Dynamics of Prescription Fluid Fertilizer Production

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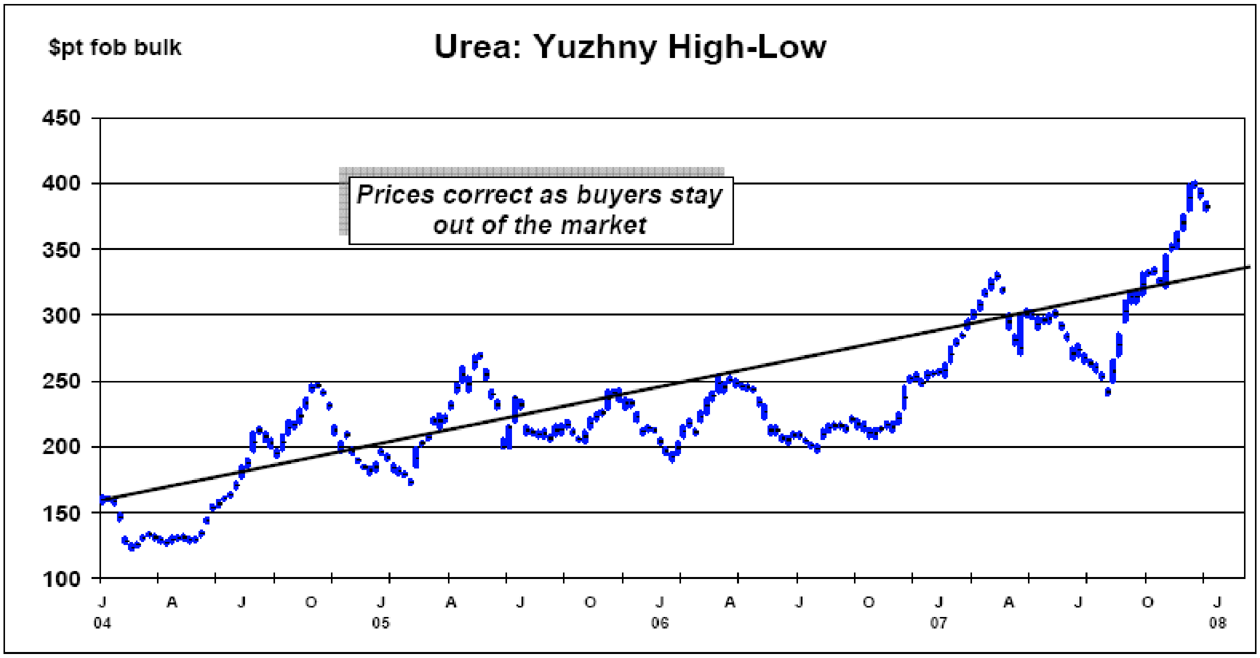
We are living in a world of very dynamic change. Energy prices are soaring, Global warming is concerning many people and International competition is increasingly affecting our businesses and daily lives. Fertilizer prices are out of control. See the attached graphs, courtesy of ICIS, showing historical urea and DAP prices. In preparing for this talk we called some of our users for prices to use as examples. They have never experienced such change and they fear the impact on their customers.

If we wish to survive as an industry we must strive to understand how to use these changes to our benefit. Another aspect of change is the way technology is impacting us. Computers are becoming incredibly inexpensive for what they accomplish and the speed of wireless and broad band internet is making information availability and e-business connectivity a must for survival. The scary thing is not just change, but the unbelievable rapidity of this change. In the "good ole days" we had time to adjust to change, time to think about it and grow to accept or reject it. We had time to study the impact of this change on our business or our families before we accepted or rejected it. Those days are gone. Today we must equip ourselves with the best tools and the best helpers we can find to enhance our decision making.

Today I will show a tool that can be helpful in evaluating some alternative inputs for making fluid fertilizers. The tool, Form-U-Share® has been around for over 50 years. I began my research on it as a senior in under graduate school at Case Institute of Technology and continued refining it throughout the 1960's in Graduate school at N.C. State, under an assistantship from TVA. This was almost 10 years before the acceptance of personal computers. I had been exposed to fertilizer as a young boy as my father was an active leader in the industry and the "father" of "High Analysis Fertilizer" and the Amo-Phos trade name of Olin-Matheson. I fell in love with liquid fertilizers in the early '60's and my father continually fed me with the latest information he could find on products and equipment suppliers. Names such as Bernard and Lees and their liquid fertilizer plants stimulated my imagination.

As a graduate student I studied many aspects of the fertilizer industry. I came to understand that the natural advantage of the liquid nitrogen fertilizer industry over dry was the elimination of the expense of urea and ammonium nitrate prilling. This expense comes not only from evaporation of water, but also from the capital expense of prilling towers. As an employee of TVA's National Fertilizer Development Center, a lot of work was done with pan granulation of urea and urea-ammonium phosphate products. While interesting as a development technology, it was never adopted as a commercial process. On the other hand, as a means of sulfur coating urea, pan granulation was adopted. Regardless of the process, converting nitrogen to a solid form is expensive.



$pt fob bulk
Urea: Yuzhny High-Low
Prices correct as buyers stay out of the market
450
400
350
300
250
200
150
100
J 04
A
J
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J 05
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J 06
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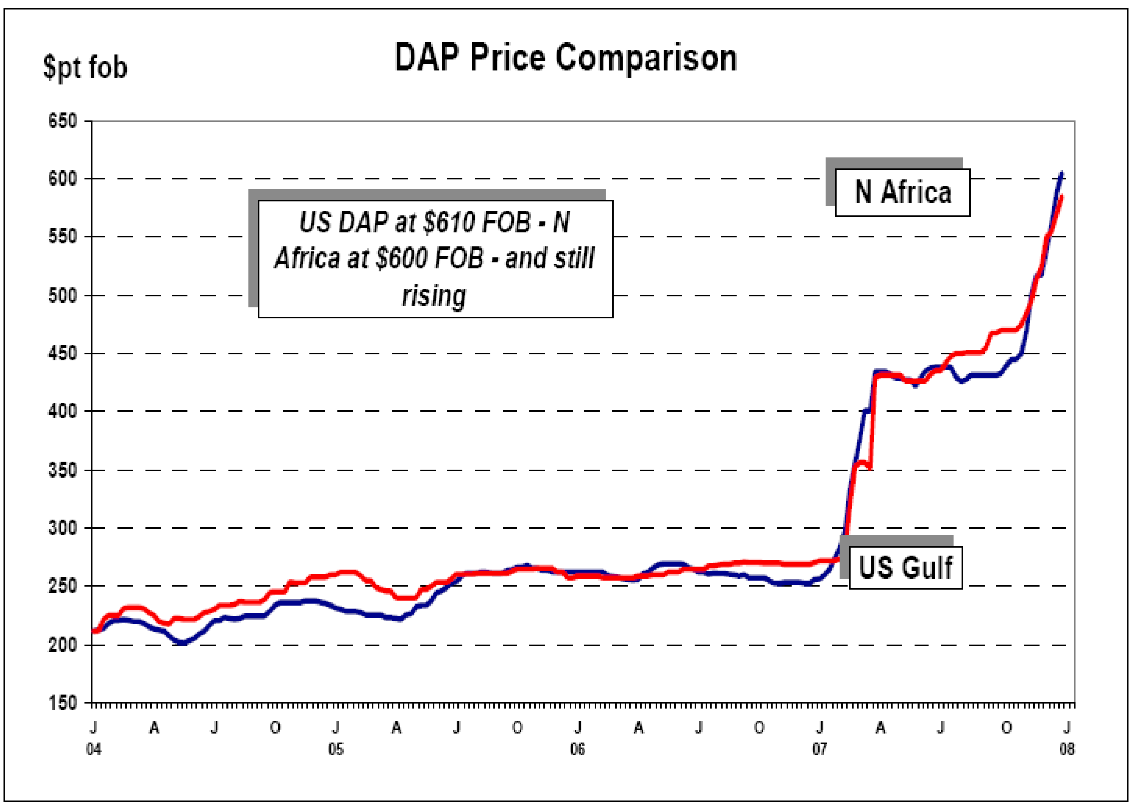

$pt fob
DAP Price Comparison
US DAP at $610 FOB - N Africa at $600 FOB - and still rising
N Africa
US Gulf
650
600
550
500
450
400
350
300
250
200
150
J 04
A
J
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J 05
A
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J 06
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The way it was

The bottom line is that converting urea or ammonium nitrate to a solid form suitable for application or blending is expensive, compared to going directly to a urea ammonium nitrate solution. This was the natural advantage of fluid fertilizer production in the US since we produced both here.

The way it is

Natural gas is the basis for our nitrogen industry because it is the source for making the hydrogen (H) in anhydrous ammonia (NH_3). The nitrogen (N) is "free" since the air we breathe is 78% N. The worldwide production in 2004 was 109,000,000 metric tons. China produced 28.4% of the worldwide production followed by India with 8.6%, Russia with 8.4%, and the United States with 8.2%. About 80% or more of the ammonia produced is used for fertilizer. A by product of ammonia production is carbon dioxide (CO_2) which when combined with ammonia produces urea $(NH_2)_2CO$. The United States is continuing to lose its nitrogen industry. Ammonia can be liquefied and stored and transported at a reasonable cost, but urea can be transported and stored even cheaper. Natural gas cannot be compressed and transported economically. There is no shortage of natural gas world wide. The problem is transporting it to consumers. Combine this with the continuing decrease in the value of the dollar and you can expect world wide urea production to be the future of our industry. The natural advantage of the fluid fertilizer industry has come to an end. Had this natural advantage not existed there may not have been the evolution of the fluid fertilizer industry we enjoy today. Now it is critical that we learn how to use solid forms of urea and other nitrogen products in our fluid products to remain competitive.

The Basic Dynamics

Almost any solid with nutrient value can be dissolved in water and sold as a fluid. The problem is economics. Selling a fertilizer with 50% or more water increases the cost of storage, distribution and application. Water is just a carrier with no nutrient value. Of course if it is carrying a herbicide, then it is beneficial. If it is going into an irrigation system then lower concentration may not matter. With farmer applied or custom spread fertilizers, the major expense is fewer acres spread between fill ups or loads. As an economic model, quantifying this marginal, weight related cost per ton is not obivious[1].

To help cover this ton related cost you can just add less water. The problem is that this directly affects the temperature at which salts begin to form. Salts can grow into crystals that can plug nozzles and eventually form residue in tanks. If mixtures are taken immediately to the field and spread, then the presence of salts can be managed. An alternative is to keep salts from falling out by suspending them or slowing the rate of fall by increasing the viscosity of the fluid carrier. Suspensions typically have 30% total water or less. The most common suspension agent is attapulgite clay. Suspensions are most advantageous when high potash grades are produced. Form-U-Share has tools for maintaining the consistency of viscosity among custom mixed products.

The next critical dynamic is the fact that dissolving a solid such as urea, ammonium nitrate or potassium chloride removes considerable heat from water lowering its temperature. This negative heat of solution must be replaced by either heating the water or producing chemical heat by reacting ammonia with an acid such as phosphoric or sulfuric. With the cost of energy increasing, supplying BTU's as hot water should be scrutinized. Another dynamic is the number of BTU's required to change one pound of an input one degree Fahrenheit. This is called heat capacity. Water is by definition 100 BTU's per 100 lbs of water, while potassium chloride is only 18.

All three of these factors must be modeled to predict final product temperature given the original temperature of the inputs. In summery these dynamics are:

1) Heat of chemical reaction
2) Heat of solution
3) Heat capacity
4) Temperature of original inputs

The next dynamic is mixing time. If final product temperature is the same as salt out temperature, salts come out at the same rate salts go into solution. Theoretically this will take forever unless you stir the mixture vigorously. But this is just another, less efficient form of energy, called mechanical energy. The larger the difference between these two temperatures the faster mixing will go to equilibrium. We suggest a difference of 6^o-10^oF. Meeting all these dynamic conditions while computing a fertilizer formula that will meet a growers soil requirements at the lowest cost per acre is no small task. Accomplishing all this in a world where input prices have gone crazy and shortages make life even more frustrating, requires an incredibly powerful tool and a support staff to help you navigate these troubled waters. Such a tool does exist and its name is:

Form-U-Share®

And the company that supplies the support is:

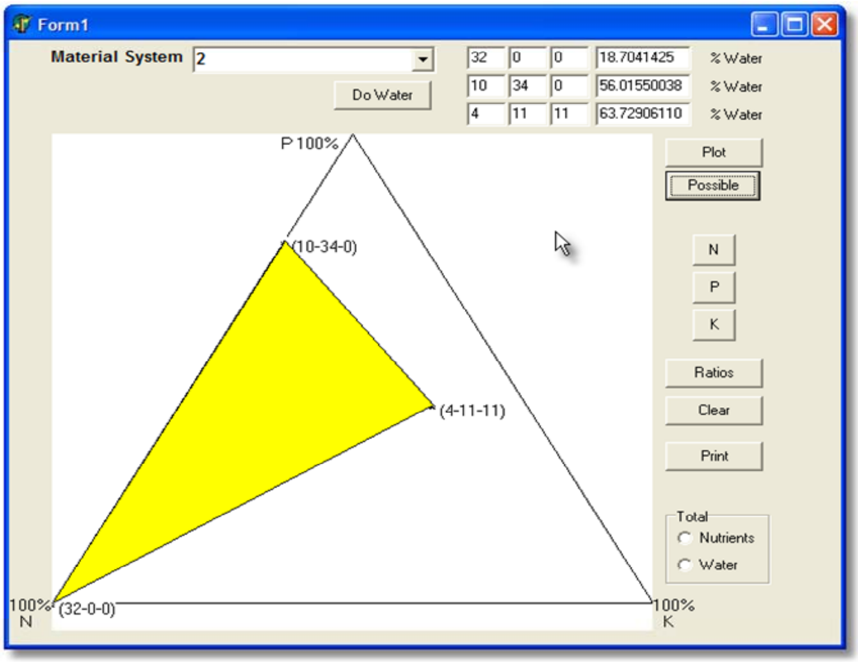
FUS Support, Inc.

I am the owner and author of this product. Please excuse my exuberance about the product and pride I have for about 50 years of my life in this endeavor. The enthusiasm stems from my inherited interest in fertilizer and my 30 years of working for TVA introducing new fertilizer technology. The fluid fertilizer industry might not exist as we know it without the natural economic advantage mentioned above on the nitrogen side and TVA's research and introduction efforts on the ammonium poly phosphate side. The remainder of this talk will focus on examples of using Form-U-Share to explore alternative products for use in fluid fertilizer production.

Form-U-Share® Examples

Most of our customers (over 900 licenses) use the product as a production tool, creating formulas under the pressure of the hectic season, pricing under ever changing conditions, managing inventory, invoicing customers (some with splits and prepayments), collecting payments and some interface to their favorite account system (often Quick Books). Frankly, most users do not realize the power of FUS as a research and educational tool. These are the aspects we will be looking at now.

Cold mixing – The first example is a common model used by many of our users, with minor variations. Materials consist of UAN 32-0-0, 10-34-0 and 4-11-11. In colder areas UAN 28% or 30% might be used because of lower salt out temperatures. Some may use 11-37-0 as a phosphate source. The example also uses ammonium thio-sulfate 12-0-0-26S as a sulfur source; though an increasing number of our users are switching to ammonium sulfate solution. The example is very simple. The Grower wants 50 Lbs./Acre of nitrogen, phosphate and potash respectively. The dealer just types in the numbers and FUS chooses the set of materials that will result in the lowest cost per acre way to meet the minimum requirements of the grower's order. Some say this is so easy to do with a pencil and paper why use a computer. But in the heat of the season when trucks are lining up at the gate there is no room for error. Clearly printed reports for the customer and the mix plant operator cut down on misunderstandings and mistakes. If your plant is equipped with automation, FUS can even send formulas directly to the plant for even faster more accurate mixing. I teach a class on formulation by hand, because I believe in understanding the fundamentals of our industry. As us old timers fade away newcomers need this background. The math in this example is deceptively simple. In the example triangular diagram note the feasible region of ratios that can be made from the example materials and more importantly those that cannot be made. In the example I have added 20 Lbs./Acre of sulfur to the growers order and 12-0-0-26S was added to the mix. Again this is not rocket science but still very useful.



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Now let's look at some rocket science. I included the materials I mentioned earlier but blocked them. The value report shows two kinds of information. First the marginal cost of each nutrient is shown. For example, if a grower wants 10 Lbs./Acre more N you can quote his cost per acre without using the computer ($6,25). The second part of the value report shows substitution costs which tells you how much you would have to pay for the material to be used in the least cost solution. You don't actually have to include every material; just use the values of each nutrient to evaluate the substitution cost of the material. In the more complex hot mix examples to follow, values for the ability to fix free ammonia, produce heat or cool, even avoid unwanted chlorine etc. will be generated. These tools can help evaluate alternative materials you might consider. As a material supplier, you can use these tools to help price your product. I did this for years in helping price TVA introductory materials.

Economic Value Report
Nutrients of Value

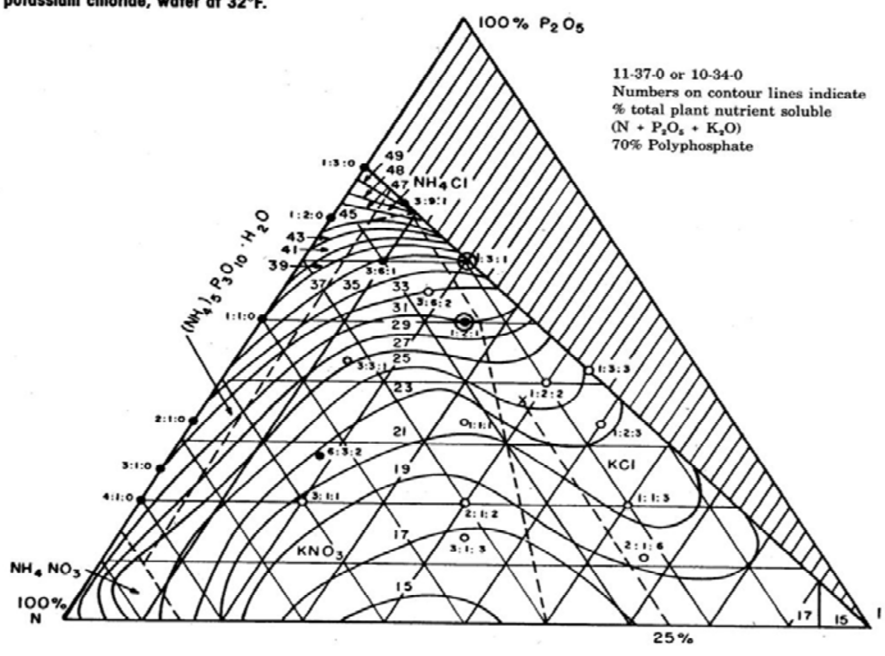
Nutrient	Rate (Lbs)	Value ($/Lb)	Total ($)
Nitrogen	50.000	0.625	31.25
Phosphate	50.000	0.309	15.44
Potash	50.000	0.373	18.65
Sulfur	10.000	0.092	0.92
Weight balance	0.000	0.000	0.00
Total			66.26

Substitution Cost

Material Name	Code	Unit	Cost ($/Unit)	Value ($/Unit)	Difference ($/Unit)
Water	WATER	Ton	0.01	0.00	0.01
28-0-0	I280000	Ton	355.00	350.00	5.00
30-0-0	I300000	Ton	380.00	375.00	5.00
11-37-0	I113700	Ton	374.00	366.03	7.97
10-34-0	I103400	Ton	335.00	335.00	0.00
0-0-62	I000062	Ton	376.00	462.51	-86.51
21-0-0-24S	I210000	Ton	240.00	306.81	-66.81
46-0-0	I460000	Ton	495.00	575.00	-80.00

Salt out models – In the next example we add potassium chloride as a material. This brings salt out temperatures into the model. Most of you are familiar with the salt out diagrams produced at TVA. A digitized version of most of these has been a part of FUS for many years. I have some of the original hand sketched drawings, but more importantly the original data points. These were supplemented with additional boundary points from other sources and fit to a polynomial equation. An example diagram for UAN, 11-37-0 and KCL is shown. To be honest, the original diagrams reflect a clever use of a French curve and some imagination. The model may be more reliable. The diagram shows total N+P+K that won't salt out for any given ratio at 32^{o} F. The diagram also shows the salt that is formed (crystal phase) for each ratio. Knowing this phase is critical for adjusting for different temperatures. These phases were also modeled mathematically.

Figure 3.7: System 11-37-0, UAN solution, potassium chloride, water at 32°F.



In the example the initial solution shows the least cost per acre solution that won't salt out at 55^{o} F. Note we can adjust the grade up or down and watch the salt out temperature change. This has been used by many FUS users for years despite the warning that the original diagrams did not reflect the use of minor elements such as sulfur or zinc. The data also is based on chemically pure ammonium phosphate. In later years I took the original salt out data and modeled it using total water rather than total N+P+K. The resulting diagram is shown as iso-water lines rather than iso-analysis lines. Notice the flatness of these lines once we pass the 20% nitrogen point. In the next example the control total water model is used. As a result adding sulfur to the order reduces the analysis but maintains the level of total water. The model may also reflect the effect of different quality phosphoric acids. Use of this model requires accurate total water estimates. These are supplied by our Community Chemical Data Base (CCDB) though your supplier should be consulted for more accurate data. Without accurate data use of this model can produce strange results.

The next example uses a model that looks at the amount of total water required for each material at 32^{o} and 77^{o} F to maintain solubility. By consolidating this data for a given formula a curve such as is shown, estimates the effect of changing analysis on salt out temperature. The literature abounds with very reliable data on salt out temperatures for individual materials. This model can be very useful in evaluating alternative materials for use in fluid fertilizers. It adjusts itself if UAN is used in large amounts. This model is even more dependent on the CCDB.

Hot mixing – The next example looks similar to the last except that estimated product temperature is shown to be 67^{o} F and the mix sheet shows how much hot water is required to maintain the 6^{o} F minimum temperature difference imposed to mix the KCL in a timely manner. Also the cost per acre is higher reflecting the added cost of heating the water. FUS looks for other less costly sources of heat but finds phosphoric acid blocked. Unblocking 0-54-0 increases product temperature to 121^{o} F and reduces cost per acre further. Looking at the mix sheet we see 10-34-0 is replaced with 0-54-0 and 82-0-0 replacing the need for hot water. Now if we unblock urea (46-0-0) cost per acre reduces more and product temperature drops to 106^{o} F reflecting the cooling effect of dissolving this material. Now unblock ammonium sulfate and notice the cost per acre drops again and product temperature drops to 97^{o} F. But also notice the grade drops to 5-5-5 and total water goes up to 64%. While this low analysis may turn you off, it is still less costly per acre even with a marginal ton related cost of $20. Finally, suppose the grower wants a chlorine free product. Zeroing the chlorine increases the product temperature to 133^{o} but the analysis jumps to 7-7-7. The mix sheet shows 0-0-62 is replaced with 0-0-25, a more expensive source of potash, but chlorine free. This example has a maximum temperature setup at 157^{o} F which the user can set to meet his needs. The example also has aqua ammonia in it which would probably kick in if temperature became constricting.

Summary

We can go on endlessly with examples, but hopefully this gives you a peek at the tremendous level of complexity FUS can handle. Results FUS comes up with obviously need to be tested in your lab or plant on a small scale before making a major commitment to full scale production. Also data supplied by the CCDB is largely “text book data” which is probably the best currently available. As you work with our models please provide feed back so as a community we can continue to improve predictability.

With these cautions, I think you will find FUS a very useful tool in evaluating alternative materials for use in prescription fluid fertilizer production in this dynamic, sometimes crazy world economy.