Western Fluid Fertilizer Technology Workshop
Piccadilly Inn Airport
Fresno, CA

Tuesday, December 9, 2008

12:30 - 12:45 Welcome and Announcements (R. Hopkins)
12:45 - 1:15 Fluid Fertilizer Solutions For Crop Production (L. Murphy)
1:15 - 2:00 West Coast/Global Fertilizer Outlook and Trends: 2009 and Beyond (J. Yost)
2:00 - 2:15 Break

Session A
2:15 - 3:15 Local Plant Operation/Maintenance Issues (L. Lankenau)
3:15 - 4:15 Properties, Characteristics, Salt-out, precipitate formation of common fluid fertilizers (D. Leikam)
4:15 - 5:15 Compatibilities, formulation of ATS, CaTS, MgTS, K$_2$CO$_3$, KNO$_3$, etc. (C. Louie, R. Satterfield, etc.)

Session B
2:15 - 3:15 New Products, Techniques and Equipment (R. Mikkelsen)
3:15 - 4:15 Fluid Surfs: Essential crop nutrition and soil amendment (T. Fairweather)
4:15 - 5:15 Chelates: What they are and how/where they fit (V. Jurin)

Wednesday, December 10, 2008

Session A
8:00 - 9:15 Advances in Drip Systems and Nutrient Management (A. Lobato, Chile)
9:15 - 10:00 Producing Urea, K$_2$CO$_3$, KNO$_3$ and 10-34-0 Solutions: Plant Operation Issues. (M. Orr, R. Satterfield, etc.)
10:00 - 10:20 Break
10:20 - 11:20 Storage Tank Failures and Maintenance (C. Kominski)
11:20 - 12:00 Soil & Water Protection: Regulatory Update & Issues (R. Pinel)
12:00 - 12:20 Fertilizer Chain of Custody, Other Operation Issues, Questions and Discussion. (Group)
12:20 - 12:30 Wrap-Up, Thank You. Have a safe trip home!

Session B
9:15 - 10:00 Nutrient/Water Application Uniformity via Fertigation (L. Schwankl)
10:00 - 10:20 Break
10:20 - 11:20 Drip Systems: Soil P Movement Of Various P Sources (C. Krauter)
11:20 - 12:00 Foliar Nutrient Application Update: Opportunities & Solutions (P. Brown)
Fluid Fertilizers

- Increasing in popularity in U.S. and elsewhere
- Advantages include
  - Flexibility and versatility in application
  - Efficiency and adaptability
  - Potential benefits of continuous bands
  - Ease of handling
  - Does not segregate
  - Etc.

- Limitations
  - Generally higher purchase cost than solid fertilizers
  - Salt-out and precipitate formation potential with certain products and blends
U.S. Nitrogen Fertilizer Consumption

Tons N/year

Year


Ammonia
Ammonium Nitrate
Urea
UAN Solution

Anhydrous Ammonia
UAN Solution  51,000 Tons per year Increase
Urea  60,000 Tons N per Year Increase
Ammonium Nitrate  12,500 Tons N per Year Decrease
USA N fertilizer consumption by product.

Data source: Commercial Fertilizers, AAPFCO & TFI

*Blended multi-nutrient materials excluded
USA P fertilizer market share.

Data source: Commercial Fertilizers, AAPFCO & TFI
**Fluid Fertilizers**

**Terminology, Solubility, Density and N Solutions**

**Solution** – All salts totally dissolved in water. No solids allowed!

**Slurry** – Fluid product containing water, dissolved salts and undissolved salts. Settles out quickly. Not Common.

**Suspension** – Fluid product containing water, dissolved salts, fine undissolved salt crystals and a suspending agent – normally attapulgite clay.

**Muddy Water** – Solutions with undissolved solids or suspensions containing too few undissolved salt crystals. Not a good range to try and operate in!!.

**Falling Out Of Solution** – No such thing.
Salt-Out – Crystals form as solution cools; goes back in solution as product is warmed. Example; UAN Solution.

Precipitate Formation – Non-crystalline mass forms which has much lower solubility than original ingredients in solution. Example; Improperly stored fluid phosphates
EFFECT OF SALTS ON FREEZING POINT

Order Of Effectiveness:

CaCl2 > NaCl > KCl > Urea

Urea Is Much Less Corrosive Than Others
Eutectic Point – point of maximum solubility

32% UAN contains:
  • approximately 35% ammonium nitrate, 45% urea and 20% water at eutectic point

28% UAN contains 30% water
Salt-out is an issue in many environments

- There is very little water in UAN solution.
- Warm water has ability to dissolve more salts than cold water.
- Salt-out occurs when salt content exceeds solubility at a given product temperature.
- Crystals form on tank walls as temperature cools.
- Eventually salts accumulate at tank bottom.
- Salts will re-dissolve with sufficient heat and recirculation.
<table>
<thead>
<tr>
<th>% N</th>
<th>Freezing Temperature F</th>
<th>28-0-0 gal per 100 gal water</th>
<th>32-0-0 gal per 100 gal water</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>32</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>27</td>
<td>6.1</td>
<td>5.2</td>
</tr>
<tr>
<td>4</td>
<td>23</td>
<td>13.1</td>
<td>11.2</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>21.5</td>
<td>18.2</td>
</tr>
<tr>
<td>8</td>
<td>14</td>
<td>31.5</td>
<td>26.2</td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td>43.7</td>
<td>35.6</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
<td>59.0</td>
<td>47.2</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>78.7</td>
<td>61.2</td>
</tr>
</tbody>
</table>
Liquid Phosphate Products

Fluid Phosphate Products and Characteristics

[Flowchart image showing the process of producing liquid phosphate products, including the conversion of raw materials into different grades of phosphate and the handling of by-products.]
Phosphoric Acid

Wet-Process Acid
- Black, brown, green (calcined)
- Contains many rock impurities
- Used in fertilizer industry

Furnace, food-grade acid
- Clear
- No impurities
- Food and industrial processes
## Orthophosphoric Acid Examples

<table>
<thead>
<tr>
<th>Source</th>
<th>Acid 1</th>
<th>Acid 2</th>
<th>Acid 3</th>
<th>Acid 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2O5</td>
<td>61</td>
<td>53.2</td>
<td>52.8</td>
<td>57</td>
</tr>
<tr>
<td>MgO</td>
<td>0.3</td>
<td>1.2</td>
<td>1.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Fe2O3</td>
<td>0.35</td>
<td>0.5</td>
<td>1</td>
<td>0.32</td>
</tr>
<tr>
<td>Al2O3</td>
<td>0.18</td>
<td>0.4</td>
<td>0.5</td>
<td>0.16</td>
</tr>
<tr>
<td>F</td>
<td>0.3</td>
<td>0.4</td>
<td>2.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Solids</td>
<td>0.5</td>
<td>0.1</td>
<td>0.1</td>
<td>Nil</td>
</tr>
<tr>
<td>Visc.@100F</td>
<td>40</td>
<td>90</td>
<td>100</td>
<td>27</td>
</tr>
<tr>
<td>P/F</td>
<td>89</td>
<td>58</td>
<td>46</td>
<td>248</td>
</tr>
</tbody>
</table>

Source: Texas Gulf
Ammonium Polyphosphate

- Primary P source for much of fluid industry
- Most NPKS products made from APP
- Produced from ammonia, superphosphoric acid and water
- Generally equal agronomic performance as compared to solid fertilizers
  - If applied at equal P rates in similar manner
  - Potentially superior to solids if discontinuous bands result from with solid fertilizer band applications
- Contains most P as polyphosphate
  - Polyphosphates and orthophosphates are considered agronomically equal
Heat links phosphates by removing chemically bound water

Heat comes from chemical reaction of reacting phosphoric acid with ammonia
Flow Diagram For Ammonium Polyphosphate Production
10-34-0 & 11-37-0
Why Do We Want Polyphosphates?

- Not necessarily for agronomic reasons
- Manage sludge problems in fluid P products
  - Polyphosphates sequester metal cation impurities in the product (especially Mg) to form relatively insoluble precipitates
  - Provides superior storage qualities
- Increased analysis compared to orthophosphate
- Provides ability to include higher amounts of micronutrients in product (not Ca or Mg)
# Hydrolysis Of Polyphosphate To Orthophosphate

<table>
<thead>
<tr>
<th>Soil Temperature</th>
<th>Hydrolysis (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>41 F</td>
<td>30-40 %</td>
</tr>
<tr>
<td>68 F</td>
<td>50-60 %</td>
</tr>
<tr>
<td>95 F</td>
<td>80-90 %</td>
</tr>
</tbody>
</table>

Chang and Racz, 1977

---

*After application to soils, polyphosphate is quickly converted to orthophosphate by abundant soil enzymes.*

*Plants utilize orthophosphates.*
Effect of Poly Content and N:P2O5 Ratio On Solubility

N:P2O5 Weight Ratio

Percent Total N + P2O5 Content

0% Poly
45% Poly
70% Poly

0.28 0.29 0.30 0.31 0.32 0.33 0.34
Temperature Effect On 10-34-0 Quality

- 15 Degrees F
- 50 Degrees F
- 75 Degrees F
- 110 Degrees F

Polyphosphate Content (%) vs. Weeks In Storage
Polyphosphate Loss vs. Temperatures
Poly 11 - Geismar

Polyphosphate Content

Number of Days

140F 95F 75F

- 140F
- 95F
- 75F
Factors Impacting Precipitate Formation In Storage

- Amount of polyphosphate initially present
- Amount of impurities in super-acid
- Other ‘impurities’ added to product
  - Zinc
  - Previous product sludge
- Temperature of stored product
- Length of time product stored
### Zinc Sequestering By 10-34-0

#### Zinc Sources

<table>
<thead>
<tr>
<th>Original Zinc Source</th>
<th>% Zinc Remaining As Original Source</th>
<th>% Zinc Sequestered By Polyphosphate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn EDTA</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Zn Sulfate</td>
<td>4</td>
<td>96</td>
</tr>
<tr>
<td>Zn-NH3 Complex</td>
<td>8</td>
<td>92</td>
</tr>
<tr>
<td>Zn Phenolic Acid</td>
<td>11</td>
<td>89</td>
</tr>
<tr>
<td>Zn Citrate</td>
<td>8</td>
<td>92</td>
</tr>
<tr>
<td>Zn Nitrate + UAN</td>
<td>15</td>
<td>85</td>
</tr>
<tr>
<td>Zn HEIDA</td>
<td>19</td>
<td>81</td>
</tr>
</tbody>
</table>

Values Are For 4 Minutes After Mixing - U of Neb.
APP Storage and Housekeeping Suggestions

- Do not store longer than necessary
- Avoid storage in summer months
- Completely empty and clean tanks regularly
- Know the quality of remaining product before adding additional product to tanks
- Do not contaminate with products/impurities that may affect storage properties
- Never mingle any calcium or magnesium with product or mix plant
- Make sure that farmers and dealers lines, tanks and equipment are completely cleaned after use
• Final maximum grade May Contain 31 Total Plant Food Units.

- N = 25% of 31 = .25 X 31 = 7.75% N
- \( \text{P}_2\text{O}_5 \) = 50% of 31 = .50 X 31 = 15.5% \( \text{P}_2\text{O}_5 \)
- \( \text{K}_2\text{O} \) = 25% of 31 = .25 X 31 = 7.75% \( \text{K}_2\text{O} \)
## Solution Grades For UAN Solution (28-32% N), Potassium Chloride (0-0-62) and Ammonium Polyphosphate (10-34-0, 11-37-0) System

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1:0:1</td>
<td>7:0:7</td>
<td>3:0:1</td>
<td>13.5:0:4.5</td>
</tr>
<tr>
<td>1:0:2</td>
<td>5.5:0:11</td>
<td>3:0:2</td>
<td>8.4:0:5.6</td>
</tr>
<tr>
<td>1:0:3</td>
<td>4.3:0:12.9</td>
<td>3:0:4</td>
<td>6.6:0:8.8</td>
</tr>
<tr>
<td>1:1:0</td>
<td>19.5:19.5:0</td>
<td>3:1:0</td>
<td>24.6:8.2:0</td>
</tr>
<tr>
<td>1:1:1</td>
<td>7.3:7.3:7.3</td>
<td>3:1:1</td>
<td>12.6:4.2:4.2</td>
</tr>
<tr>
<td>1:1:2</td>
<td>5.3:5.3:10.6</td>
<td>3:1:2</td>
<td>8.7:2.9:5.8</td>
</tr>
<tr>
<td>1:1:3</td>
<td>4.2:4.2:12.6</td>
<td>3:1:3</td>
<td>6.9:2.3:6.9</td>
</tr>
<tr>
<td>1:1:4</td>
<td>3.5:3.5:14</td>
<td>3:1:4</td>
<td>6:2:8</td>
</tr>
<tr>
<td>1:1:5</td>
<td>2.9:2.9:14.5</td>
<td>3:2:0</td>
<td>21.6:14.4:0</td>
</tr>
<tr>
<td>1:2:0</td>
<td>15.3:30.6:0</td>
<td>3:2:1</td>
<td>12:8:4</td>
</tr>
<tr>
<td>1:2:1</td>
<td>7.7:15.4:7.7</td>
<td>3:2:2</td>
<td>8.7:5.8:5.8</td>
</tr>
<tr>
<td>1:2:2</td>
<td>5.1:10.2:10.2</td>
<td>3:2:3</td>
<td>6.9:4.6:6.9</td>
</tr>
<tr>
<td>1:2:3</td>
<td>3.8:7.6:11.4</td>
<td>3:2:4</td>
<td>6.3:4.2:8.4</td>
</tr>
<tr>
<td>1:2:4</td>
<td>3.2:6.4:12.8</td>
<td>3:2:5</td>
<td>5.7:3.8:9.5</td>
</tr>
<tr>
<td>1:2:5</td>
<td>2.7:5.4:13.5</td>
<td>3:3:1</td>
<td>11.7:11.7:3.9</td>
</tr>
<tr>
<td>1:2:6</td>
<td>2.3:4.6:13.8</td>
<td>3:3:2</td>
<td>8.4:8.4:5.6</td>
</tr>
<tr>
<td>1:3:0</td>
<td>12.5:37.5:0</td>
<td>3:3:3</td>
<td>6.3:6.3:8.4</td>
</tr>
<tr>
<td>1:3:1</td>
<td>7.4:22.2:7.4</td>
<td>3:3:5</td>
<td>5.7:5.7:9.5</td>
</tr>
<tr>
<td>1:3:2</td>
<td>4.7:14.1:9.4</td>
<td>3:4:1</td>
<td>11.4:15.2:3.8</td>
</tr>
<tr>
<td>1:3:3</td>
<td>3.5:10.5:10.5</td>
<td>3:4:2</td>
<td>9:12:6</td>
</tr>
<tr>
<td>1:3:4</td>
<td>2.9:8.7:11.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:3:5</td>
<td>2.5:7.5:12.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:3:6</td>
<td>2.2:6.6:13.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Typical Characteristics of Several Fluid Fertilizer Products

<table>
<thead>
<tr>
<th>Source</th>
<th>Analysis</th>
<th>Density ( Lbs/gal )</th>
<th>Salt-Out ( ^\circ F )</th>
<th>General Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAN 28-0-0</td>
<td>10.67</td>
<td>0</td>
<td>~ 30% water</td>
<td></td>
</tr>
<tr>
<td>UAN 32-0-0</td>
<td>11.06</td>
<td>28 - 32</td>
<td>~ 20% water</td>
<td></td>
</tr>
<tr>
<td>ATS 12-0-0-26S</td>
<td>11.04</td>
<td>&lt;20</td>
<td>Fluid S Source of Choice</td>
<td></td>
</tr>
<tr>
<td>APP 10-34-0</td>
<td>11.65</td>
<td>&lt;10</td>
<td>11-37-0 grade also</td>
<td></td>
</tr>
</tbody>
</table>
Temperature Effect On Fluid Fertilizers Density

Estimated Density Of Fluid Products

<table>
<thead>
<tr>
<th>Product Temperature</th>
<th>28-0-0</th>
<th>32-0-0</th>
<th>10-34-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>10.78</td>
<td>11.17</td>
<td>11.76</td>
</tr>
<tr>
<td>30</td>
<td>10.76</td>
<td>11.14</td>
<td>11.74</td>
</tr>
<tr>
<td>40</td>
<td>10.73</td>
<td>11.12</td>
<td>11.72</td>
</tr>
<tr>
<td>50</td>
<td>10.7</td>
<td>11.09</td>
<td>11.7</td>
</tr>
<tr>
<td>60</td>
<td>10.67</td>
<td>11.05</td>
<td>11.68</td>
</tr>
<tr>
<td>70</td>
<td>10.64</td>
<td>11.02</td>
<td>11.66</td>
</tr>
<tr>
<td>80</td>
<td>10.61</td>
<td>10.99</td>
<td>11.64</td>
</tr>
<tr>
<td>90</td>
<td>10.58</td>
<td>10.95</td>
<td>11.62</td>
</tr>
<tr>
<td>100</td>
<td>10.55</td>
<td>10.92</td>
<td>11.6</td>
</tr>
</tbody>
</table>
**Salt-out** – Crystals form as solution cools; goes back in solution as product is warmed. Example; UAN Solution.

**Precipitate formation** – Non-crystalline mass forms which has much lower solubility than original ingredients in solution. Example; Improperly stored fluid phosphates

**Heat generator** – Generates chemical heat when producing solutions. Examples; ammonia + phosphoric acid; dilution of sulfuric acid)

**Fume generator** – Generates fumes which can be safety hazard. Example; UAN solution + Potassium carbonate → ammonia fumes.

\[
2\text{NH}_4\text{NO}_3 + \text{K}_2\text{CO}_3 \rightarrow 2\text{KNO}_3 + (\text{NH}_4)_2\text{CO}_3
\]

\[
2\text{NH}_3 \uparrow + \text{H}_2\text{CO}_3 \quad \text{H}_2\text{O} \quad \text{CO}_2 \uparrow
\]

UAN in Irrigation Water?
Caution: This chart contains information based on the opinions of people in the fluid fertilizer industry. This information has been compiled as a general guide only. Neither the Fluid Fertilizer Foundation or contributors guarantee the accuracy of the information. Please refer to manufacturer/supplier product information and also perform a small jar compatibility test prior to final mixing.

- 'Compatible', results in relatively stable mixture.
- 'Limited Compatibility', generally compatible within solubility limits.
- 'Very Limited Compatibility', generally unsuitable mixtures.
- 'Incompatible', unsuitable mixture and/or hazardous combination.
- Significant heat generated.

Fluid Fertilizer Foundation
2805 Claflin Road, Suite 200
Manhattan, KS 66502
785-776-0273
FluidFertilizer@sbcglobal.net
Thank You And Enjoy The Conference

Dale F. Leikam

Fluid Fertilizer Foundation
www.FluidFertilizer.com

Dale.Leikam@sbcglobal.net
785-776-0273
785-770-0009

The Fluid Advantage
Size Matters: ... Dry Fertilizer Segregation

The Fluid Advantage
FLEXIBILITY (Timing)
FLEXIBILITY (Method)
EFFICIENCY (Agronomic)
EFFICIENCY (Logistics)
ADAPTABILITY (Equipment)
ADAPTABILITY (Cropping System)