
<tr>
<td>Thermally and chemically stable.</td>
<td>Can be used over a broad range of temperature, pressure and pH.</td>
<td>Single program for all pressure range boilers.</td>
</tr>
<tr>
<td>Readily analyzed at use concentrations.</td>
<td>Easily monitored. Allows close dosage control.</td>
<td>Optimal economic dosage readily maintained.</td>
</tr>
</tbody>
</table>

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PHYSICAL PROPERTIES

The typical physical properties of ACUMER 3100 terpolymer are listed in Table 1.

<table>
<thead>
<tr>
<th>TYPICAL PHYSICAL PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>(These do not constitute specifications)</td>
</tr>
<tr>
<td>Total Solids, percent</td>
</tr>
<tr>
<td>Active Solids, percent</td>
</tr>
<tr>
<td>Molecular Weight</td>
</tr>
<tr>
<td>Brookfield Viscosity, cps.</td>
</tr>
<tr>
<td>Specific Gravity</td>
</tr>
<tr>
<td>Bulk Density, lbs./gal. (g/cc)</td>
</tr>
<tr>
<td>pH</td>
</tr>
<tr>
<td>Lbs (Kg) of NaOH (100%) to neutralize</td>
</tr>
<tr>
<td>1 lb (kg) of ACUMER 3100</td>
</tr>
</tbody>
</table>

CHEMISTRY AND MECHANISM OF ACTION

ACUMER 3100 terpolymer contains three functional groups: strong acid (sulfonate), weak acid (carboxylate), and a nonionic that provide optimal dispersancy for most particulates under a broad range of operating conditions.

Among the three functionalities, ACUMER 3100 carboxylate groups are most strongly attracted to particle surfaces, allowing strong dispersant adsorption to boiler sludge. ACUMER 3100 sulfonate groups are only weakly attracted to the particle surface and retain some residual negative charge to provide repulsion of similarly charged particles in the boiler circuit. This repulsion prevents sludge particles from aggregating into larger particles which can settle and deposit on tube surfaces. ACUMER 3100 nonionic groups provide both stronger adsorption and steric repulsion to other particles, depending on the exact boiler conditions encountered.

This multi-functional action contrasts sharply to other dispersants, such as polyacrylic acid (PAA) or polymethacrylic acid (PMAA), having only carboxylate functionality which can become strongly attached to certain sludge particles, leaving little residual negative charge available to provide dispersancy. Other polymers, such as those containing both sulfonated styrene and maleic acid (SSMA), can provide better dispersancy than PAA or PMA on some particle substrates, but do not have the nonionic group which allows ACUMER 3100 terpolymer to function on a broader range of particles.

PERFORMANCE RESULTS

Bench-Top Dispersancy Studies

Extensive testing of ACUMER 3100 terpolymer has shown that it provides unsurpassed control of boiler sludge. The polymer makes it possible to easily transport iron with calcium- and phosphate-containing sludges for removal during blowdown. The excellent performance of ACUMER 3100 terpolymer for dispersing iron oxide is shown in Figure 1. Acumer 3100 terpolymer outperforms SSMA, phosphinocarboxylic acid, acrylic acid/acrylamide and methacrylic acid polymers. Table 2 contains additional data on the superior performance of ACUMER 3100 for dispersing hydroxyapatite, calcium carbonate and iron hydroxide (hydrated iron oxide).
Test Conditions:
Polymer (active) = 3 ppm  \( \text{Fe}_2\text{O}_3 \) - 700 ppm
Settling Time = 4 hours  \( \text{Ca}^{\text{+2}} \) as \( \text{CaCO}_3 \) = 200 ppm

**TABLE 2.**
POLYMER PERFORMANCE FOR DISPERSING BOILER SLUDGE*

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Hydroxyapatite</th>
<th>Calcium Carbonate</th>
<th>Hydrated Iron Oxide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acumer 3100</td>
<td>65</td>
<td>104</td>
<td>20</td>
</tr>
<tr>
<td>Polyacrylic Acid</td>
<td>40</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Polymethacrylic Acid</td>
<td>25</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>Phosphinocarboxylic Acid</td>
<td>27</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Acrylic Acid/Acrylamide Copolymer</td>
<td>22</td>
<td>18</td>
<td>13</td>
</tr>
</tbody>
</table>

* These tests compared to 10-15 ppm active polymer at pH11 in 200 ppm \( \text{Ca}^{\text{+2}} \) as \( \text{CaCO}_3 \) and used 700 ppm hydroxyapatite, 700 ppm calcium carbonate or 10 ppm \( \text{Fe(OH)}_3 \) as \( \text{Fe}^{\text{+3}} \). Settling time is 1 hour.

**Thermal And Hydrolytic Stability**

ACUMER 3100 terpolymer is highly resistant to breakdown in aqueous solution under conditions of high temperature, pressure, and pH. Hydrothermal stability studies of ACUMER 3100 terpolymer in synthetic boiler water show no significant breakdown at 250°C/490°F (600 psig or 42 kg/cm²). However, considerable breakdown of the polymer does occur at 300°C/570°F (1200 psig or 84 kg/cm²) and, thus, is not recommended for boiler pressure above 900 psig or 63 kg/cm² (280°C/530°F).

In contrast, thermogravimetric analysis of ACUMER 3100 terpolymer, as the sodium salt, shows that the onset of degradation does not occur until about 370°C (698°F). Please note that thermogravimetric analysis (TGA) may not simulate boiler conditions and this result is only provided for comparison to other boiler chemicals evaluated by TGA.

Samples of ACUMER 3100 terpolymer stored at pH 13.5 show no loss in performance even after storage for six months at ambient temperature.
FORMULATING PHOSPHATE-BASED PROGRAMS

Calcium phosphate’s extremely low solubility product enables phosphate added to boiler water to efficiently precipitate calcium as calcium phosphate while preventing problem precipitates (calcium silicate, calcium carbonate, and calcium sulfate). With proper boiler water alkalinity and phosphate concentration, the preferred hydroxyapatite precipitate can be formed and subsequently dispersed by ACUMER 3100 terpolymer and removed during blowdown. Since phosphate can also precipitate magnesium (an adherent sludge), control of the boiler water chemistry ensures that it precipitates as the more easily conditioned magnesium silicate or magnesium hydroxide.

The type of phosphate used generally depends on the feed point within the boiler system and the alkalinity of the boiler water. If the product is fed directly to the steam drum, orthophosphate is preferred. If the phosphate is added to the feedwater, a polyphosphate is preferred to avoid precipitation reactions from occurring in the feedwater line.

The formulations listed in Table 3 are for phosphate-based boiler water treatment programs based on SHMP (sodium hexametaphosphate); as indicated in the foregoing discussion, they should be added to the feedwater line. These formulations are not intended for commercial use “as is” but rather should be considered starting-point formulations, requiring additional development, modification, and adaptation to specific operating conditions.

<table>
<thead>
<tr>
<th>TABLE 3</th>
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</thead>
<tbody>
<tr>
<td>STARTING-POINT FORMULATIONS FOR THE CONTROL OF BOILER SLUDGE DEPOSITS BASED ON ACUMER 3100 TERPOLYMER</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>BW-87-1</th>
<th>BW-87-2</th>
<th>BW-87-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deionized Water</td>
<td>82.49</td>
<td>77.29</td>
<td>72.69</td>
</tr>
<tr>
<td>Ucon 50 HB 5100&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>ACUMER 3100&lt;sup&gt;2&lt;/sup&gt;</td>
<td>7.50</td>
<td>7.50</td>
<td>7.50</td>
</tr>
<tr>
<td>Sodium hexametaphosphate&lt;sup&gt;3&lt;/sup&gt; (food grade)</td>
<td>10.00</td>
<td>15.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Totals</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Ratio of SHMP/ACUMER 3100&lt;sup&gt;4&lt;/sup&gt;</td>
<td>3.3/1</td>
<td>5.0/1</td>
<td>6.7/1</td>
</tr>
</tbody>
</table>

Dose formulation at 15 to 50 ppm into feedwater to maintain 30 to 60 ppm residual PO<sub>4</sub> in the boiler circuit. pH of boiler water should be above pH10.

<sup>1</sup>Union Carbide Company  
<sup>2</sup>Rohm and Haas Company  
<sup>3</sup>FMC Corporation  
<sup>4</sup>SHMP/ACUMER 3100 is the ratio of sodium hexametaphosphate to active ACUMER 3100 (expressed in acid form).
The following graphs are designed to help determine the formulation and feed rate that will give 30-60 ppm residual PO₄ and about 12-18 ppm active ACUMER 3100 terpolymer in the boiler circuit under a variety of feedwater contaminant loadings and cycles of concentration.

**Selecting The Appropriate Formulation**

For a low-medium pressure boiler and assuming that feedwater iron contamination is less than 0.1 ppm, the best formulation can be determined from Figure 2 based on feedwater calcium concentration and anticipated number of cycles of concentration.

**FIGURE 2. FORMULATION SELECTION AS A FUNCTION OF FEEDWATER HARDNESS AND CYCLES OF CONCENTRATION**

Graph assumes <0.1 ppm Fe in feedwater, and boiler pressure of 200-400 psig (14-28 Kg/cm²). If feedwater ≥ 0.2 ppm Fe, use next lower SHMP/ACUMER 3100 ratio. For higher boiler pressure, use next lower SHMP/ACUMER 3100 ratio.
Example 1:

A 300 psig (21 Kg/cm²) boiler operating at ten cycles of concentration and having 0.05 ppm iron in the feedwater has a normal feedwater calcium concentration of about 2 ppm (as CaCO₃). What is the appropriate phosphate program formulation to use?

From Figure 2 based on 2 ppm Ca²⁺ in the feedwater and ten cycles of concentration, Formulation BW-87-2 should be selected.

Determining Feed Rate

Figure 3 can be used to determine formulation feed rate based on the cycles of concentration of the boiler.

Example 2:

Formulation BW-87-2 has been selected for the boiler operation given in Example 1. What is the correct feed rate needed to maintain about 12-18 ppm ACUMER 3100 terpolymer and 30-60 ppm residual phosphate in the boiler circuit?

From Figure 3, at ten cycles of concentration, about 50 ppm of Formulation BW-87-2 should be added to the feedwater line.
Determining ACUMER 3100 And Residual Phosphate In Boiler Circuit

The amount of active ACUMER 3100 terpolymer and residual phosphate in the boiler circuit can be calculated knowing the formulation concentration of ACUMER 3100 terpolymer, SHMP, cycles of concentration, feedwater calcium levels, and formulation feed rate.

Example 3:

From Examples 1 and 2,
Cycles of concentration = 10
Feedwater calcium level = 2 ppm
Formulation BW-87-2 feed rate = 50 ppm
Active SHMP in Formulation BW-87-2 = 15%
Active ACUMER 3100 terpolymer in Formulation BW-87-2 = 3%

Residual PO₄ In Feedwater And Boiler Circuit

Feeding 50 ppm of Formulation BW-87-2 gives 7.5 ppm SHMP (50 ppm x 15 weight percent SHMP) in the feedwater. About 2 ppm SHMP hydrolyze in the boiler to form sufficient PO₄ to stoichiometrically combine with 2 ppm Ca as CaCO₃. Residual SHMP in the feedwater is thus 5.5 ppm (7.5 ppm - 2 ppm). About 1.1 ppm SHMP hydrolyze in the boiler water to form 1 ppm residual PO₄. Thus, 5.0 ppm (5.5 ppm SHMP/1.1) residual PO₄ is in the feedwater.

Since the boiler is operating at 10 cycles of concentration, the residual PO₄ concentration in the boiler is 50 ppm (10 x 5 ppm). This is within the recommended control limits of 30-60 ppm PO₄ for the phosphate program.

ACUMER 3100 Terpolymer Level In Feedwater And Boiler Circuit

Feeding 50 ppm BW-87-2 gives 1.5 ppm (50 ppm x 3% active) active ACUMER 3100 terpolymer in the feedwater. At 10 cycles of concentration, there are 15 ppm (10 x 1.5 ppm) active ACUMER 3100 terpolymer in the boiler. This is also within the recommended guidelines of 12-18 ppm ACUMER 3100 terpolymer in the boiler circuit.
Toxicity data is not available on ACUMER 3100 terpolymer. Data for a similar material are presented in Table 4.

### TABLE 4

**ANIMAL TOXICITY**

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Oral (LD₅₀), rates</td>
<td>&gt; 5 g/kg</td>
</tr>
<tr>
<td>Acute Dermal (LD₅₀), rabbits</td>
<td>&gt; 5 g/kg</td>
</tr>
<tr>
<td>Eye Irritation, rabbits</td>
<td>moderate to severe</td>
</tr>
<tr>
<td>Skin Irritation, rabbits</td>
<td>moderate to severe</td>
</tr>
</tbody>
</table>

**ENVIRONMENTAL TOXICITY**

<table>
<thead>
<tr>
<th>Species</th>
<th>Duration of Study (hours)</th>
<th>LC₅₀ (mg/L)</th>
<th>NOEL* (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluegill</td>
<td>96</td>
<td>&gt; 1000</td>
<td>&gt; 1000</td>
</tr>
<tr>
<td>Trout</td>
<td>96</td>
<td>&gt; 1000</td>
<td>560</td>
</tr>
<tr>
<td>Daphnia</td>
<td>48</td>
<td>&gt; 1000</td>
<td>&gt; 1000</td>
</tr>
<tr>
<td>Algae (EC₅₀)</td>
<td>96</td>
<td>58</td>
<td>&lt; 10</td>
</tr>
</tbody>
</table>

*NOEL = No Observed Effect Level
SAFE HANDLING INFORMATION

Caution: For Industrial Use Only! Keep Out of Reach of Children! Wear chemical splash goggles and impervious gloves when handling. An approved respirator, suitable for the concentrations encountered, should be worn.

FIRST AID INFORMATION

Contact With Skin Wash skin immediately with soap and water. Remove contaminated clothing and launder before rewearing.

Contact With Eyes Flush eyes immediately with plenty of water for at least 15 minutes and get prompt medical assistance.

Vapors If inhaled, move victim to fresh air. If necessary, administer oxygen or artificial respiration.

If Swallowed If victim is conscious, dilute by giving water to drink and then call a physician. If victim is unconscious, call a physician immediately. Never give an unconscious person anything to drink.

MATERIAL SAFETY DATA SHEETS

Rohm and Haas Company maintains Material Safety Data Sheets (MSDS) on all of its products. These contain important information that you may need to protect your employees and customers against any known health and safety hazards associated with our products. We recommend you obtain copies of MSDS for our products from your local Rohm and Haas technical representative or the Rohm and Haas Company. In addition, we recommend you obtain copies of MSDS from your suppliers of other raw materials used with our product.

Under the OSHA Hazard Communication Standard, workers must have access to and understand MSDS on all hazardous substances to which they are exposed. Thus, it is important that appropriate training and information be provided to all employees and that MSDS be available on any hazardous products in their workplace.

Rohm and Haas Company sends MSDS on non-OSHA-hazardous as well as OSHA-hazardous products to both “bill-to” and “ship-to” locations of all our customers upon initial shipment (including samples) of all of our products. Updated MSDS are sent upon revision to all customers of record. In addition, MSDS are sent annually to all customers of record.

PATENTS

The use of ACUMER 3100 terpolymer for deposit control is covered by Rohm and Haas U.S. patent 4,711,725.

ISO-CERTIFICATION

All ACUMER polymers are produced in ISO 9002-certified plants.
For additional information, a sample, a Material Safety Data Sheet or to have a technical representative call for the nearest Rohm and Haas Office.

**THE AMERICAS**

**Corporate Headquarters**
Rohm and Haas Company
100 Independence Mall West
Philadelphia, PA 19106
Phone: 1-800-223-3897
Fax: 610-437-5212

**Canada**
Phone: 416-284-4711
Fax: 416-284-2982

**Brazil**
Phone: 55-11-5185-9000
Fax: 55-11-5182-5110

**Mexico**
Phone: 525-728-6666
Fax: 525-728-6653

**EUROPE**

**France, Verneuil en Halatte**
Phone: 33-3-44-61-78-78
Fax: 33-3-44-34-79-60

**France, Paris**
Phone: 33-1-40-02-50-00
Fax: 331-43-45-28-19

**Germany**
Phone: 49-69-78996-0
Fax: 49-69-7895356

**Italy**
Phone: 39-02-95250-1
Fax: 39-02-95250399

**ASIA/ PACIFIC**

**Australia/ New Zealand**
Phone: 61-3-92724222
Fax: 61-3-92724211

**China, North**
Phone: 86-10-6464-3450-60
Fax: 86-10-6464-3466

**China, South**
Phone: 86-757-3363-3708
Fax: 86-757-336-5478

**India**
Phone: 91-11-464-7570
Fax: 91-11-464-7683

**Japan**
Phone: 81-3-5488-3100
Fax: 81-3-5488-3179

**Philippines**
Phone: 63-2-8925091/98
Fax: 63-2-818908

**Singapore/Malaysia**
Indonesia
Phone: 65-7350855
Fax: 65-7350877

**Taiwan**
Phone: 886-2-2718-7090
Fax: 886-2-2713-3857

**Thailand**
Phone: 66-2-6791030
Fax: 66-2-6791039

**Internet Address:** http://www.acumer.com or www.rohmhaas.com

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