DAP/MAP PLANT EXPANSION AT FARMLAND HYDRO, L.P.

In August 1991, Farmland Hydro, L. P. (then Farmland Industries, Inc.) contacted HiTech Solutions, Inc. for assistance in evaluating options to modify their North Train fertilizer plant. At the time, Farmland Hydro, L. P. was conducting a plant wide expansion and modification program which included sulfuric acid, phosphoric acid, and fertilizer modifications. The main purpose of the program was not only an expansion in output capacity but modernization of all plants and improvement in recoveries.

I. Plant History

The North Train fertilizer plant had originally been constructed in the mid 1960's as part of the original Green Bay facility. At that time, a two train facility for fertilizer production had been constructed with the North Train being dedicated to producing Granular Triple Super Phosphate (GTSP). In 1967, Dorr Oliver expanded the North Train production capacity to 28 TPH of GTSP.

As market conditions changed, it became obvious that the fertilizer market was moving towards ammoniated fertilizers and away from phosphate only fertilizers. In 1981, Farmland therefore modified the plant to be capable of producing MAP and DAP fertilizers in addition to GTSP fertilizers.

II. Plant Description

The plant had originally been equipped with blungers for mixing the GTSP slurry with the recycle. During the 1981 modification, the top of these blungers had been raised to allow disengagement space for the ammonia gas sparged under the bed and the moisture evaporated from the product. A new reactor tank had been added to produce DAP slurry and the existing GTSP reactors were still in place to allow rapid conversion to GTSP production as the market dictated. The reactor/blunger scrubber system had been modified to accommodate the increased gas from the DAP reactor and the remaining scrubbers had been minimally modified to accommodate increased air flows in other parts of the plant. In the mid 1980's, a fluid bed cooler had been added to cool the product to storage. About one-half of the air flow from the dust evacuation system had been utilized as cooler flow to provide this cooling.

III. Baseline Operation

When HiTech Solutions evaluated the plant operations in August and September 1991, it was found that the plant primarily produced MAP fertilizers. This operation was necessitated since the MAP rate was significantly higher than the DAP rate and the ammonia losses when producing MAP were acceptable. The ammonia losses from the blungers when producing DAP were unacceptably high. Plant rates averaged about 65 TPH for MAP fertilizers and about 40 TPH for DAP.

The recycle load was limited to about 350 TPH primarily by the capacity of the recycle drag flite conveyor. Even at this load, the existing screening system was overloaded and the screening efficiencies (overs and fines) were low. The major equipment problem was considered to be the dryer since it was originally designed to dry 250 TPH of GTSP with a moisture removal capacity of about six (6) TPH of moisture. Even at the present recycle rate, the dryer volume fill was in excess of that recommended to achieve optimum drying in a rotary dryer.

The existing dryer and dust evacuation scrubbing systems performed adequately but reactor/blunger system was entirely inadequate for the modifications. The primary items to be examined were the modifications required by reaction section modifications and the other possible scrubbing system modifications which might be required by emission limits imposed by the DER. It was also determined that the cooler was not performing adequately due to lack of air flow. If additional air flow were utilized in the cooler, then some modifications would be required in this circuit.

IV. Results of Modification Studies

From August through November 1991, Farmland Hydro, L. P. and HiTech Solutions, Inc. jointly proposed and investigated possible modifications. Each proposed modification was examined briefly to determine:

1. Production Impact
2. Environmental Impact
3. Quick Estimate of Capital Cost
4. Time to Execute

Many different modifications were examined during this time period. In the end, three major plans were decided upon and presented to management. For sake of clarity, these were referred to as the minimum plan, the proposed plan, and the maximum plan. Briefly, these plans were:

- Minimum Plan

  The blungers would be removed and replaced by a granulator. The associated scrubbing system (called R/B then) would be removed and replaced by a double mol scrubbing system to maximize ammonia recovery. No modifications would be performed to the reactor, the recycle system, or the other scrubbing systems.

- Proposed Plan

  The minimum plan would be performed along with modifications to the reactor, the screening system, the recycle system, and the cooler air system to increase flow. The increased cooler air flow necessitated a new cooler scrubber.

- Maximum Plan

  The Proposed Plan modifications would be performed along with other modifications such as changing the dryer (larger diameter) and increased recycle modifications to maximize the ability of the plant to produce fertilizer.

In general, the proposed rates for these plans indicated the minimum plan would yield a rate of about seventy (70) TPH for either DAP or MAP, the proposed plan would yield a rate of about 85 TPH for DAP and 110 TPH for MAP, and the maximum plan would yield a rate of about 125 TPH for DAP and 150 TPH for MAP. If the "Minimum Plan" is given a cost factor of 1.0, then the multipliers for the more extensive plans were 2.2 for the "Proposed Plan" and 3.6 for the "Maximum Plan". Either the minimum or the proposed plan schedule fit well with Farmland Hydro's overall complex plan while the maximum plan schedule was several months longer than the overall complex plan.

In early December 1991, Farmland Hydro, L.P. management elected to proceed with the Proposed Plan. Several decisions were also reached at this time regarding energy conservation modifications and type of instrumentation system. These were incorporated into the overall plan and the project capital budget was prepared by HiTech Solutions, Inc. and approved by Farmland Hydro, L.P.

V. Plant Modifications

Farmland Hydro, L.P. chose HiTech Solutions, Inc. to prepare a process package consisting of Process Flow Diagrams, Equipment Specifications, P & I Diagrams, and preliminary General Arrangements. HiTech was also to assist Farmland Hydro, L.P. as a consultant to detail design, equipment purchasing, construction, and start up. The initial schedule called for an early May start up.

The basic plant modifications consisted of:

- Remove existing blungers and replace with a large granulator rated at the ultimate 125 TPH rate of the maximum plan. This would allow future capacity expansion without modifications to the granulator.

- Install a second recycle drag flite conveyor and increase the dryer and recycle elevator speeds in order to increase the recycle capacity to about 600 TPH.

- Install new larger overs screens and install the HiTech Fines Screen Diverter to allow screening of only the product over the fines screens.

- Install a larger DAP reactor to provide for increased surface area. The reactor design was the modified HiTech design to minimize retention time (minimize citrate insoluble).

- Install a double mol scrubbing system for the reactor/granulator circuit to maximize ammonia recovery.

- Modify the old R/B scrubber as the new cooler scrubber and install a new cooler air system. This modification allowed for increased dust evacuation inside the plant along with increased air flow through the cooler.

- Install new product belts in the storage building to allow storage of product in additional bays.

- Install a cooler chiller coil to utilize incoming ammonia liquid as a refrigerant and cool the incoming cooler air to about 50° F. to improve product cooling.

After the project was well under way, Farmland Hydro, L.P. and HiTech Solutions, Inc. jointly studied the plant ammonia system. A single set of storage bullets provided ammonia to both the North and the South Train through separate systems. It had been decided early in the project to install the HiTech Solutions, Inc. licensed BFL ammonia vaporization system which utilizes waste heat to vaporize ammonia. During the project, it was decided to vaporize ammonia for both trains in the BFL system. This modification necessitated some redesign of the overall system which included conversion of the cooler coil from a direct expansion coil to a flooded coil and installation of supplemental steam vaporizers for start up and North Train outages.

At the project inception, the plan to produce MAP had been back titration of DAP slurry in the granulator with 54 percent phosphoric acid. The granulator was therefore ordered with both a DAP slurry distribution system and a phosphoric acid distribution system. During the early phases of the project, the overall rate requirements were examined in some detail. The dryer capacity limited the plant rate to about 90 TPH at about one (1) percent moisture and about 110 TPH at about 1.5 percent moisture. Since future sales forecast indicated a need for additional MAP tonnage, it was decided to add a MAP pipe reactor to the granulator. The pipe reactor would allow for MAP tonnages beyond the 110 TPH. The granulator manufacturer (FEECO) designed and supplied the pipe reactor as part of the overall granulator supply contract.

VI. Plant Innovations

In most areas, this project was a straight forward retrofit of an existing fertilizer plant to increase capacity and improve recoveries. However, certain innovations were incorporated in the plant. These had been proposed by HiTech Solutions, Inc. to Farmland Hydro, L.P., discussed at length , and incorporated into the basic design. These innovations include:

- Lowering the screen angles. Farmland Hydro, L.P., as with many fertilizer producers, complained that the speed of the material over the screen surface was excessive. When HiTech Solutions, Inc. analyzed the problem, it was determined that most likely problem was the screen angle. Most vibrating screen installations have been at 34 to 37 degree from the horizontal. The original design criteria for vibrating screens was two to three degrees over the angle of repose of the material being screened. Since fertilizer materials have a nominal angle of repose of about 28 degrees, it was decided to lower the screen installation angle to slow the material speed over the screen.

- Install the HiTech Solutions, Inc. screen feed diverter between the overs and the fines screens. (This design received the Valaar award in 1983 for material handling.) The diverter allows the operator to screen only the required amount of product and bypass the remainder of the minus six mesh material under the fines screens directly to the recycle. This bypass unloads the fines screens and allows for better removal of fines from the product.

- Granulator Slope. FEECO was the selected supplier of the granulator. HiTech Solutions, Inc. worked with FEECO to install the granulator slope that would produce the "natural retention time". This is defined as the time the material wants to flow through the granulator. Considerable effort was expended to attempt to maximize granulation effects and minimize ammonia loss in the granulator by HiTech Solutions,Inc., Farmland Hydro, L.P., and FEECO.

- Location of the BFL Ammonia Vaporizer. In previous installations, this heat exchanger had been located in the gas stream exiting the DAP reactor. While the system worked quite well, a byproduct of this location was a liquid stream containing about two percent ammonia. This liquid stream would either have to be consumed in the DAP plant or be discarded to the pond system. HiTech Solutions, Inc. and Farmland Hydro, L.P. jointly decided to install this heat exchanger after the double mol scrubber system. In this location, the ammonia in the gas stream would be minimum and the liquid stream produced could be deposited to the pond without contaminating the pond with ammonia. In addition, calculations indicated that the scrubbing action of the heat exchanger was sufficient to allow no tail gas scrubber.

VII. Plant Construction

The initial schedule of a May start up was modified early in the project. It became obvious that equipment and material deliveries would force a mid to late July shut down with a late August to early September start up. During 1992 prior to the shut down, HiTech Solutions, Inc. worked with Farmland Hydro, L.P. to prepare equipment and material bids, evaluate bids, prepare the process package, aid in the detail design, perform project cost tracking, and aid in the design of the revised ammonia system and pipe reactor system.

During construction, HiTech Solutions, Inc. personnel worked with the contractor as a representative of Farmland Hydro, L.P. to resolve problems and adhere to the schedule. As with all retrofit projects, certain problems were encountered during construction. These included unexpected problems due to incomplete plant information and some design problems in overall fit. These problems were not extremely major, but they did delay the overall construction effort by about two weeks and cause an overrun in the construction contract. Up to the start of construction, the project was within budget and the construction contract awarded had been within the budgeted amount.

Construction was completed on Labor Day, 1992, and the plant actually went into start up mode late that night.

VIII. Start Up

The plant started on DAP since that product is easier to produce. The initial start up was at a rate of about 70 TPH and most of the early DAP production difficulties were associated with the learning curve of the operators. The entire control system from the plant had been removed and replaced with a Moore Products SCADA system. In addition, significant new controls were added. It simply required time for the operators to become accustomed to the new system. As familiarity increased, the plant rate gradually increased and by the end of September, the plant was consistently operating at a 70 to 80 TPH rate.

In early October, it was decided to make MAP utilizing the pipe reactor. To the best of everyone's knowledge, this pipe reactor (at twelve inch diameter) is the

world's largest. A number of problems were encountered in the initial start up which necessitated the plant switching back to DAP production. These included:

- Liquid ammonia flowmeter to the pipe reactor was not reading accurately and could not be calibrated.
- Controls for acid feed to the pipe reactor did not respond adequately.
- At low rates (about 50 to 70 TPH), the large pipe reactor apparently did not mix adequately.
- The pipe distribution was such that material was blasted out of the back of the granulator.

After several hours, the attempt to produce MAP by the pipe reactor was abandoned and the plant resumed producing DAP.

After making some modifications to correct the above problems, a second attempt to make MAP with the pipe reactor was made in about a week. Most of the same problems surfaced and the effort was abandoned after several hours. The plant then began producing MAP by back titration.

Back titration proved to be successful and the plant rate was gradually increased. As predicted, the moisture content was quite high when the rates were above 100 TPH. For this reason, efforts were made to correct the pipe reactor problems and initiate MAP production by pipe reactor.

Farmland Hydro, L.P. continued these efforts through late 1992 and early 1993. Recently, the pipe reactor achieved the required rate (120 TPH).

IX. Summary Of Modifications

In April 1993, the modified plant has been operating successfully for about seven months. The plant rate and operating factor have gradually increased as the operators have become familiar with the plant and the plant is now operating more

consistently at or near design rates. In summary, the various areas can be detailed as follows.

SCREENS

The decrease in screen angle and the installation of the HiTech Fines Screen Diverters have proven to be successful. The product has consistently met size specifications and no flow problems have been encountered in the screens. The screens have proven to be quite sensitive to proper vibration (stall with too low vibration).

RECYCLE SYSTEM

The recycle capacity has been increased, but there have been a few problems. Due to lay out considerations, the bottom drag flite recycle conveyor has several feet between the drop point and the end of the conveyor. Material has consistently carried over the drop point and compacted in the 'dead zone" beyond. This zone has been modified to allow material discharge, but the operation is still not completely satisfactory. To date, the problem has been studied extensively, but no reason has been determined for the carry over.

The remaining modifications to the recycle system have worked satisfactorily. The major problem has been splitting the material flow equally to the screens since there is a total of three diverters to adjust. These diverters were not significantly altered during the project, but the amount of material flow has increased. The splitting problem, which was minor prior to modification, has now become more critical to properly load the screens and mills.

DRYER

Although the dryer was not modified as part of the basic project, Farmland Hydro, L.P. had the original dryer manufacturer (Reneberg) evaluate the dryer. They recommended modifying both the spiral and the lifter flites to increase passage through the dryer. These modifications were performed by Farmland Hydro, L.P. personnel during the plant outage.

As of this time, the modifications do not seem to have lowered the bed depth in the dryer. While dryer capacity to remove moisture has proven to be adequate, spillage of material from the front end has continued to be a serious problem. The plant rate has been limited because of inability to increase the recycle load to that required without excessive spillage. This problem is still being studied by Farmland Hydro, L.P. As of yet, no satisfactory solution has been determined.

GRANULATOR

The studies performed by the manufacturer (FEECO) and HiTech Solutions, Inc. resulted in a granulator that has given good granule formation and does have low ammonia losses. After several months of operation, it became apparent that the granulator developed excessive spillage out of the feed end under certain circumstances. HiTech Solutions, Inc. consulted with Farmland Hydro, L.P. on this problem and discovered several problems. First, the calculated bed depth was 30 to 36 inches at 600 TPH recycle rate. The measured bed depth at a slightly lower recycle rate was actually 42 to 44 inches. In large granulators (greater than 12 foot diameter), this increased bed depth (deeper than calculated) seems to be a consistent problem. The arrangement of the slurry sprays allowed one of the sprays to discharge directly on one of the sparger supports. The spray layout and operational pluggage also tended to discharge too much slurry on the recycle too close to the feed end. Modifications were recommended by HiTech Solutions, Inc. to Farmland Hydro, L.P. Among the improvements recommended were lowering the height of the discharge dam, rearranging the sprays to deliver more slurry to the discharge end and to avoid spraying on any sparger supports, and increasing the granulator speed of rotation slightly. To date, some of these have been performed and the problem of excess spillage is improving.

PIPE REACTOR

In January 1993, Farmland Hydro, L.P. had modified the various control systems for the pipe reactor and the pipe reactor itself such that they believed that consistent operation was possible. They therefore began a process of determining proper operating parameters. During 1993, the rate, product quality, and operation have all improved consistently with much hard work on the part of

Farmland Hydro, L.P. personnel. At present, the proper operating parameters are being refined and the plant is producing MAP using the pipe reactor.

AMMONIA SYSTEM

In order to maximize the waste heat usage from the North Train, the ammonia system was modified during the project to have all incoming ammonia go from the storage bullets to the liquid head tank for the cooler chiller coils. Since not all of the ammonia would be vaporized by the chiller coils, the excess liquid would then go to the BFL vaporizer. Vapor from the BFL and the head tank would then be combined in a common header system which would supply vapor ammonia to the North train and the South Train.

The overall controls on this system were quite complex. During start up, the system operated fairly well. During the cooler months, however, some control problems were encountered due to lack of turn down capability on some control valves. The system is presently operating but does require some minor modifications to instruments in order to achieve the goal of completely automatic operation.

DOUBLE MOL SCRUBBING SYSTEM

A typical double mol scrubbing system was installed on the reactor/granulator gas system. This system scrubs the gases first with a high mol (about 1.45 mol ratio) phosphoric acid and then with a lower mol (about 0.5 mol ratio) phosphoric acid. Several systems are in use at various DAP plants and the system is typical of all of these systems. This system was first proposed and installed by Dick Maginnis of USAC during the early 1980's and has since been successfully installed on several plants.

The ammonia slip has been lower than predicted for the granulator and reactor. When producing DAP, this has not been a significant problem, but it has led to some problems when producing MAP since the lower ammonia losses make it difficult to maintain a high enough mol ratio in the low mol scrubber acid. Extremely low ratios tend to evolve excess fluorine into the gas stream. Farmland Hydro, L.P. has slightly altered the flow scheme of acids and the

system is operating satisfactorily.

BFL VAPORIZER

HiTech Solutions, Inc. offered the licensed BFL vaporizer technology to Farmland Hydro, L.P. as part of the initial studies. Although these heat exchangers had previously been installed in the gas stream exiting the reactor, the exact location of this unit was discussed at length. Farmland Hydro, L.P. had extensive experience in condensing scrubbing for fluorine removal and Farmland Hydro, L.P. and HiTech Solutions, Inc. jointly agreed that the condensing effect of the vaporizer could prove beneficial to scrubbing if located after the double mol scrubber system. This location also had the effect of minimizing the amount of ammonia in the condensate stream and therefore introducing less ammonia into the pond system.

The system has achieved its goal of significantly lowered ammonia content in the condensate. When producing DAP, the system does act to lower fluorine emissions and has allowed the plant to operate without a tail gas scrubber.

Operation has proven to be mostly satisfactory with cold start ups possible using only heat from the air stream.

X. Conclusions

From the initial studies performed in August 1991 to the start up in September 1992, the modifications to the Farmland Hydro, L.P. North Train Fertilizer Plant were performed on a fast track. The extensive modifications necessitated a learning curve by the operations and maintenance personnel and required several months for the plant to come up to full designed rates. Problems have been encountered, but most of these problems required minor adjustments to controls or equipment and not major changes. The only item which required extensive work and effort was the MAP Pipe Reactor.

To date, the excessive spillage from the dryer is proving to be a major problem which is not yet rectified. The pipe reactor has also required higher strength acid and this requirement has limited the ability of the plant to consume low strength

acid and scrubber water. The pipe reactor has not operated anywhere initial design conditions with respect to temperature, acid strength, or back pressure. While the present operation allows the plant to produce MAP with little or no fuel energy, it is not producing satisfactory low strength acid consumption.

The innovations incorporated in this plant of the lower screen angle and associated fines screen diverters and the new location of the BFL vaporizer have proven successful. Farmland Hydro, L.P. evaluated and accepted the innovations as part of the overall plan and should be congratulated for its forward outlook. The innovations themselves have proven to have few problems and should be considered by other fertilizer producers when examining possible modifications to their fertilizer plants.